

**PROGRESS REPORT  
March–September 1994**

**CHERNOBYL STUDIES PROJECT**

**WORKING GROUP 7.0  
ENVIRONMENTAL TRANSPORT  
AND HEALTH EFFECTS**

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**December 1, 1994**

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**MASTER**

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Physikzentrum, Bad Honnef, Germany  
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*Environmental Measurements Laboratory*

- EH Monthly Detailed Summary
- Progress Report — MARCH - SEPTEMBER 1994

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*Yasuo Onishi*

*Battelle Pacific Northwest Laboratories*

- EH Monthly Detailed Summary
- Progress Report — MARCH 1994
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  - Publication: Y. Onishi, "Environmental and Remediation Assessment Around Chernobyl," *Energy Review, Japan*, (1994) Vol. 14. No. 3, pp. 23-26

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- Progress Report — APRIL 1994
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*Lawrence Livermore National Laboratory*

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  - Publication: The Development and Application of Biomarkers, Selected Abstracts, DOE-EH-0377T
  - Publication: T. Straume and J. Lucas, "Validation Studies for Monitoring of Workers Using Molecular Cytogenetics," UCRL-JC-116579 (1994) [*Contact T. Straume or J. Lucas for copy of report*]
  - Publication: T. Stauume and J. Lucas "Validation Studies for Monitoring of Workers Using Molecular Cytogenetics," submitted as a chapter in a book for National Academy Press [*Contact T. Straume or J. Lucas for copy of report*]
- Progress Report — MAY 1994
- Progress Report — JUNE 1994
  - Foreign Trip Report  
Tore Straume  
Bad Honnef, Germany  
June 6-9, 1994  
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- Progress Report — JULY 1994
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  - Foreign Trip Report  
Joe Lucas  
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*University of California, Davis*

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### 7.2F — THYROID STUDIES

*Lynn Anspaugh*  
*Lawrence Livermore National Laboratory*

- EH Monthly Detailed Summary
- Progress Report — MARCH – SEPTEMBER 1994
  - Foreign Trip Report  
Lynn R. Anspaugh  
Scientific Centre for Radiation Medicine and other Institutes  
Kiev, Ukraine  
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April 16–19, 1994

### 7.2G — LEUKEMIA STUDIES

*Lynn Anspaugh*  
*Lawrence Livermore National Laboratory*

- EH Monthly Detailed Summary
- Progress Report — MARCH – SEPTEMBER 1994
  - Foreign Trip Report  
Lynn Anspaugh  
Scientific Centre for Radiation Medicine and other Institutes  
Kiev, Ukraine  
July 16–29, 1994

## BACKGROUND

## **BACKGROUND**

In April 1988, the US and the former-USSR signed a Memorandum of Cooperation (MOC) for Civilian Nuclear Reactor Safety; this MOC was a direct result of the accident at the Chernobyl Nuclear Power Plant Unit 4 and the following efforts by the two countries to implement a joint program to improve the safety of nuclear power plants and to understand the implications of environmental releases. A Joint Coordinating Committee for Civilian Nuclear Reactor Safety (JCCCNRS) was formed to implement the MOC. The JCCCNRS established many working groups; most of these were the responsibility of the Nuclear Regulatory Commission, as far as the US participation was concerned. The lone exception was Working Group 7 on Environmental Transport and Health Effects, for which the US participation was the responsibility of the US Department of Energy (DOE). The purpose of Working Group 7 was succinctly stated to be, "To develop jointly methods to project rapidly the health effects of any future nuclear reactor accident." To implement the work DOE then formed two subworking groups: 7.1 to address Environmental Transport and 7.2 to address Health Effects. Thus, the DOE-funded Chernobyl Studies Project began. The majority of the initial tasks for this project are completed or near completion.

The focus is now turned to the issue of health effects from the Chernobyl accident. Currently, we are involved in and making progress on the case-control and co-hort studies of thyroid diseases among Belarussian children. Dosimetric aspects are a fundamental part of these studies. We are currently working to implement similar studies in Ukraine. A major part of the effort of these projects is supporting these studies, both by providing methods and applications of dose reconstruction and by providing support and equipment for the medical teams.

During Fiscal Year 1993, the work conducted under the auspices of Working Sub-Groups 7.1 and 7.2 was substantially changed, and many tasks were completed. Thus, the two Sub-Groups were combined into a single Group 7.

Current FY 94 tasks for the Chernobyl Studies Project are

### **7.0A Management**

Lynn Anspaugh and Sheilah Hendrickson  
Lawrence Livermore National Laboratory.

### **7.1C External Dose**

Harold Beck  
Environmental Measurements Laboratory.

**7.1F Hydrological Transport**

Yasuo Onishi

Battelle Pacific Northwest Laboratories

(\$50 K direct funding to PNL). Expected completion in FY 94.

**7.2A4 Chromosome Painting Dosimetry**

Tore Straume and Joe Lucas

Lawrence Livermore National Laboratory.

**7.2D Stochastic Effects**

Marvin Goldman

University of California, Davis.

Expected completion in FY 94.

**7.2F Thyroid Studies**

Lynn Anspaugh

Lawrence Livermore National Laboratory.

**7.2G Leukemia Studies**

Lynn Anspaugh

Lawrence Livermore National Laboratory.

## 7.0A – MANAGEMENT

# EH Monthly Summary

## Chernobyl Studies Project: Summary of Financial Status

Budget Category: HA-01-17

(1,000 Dollars)

Month Ending: September 1994

DOE Project Number	LLNL Project Number	Project Title	FY 1994 Budget*	FY 1994 Total Cost To Date**	Percent Spent	Remaining Balance	Variance Linear Rate***
93-ES-966	6288-15	7.0A Management L. Anspaugh / S. Hendrickson (LLNL)	247.4	242.1	98%	5.3	(5)
	6288-08	7.1C External Dose Harold Beck (EML) L. Anspaugh / S. Hendrickson (LLNL)	0.0	0.3	0%	-0.3	0
94-ES-1031	XXXX	7.1F Hydrological Transport Yasuo Onishi (PNL) \$50 K + \$15 K <i>Direct Funding to PNL</i>	65.0	52.4	81%	12.6	(13)
	6288-09	7.2A4 Chromosome Painting Dosimetry Tore Straume / Joe Lucas (LLNL)	100.0	111.7	112%	-11.7	12
	6288-11	7.2D Stochastic Effects IntraUniversity Transaction to Marvin Goldman (UC Davis, \$24 K) L. Anspaugh / S. Hendrickson (LLNL)	38.0 24.0	9.3 5.3	24% 22%	28.7 18.7	(29) (19)
	6288-16	7.2F Thyroid Studies Lynn Anspaugh (LLNL)	434.3	416.1	96%	18.2	(18)
•6288-14	(7.2F)	Belarus Equipment/Supplies L. Anspaugh / S. Hendrickson (LLNL)	0.0	0.4	0%	-0.4	0
	6288-12	7.2G Leukemia Studies Lynn Anspaugh (LLNL)	5.7	5.7	100%	0.0	0
LLNL TOTALS			\$825.4	\$785.6	95%	\$39.8	(40)

\* Includes FY 1993 carryover, if marked with an \*

\*\* Includes commitments (Liens, Subcontracts, IUTs, ICOs, etc.)

\*\*\* Amount in parenthesis () indicates total cost to date is under the cumulative linear spending rate

• Also See Budget Sheets for Capital Equipment Account 7861-01

11/17/94

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
(1,000 Dollars)

**Project:**

**7.0A Manangement (Lynn Anspaugh / Sheilah Hendrickson)**

**LLNL No: 6288-15**

**DOE No: 94-ES-1031**

Cost Item	Months												Year-to-Date
	1993			1994									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits	7.5	13.3	5.5	6.8	3.2	17.2	7.3	3.6	4.4	7.0	5.1	0.0	80.9
Travel	2.9	0.4	5.6	0.5	3.4	2.5	1.8	-0.2	0.0	-0.7	0.8	1.3	18.3
Procurement and Expenses*	0.8	-0.2	0.3	0.4	2.5	0.7	1.6	0.1	-0.2	0.0	0.1	0.0	6.1
Technical Information Department	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.6	0.0	0.0	0.1	0.2	1.8
Facility/Service/Distributed Charges	0.1	0.1	0.2	0.4	0.2	0.0	0.4	0.0	0.0	0.1	0.0	0.0	1.5
LLNL Overhead+ /Taxes**	5.9	9.5	4.8	29.5	3.1	9.8	32.2	2.5	3.9	26.5	4.6	0.2	132.5
TOTAL	17.2	23.1	16.4	37.6	12.4	30.2	44.2	6.6	8.1	32.9	10.7	1.7	241.1
Liens/Preliens												1.0	242.1
Budget	240.4	240.4	240.4	240.4	240.4	240.4	240.4	240.4	240.4	240.4	240.4	240.4	
Funds Available	223.2	200.1	183.7	146.1	133.7	103.5	59.3	52.7	44.6	11.7	1.0	-1.7	

\* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts

\*\* General & Administrative (G&A)

+ LDRD; Division and Directorate Burdens, etc.

11/17/94

# EH-40 Monthly Report

March—September 1994

**Project Title:** Chernobyl Studies  
7.0A Management

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-15

**Principal Investigator(s):** Lynn Ansbaugh / Sheilah Hendrickson  
**M&O Contractor:** Lawrence Livermore National Laboratory

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*Address each item, if applicable.*

- I. Project Objective**
- II. Current Project Status / Monthly Progress**
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns**
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff**
  - Identify EH-40 staff member(s) with each requests.

## **I. Project Objective**

The main content of this work will continue to be to manage the overall activities of former subgroups 7.1 and 7.2, to integrate all remaining tasks into a coherent and focussed program, and to provide the additional support for buying and furnishing supplies. An additional charge is to maintain coordination with other studies of similar nature, so that duplication is avoided and the maximum leverage is obtained with the funding that is available. At the present time the European Union (formerly known as the Commission of European Communities) has a large, well-funded program that has similar goals. Thus, one of our primary goals is to maintain a close liaison with the managers of the European Union program and with the managers of other programs that have potential overlap with the DOE-funded projects.

## **II. Current Project Status / Monthly Progress**

Activities have been to manage the contracts and coordinate activities and information for work being done outside of LLNL. This includes the work being done by (1) Professor Goldman of the University of California, Davis, on completing the project on assimilating data from the former Soviet Union on radiogenic health effects (for events and accidents occurring prior to the Chernobyl accident), (2) Dr. Yasuo Onishi of Battelle Pacific Northwest Laboratory, on completing the project on assessing radionuclide migration in the water and soil

environment with mathematical modeling to provide information on potential health impact and remediation requirements associated with the Chernobyl accident, and (3) Mr. Harold Beck of Environmental Measurements Laboratory, on improving and validating methods of forecasting doses and dose commitments from external exposure.

We are also managing the contract and administrative details for work being done by SENES, Oak Ridge, on international model-validation studies. This project is now much broader in scope than just Chernobyl, and the agreement has been with Dr. Thomas and others to not include this as a direct part of the Chernobyl Project. However, the project is currently being managed through this activity. Sheilah Hendrickson, Subcontract Technical Representative, attended the International Atomic Energy Agency VAMP Multiple Pathways Assessment Working Group Meeting in March. The meeting was hosted by SENES Oak Ridge, and was organized in Oak Ridge to facilitate an increased participation from US experts, and from Russian and Ukrainian experts who were attending a BIOMOVs II Working Group Meeting the preceding week. The current subcontract with SENES Oak Ridge is through August 24, 1994. Additional funding was received for the extension and completion of the SENES Oak Ridge subcontract for the international model-validation studies. Appropriate administrative paperwork and subcontract negotiations were completed to extend the subcontract through December 31, 1994, and add an additional \$100 K for the completion and close-out of the subcontract and this study.

Through the request of Professor Goldman, President of the Health Physics Society, we co-hosted the special Former-Soviet Union (FSU) delegation attending the June Health Physics Society Annual Meeting in San Francisco, California. Administrative details were worked out with DOE Headquarters to assist with travel related expenses for the FSU delegation attending the Health Physics Society Meeting for a "special" FSU session and a subsequent stochastic effects meeting in Davis, California. Several informal meetings with colleagues from the FSU were held during the San Francisco meeting regarding current and future collaborative work. Participation included LLNL, DOE, NCI, NRC, and colleagues from the FSU. At the conclusion of the Health Physics Society Meeting, we met in Davis, California, with Professor Goldman, Dr. Igor Filushkin, Dr. Lev Buldakov, Dr. Mira Kosenko, and Dr. Catherine Zhydkova. We assisted with the translation and editing of the final drafts of papers/presentations from the Stochastic Workshop Proceedings held in June 1992. Professor Goldman expects the workshop proceedings to be completed and published in December 1994 with the completion of our subcontract with him.

As part of the US team, Dr. Lynn Anspaugh and Dr. Edwin Haskell participated in the Workshop on Dose Reconstruction, Bad Honnef, Germany, June 1994. See attached foreign trips reports.

See Section 7.2F — Thyroid Studies for the resolution of the issue of providing equipment and supplies to Belarus (and later to Ukraine), as specified in the Protocol (October 1993–January 1994, Progress Report, 7.0A—Management) for the cohort study on childhood-thyroid cancer.

III. Significant Problems/Issues/Concerns

None.

IV. Assistance Required of EH-40 Staff

None.

FOREIGN TRIP REPORT

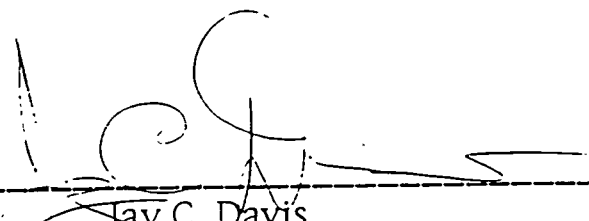
Lynn R. Anspaugh

Risk Sciences Center  
Health and Ecological Assessment Division  
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Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

July 11, 1994

Approved by:



Jay C. Davis  
Acting Associate Director  
Environmental Programs Directorate

## SECTION A: SUMMARY

a. Traveler

Lynn R. Anspaugh, Director, Risk Sciences Center  
 (510) 424-6409  
 Health and Ecological Assessment Division  
 Environmental Programs Directorate  
 Lawrence Livermore National Laboratory  
 University of California  
 Livermore, CA 94551-9900

July 11, 1994

b. Dates and Destinations

6/4/94-6/6/94	Kongsvold Biologiske Stasjon, Kongsvold, Norway
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6/7/94-6/10/94	Physikzentrum, Bad Honnef, Germany
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c. Purpose of the Trip

The purposes of this trip were 1) to present an invited paper on "Sources and Distribution of Radionuclides in the Biosphere" at the International Symposium on Biomedical and Psychological Consequences of Radiation from Man-Made Radionuclides in the Biosphere, Kongsvold, Norway, and 2) to participate in the Workshop on 'Dose Reconstruction,' Bad Honnef, Germany. I was a member of the Programme Committee for this Workshop.

d. Abstract

I attended the Symposium in Norway for only one day. During this day I presented a paper on "Sources and Distribution of Radionuclides in the Biosphere." Three other presentations were made on this day concerning general comments on man-made contamination in the environment, a review of transport of radionuclides in terrestrial foodchains, and a summary of joint work carried out by Norwegian-FSU collaborators on environmental chemistry. The primary purpose of the Germany Workshop was to present dose-reconstruction procedures and to prepare a document on "Scientific Recommendations for the Reconstruction of Radiation Doses due to the Reactor Accident of Chernobyl."

## SECTION B: TRIP REPORT

a. Purpose of the Trip

The purposes of this trip were 1) to present an invited paper on "Sources and Distribution of Radionuclides in the Biosphere" at the International Symposium on Biomedical and Psychological Consequences of Radiation from Man-Made Radionuclides in the Biosphere, Kongsvoll, Norway, and 2) to participate in the Workshop on 'Dose Reconstruction,' Bad Honnef, Germany. I was a member of the Programme Committee for this Workshop.

b. Summary of Activities

## SYMPOSIUM IN NORWAY

I was invited to attend the International Symposium on Biomedical and Psychological Consequences of Radiation from Man-Made Radionuclides in the Biosphere in Kongsvoll, Norway, by the Royal Norwegian Society of Sciences and Letters Foundation. My topic was "Sources and Distribution of Radionuclides in the Biosphere." A copy of the Final Program and the List of Participants is provided as Attachment A.

The first lecture was given by Asker Aarkrog on "Man-Made Radioactive Contamination of the Biosphere—A 50 Year Retrospective." Of particular interest was his comment about the release of  $^{137}\text{Cs}$  from Sellafield. This has amounted to about 40 PBq with a collective effective dose commitment of about 5000 man Sv. (This is many orders of magnitude less dose than the dose from about the same amount of  $^{137}\text{Cs}$  released by the Chernobyl accident.) Also, his comments about the importance of "wild produce" in delivering dose to the population of Scandinavia as a result of the Chernobyl accident were of interest. At the present time wild produce (wild mushrooms, wild raspberries, game, etc.) amounts to 68% of the intake of  $^{137}\text{Cs}$  in Finland, 81% in Sweden, 28% in Norway, and only 9% in Denmark. The largest source of intake in Denmark is fish, whereas the largest source in Norway is meat. He estimated that the collective effective dose commitment from  $^{137}\text{Cs}$  and  $^{134}\text{Cs}$  is about 30,000 man Sv.

Aarkrog used his collective experience to present a normalized (to 1 EBq of  $^{137}\text{Cs}$ ) collective effective dose commitment for the following types of releases:

Global (bomb fallout)	2,000,000
Sellafield (sea)	50,000
Chernobyl (local and regional)	5,000,000

After my paper, the next presentation was by Eiliv Steinnes on "Uptake and Transport of Radionuclides in the Terrestrial Environment." He also emphasized the importance of wild produce in the delivery of dose from  $^{137}\text{Cs}$  following the Chernobyl accident. The intake of fungi (mushrooms) can cause a variation in  $^{137}\text{Cs}$  intake of up to a factor of 40. One interesting aspect related to the consumption of mushrooms by goats under some conditions with a very large increase of  $^{137}\text{Cs}$  content in goat's milk.

There was also discussion of the use of "Prussian Blue" to block the uptake of  $^{137}\text{Cs}$  in grazing animals. Prussian Blue is ammonium-iron-hexacyanoferrate. This material can be mixed with food or can be introduced as a bolus; it binds Cs very well, but breaks down quickly in the environment, and can therefore lead to recycling of the  $^{137}\text{Cs}$ .

### MEETING IN GERMANY

I left Oslo, Norway, on the morning of June 7 and arrived in Bonn, Germany, later that afternoon. I then proceeded by taxi to Bad Honnef to join the Workshop on Dose Reconstruction that was already in progress. The announcement for this Workshop is provided as Attachment B. The objectives of this Workshop are described in detail in this attachment. I was one of ten members of the Workshop Programme Committee and the only one from the United States. I arranged for the participation of key experts from the United States; these were Drs. Ed Haskell, Tore Straume, and André Bouville. I also chaired the final Session of the Workshop.

The Final Programme for the Workshop is provided as Attachment C, and the list of participants is provided as Attachment D. Some notes and comments on the material presented follows:

G. Pretzsch presented some detailed calculations of the source term for the Chernobyl accident; these were done in conjunction with some collaborators in Russia. He repeated some of the basic information also given in Anspaugh et al. (*Science* 1988): 1659 fuel assemblies, each with 114.7 kg of U. However, he indicated a mean burn up of 11 MW-days  $\text{kg}^{-1}$  of U instead of the 10.3 previously given. He also indicated an effective average age of the assemblies of 715 days rather than the 610 days calculated by Anspaugh et al. This time and other data given by Pretzsch are important for the calculation of the ratio of  $^{129}\text{I}$ -to- $^{131}\text{I}$ . Such information was also presented, but the numbers were too small for me to see. Nonetheless, further contact with Dr. Pretzsch may be important in order to resolve this information, which is needed for our attempts to reconstruct thyroid dose based on current measurements of  $^{129}\text{I}$ -deposition densities. Other information was that 3.8% of the fuel mass was released. The release of material on aerosols through the sarcophagus was

$1.1 \times 10^{10}$  Bq during the year of 1990. This was stated to be below the limit for an operating reactor.

T. Mikkelsen has been using an atmospheric transport model to back calculate source terms from various events. He had calculated a release of 150 to 400 Ci from the more recent accident at the Tomsk site.

Ivan Kryshev presented an interesting paper on dose reconstruction in areas of Russia impacted by the Chernobyl accident. He included in his paper considerable data on  $^{131}\text{I}$  measurements that I had never seen before. His entire printed paper is provided in Attachment E.

Pröhl presented a paper dealing primarily with the interception of radionuclides by vegetation. Humidity can be an important variable, but only at the extremes of relative humidity of more than 99%. The deposition of  $\text{I}_2$  can be 10 times higher than the deposition of I bound to particles. He noted that anions are much less likely to be retained by vegetation ( $10 \times$  less) than are cations.

Peter Jacob presented more recent efforts to model the time course of external exposure. He is now using a Lorentz function:

$$F(x) = \frac{A_1}{(x - A_2)^2 + A_3^2},$$

where  $A_2$  and  $A_3$  are correlated. He provided some values for these parameters as a function of time and distance, but I was not able to write them down. He also described efforts to fit a two component exponential function to the time course of external exposure at locations more than 300 km from the Chernobyl accident. His equation is

$$r(t) = a_1 \exp^{-0.693t/T_1} + a_2 \exp^{-.693t/T_2},$$

where  $a_1 + a_2 = 1$ . He indicated that the value of  $T_2$  is about 50 years;  $T_1$  is estimated to be between 1.2 and 1.7 years; and  $a_1$  is estimated to be between 0.32 and 0.38.

K.G. Andersson presented the URGENT model, which is used to calculate exposure from the deposition of radiocaesium in urban areas. A copy of his paper is provided as Attachment F.

V. Chumak and R. Meckbach presented a paper on current efforts to reconstruct doses to Ukrainian liquidators and evacuees. Questionnaires have been accumulated from evacuees: 15,000 people from Pripyat and 18,000 other people from the 30-km zone. For Pripyat the mean calculated dose to

residents is 11.5 mSv with a maximum of 114 mSv. For others within the 30-km zone, the average dose was calculated to be 18.2 mSv with 8% having a dose >50 mSv, 3.7% >100 mSv, and .03% >250 mSv. The collective dose was estimated to be 1300 man-Sv. They also provided information on the mean doses in these villages:

Gorodcha	130
Posudovo	122
Usov	118
Tolstyles	113
Pripyat	11.5
Glinka	1.4

It has been more difficult to reconstruct doses for liquidators, but 1400 such reconstructions have been done. The results have been an average of 410 mSv for liquidators and 97 mSv for those who worked regularly at the Chernobyl Nuclear Power Station. The dose to the lens of the eye might be something like 3 times higher. The use of electronparamagnetic resonance (EPR) of tooth enamel is now very popular in Ukraine as a means of dose reconstruction. However, it was noted that background signals are different for each person, due to differences in organic content of enamel. Also, the sensitivity of an individual's teeth is different. They now have a bank of 300 teeth, but only seven have been carefully analyzed.

In response to a question, Chumak estimated that there were about 30,000 to 60,000 "real" liquidators. One hundred and fifty of these received a dose of more than 1.5 Sv and they experienced acute radiation sickness. Approximately, 10,000 received doses of 0.25 to 1 Sv. Unfortunately, the film-badge dosimeters in use saturated at about 2 rem, and the results have not been useful. It was suggested that it might be useful to reread these badges, and a might be possible to deduce doses of up to 5 rem.

Chr. Reiners discussed his results treating 49 cases of thyroid cancer in children from Belarus. His results are summarized in his Abstract, which is included in Attachment G. In addition, he noted that two of the children have died of their cancer. He also noted that most of these cancers have been brought to attention by their parents or school teachers, and the cancers have been large when found. Only a few of the 49 cases were found by mass screening. This is of major interest, as it has been suggested by others that the reported increase in childhood-thyroid cancers is not "real," but due to increased ascertainment.

M. Crick summarized the more recent dose reconstruction of thyroid doses due to the accident at Windscale. The estimated collective dose to the thyroid was 20,000 man(thyroid) Gy.

Y. Kenigsberg noted that differences in food habits have significant effects on whole-body dose to residents in Belarus. He noted that milk is the significant vector for rural people, whereas sausage and meat has been the significant vector for urban people. He also noted that berries can be responsible for 25% of the intake of radiocesium, but constitute only 2% of the total food volume.

H. Müller noted that his ecological model (ECOSYS) did not predict well the dose situation in some locations, where the  $^{137}\text{Cs}$  content in food appears to be constant after 1987 and higher than expected. He noted a firm belief that any model must be adapted to a region.

V. Stepanenko noted the new (at least to me) observation that they have finally seen an increase in childhood-thyroid cancer in Russia. (This had been an enigma, as the increases had been noted much earlier in both Ukraine and Belarus.) They have now observed 17 cases: 1 in 1986, 2 in 1990, 2 in 1992, 8 in 1993, and 4 at that time in 1994. Four cases are from Novozybkov and four from Klintsovsky. He also noted that they have 32,000 measurements of  $^{131}\text{I}$  content in thyroids with 30,000 in the Bryansk Oblast and 2,000 in Kaluga. They also have about 160,000 measurements of  $^{137}\text{Cs}$  in the whole body with 110,000 in Bryansk and the remainder in Kaluga. They have 1120 EPR measurements with 1020 in Bryansk. He reported that the maximum dose to the thyroid was 10 Gy, but only six people had doses in the 9-to-10-Gy range. He further noted that the ratio of dose to deposition density was not constant, but decreases with increase in deposition density. This had been noted previously by our colleagues from Moscow: Valeri Khrushch, Yuri Gavrilin, and Sergei Shintarev.

One ongoing activity of the Workshop was to prepare a document, "Scientific Recommendations for the Reconstruction of Radiation Doses Due to the Reactor Accident of Chernobyl." I was asked to be and served as a member of the Drafting Committee for this document. A copy of the near final document is provided as Attachment H.

During this meeting, Dr. André Bouville and I had many meetings with our collaborators from Belarus, Ukraine, and Russia. I received a paper from Alexander Ulanovsky that he wants me to edit for submission to *Health Physics*. We also had many discussions on how to proceed on our joint activities on dose reconstruction, particularly for the subjects of our several joint epidemiological studies of radiogenic cancer and lens cataracts.

#### c. Traveler's Role

My role is described above in Part B.

d. Recommendations

The information presented at this Workshop reaffirms that there is a significant and substantial increase in the incidence of childhood-thyroid cancer in the former Soviet Union as a result of the Chernobyl accident. Thus, our emphasis on studying this situation and in helping the Ministries of Health in the effected countries to cope with this problem should be continued.

e. Information Pertinent to Energy Postures

None.

f. Security-Related Concerns

None.

## SECTION C: APPENDIX

a. Itinerary

6/3/94	Left San Francisco
6/4/94	Arrived Kongs vold via Oslo and New York City
6/6/94	Business began; returned to Oslo
6/7/94	Left Oslo and arrived Bad Honnef via Munich and Bonn
6/9/94	Business ended
6/10/94	Left Bad Honnef and arrived San Francisco via Bonn, Munich, and Cincinnati

b. List of Persons contacted

See Attachments A and D.

c. Literature Acquired

See Attachments E, F, G, and H.

**INTERNATIONAL SYMPOSIUM  
ON  
BIOMEDICAL AND PSYCHOSOCIAL  
CONSEQUENCES OF RADIATION  
FROM MAN-MADE RADIONUCLIDES  
IN THE BIOSPHERE**

**5. - 10. JUNE 1994**

**at**

**Kongsvold Fjeldstue  
7340 Oppdal  
Phone: (+ 47) 72 42 09 11  
Fax: (+ 47) 72 42 22 72**

**Symposium office:  
(Kongsvold Biologiske Stasjon)**

**Phone: (+ 47) 72 42 09 85  
(9:00 a.m. - 4:00 p.m.)**

**THE ROYAL NORWEGIAN SOCIETY OF  
SCIENCES AND LETTERS FOUNDATION**

## FINAL PROGRAM

### SUNDAY, JUNE 5th

Arrival - Registration  
Evening Reception

### MONDAY, JUNE 6th

0930 - 0945	Opening address: Gunnar Sundnes
0945 - 1000	Orientation about Kongsvoll Biological Station By Simen Bretten
1000 - 1100	<b>Session I</b> <b>Convener: Gunnar Sundnes</b> Man-made radioactive contamination of the biosphere - a 50 years retrospect By Asker Aarkrog  Discussion
1100 - 1130	Coffee
1130 - 1230	<b>Session II</b> <b>Convener: Torbjørn Sikkeland</b> Sources and distribution of radionuclides in the biosphere By Lynn R. Anspaugh  Discussion
1300 - 1400	Lunch
1400 - 1500	<b>Session III</b> <b>Convener: Kjell Eimhjellen</b> Uptake and transport of radionuclides in the terrestrial environment By Eiliv Steinnes  Discussion
1500 - 1600	Results from bilateral collaborations between Norway and the former Soviet Union on radioecological consequences of Chernobyl accident in Ukraine, Belarus and Russia By Deborah Oughton  Discussion
1600 - 1800	Coffee/Getting acquainted
1830 -	Dinner

## TUESDAY, JUNE 7th

	<b>Session III cont.</b>
0900 - 1000	Uptake and transport of radionuclides in the aquatic environment By Brit Salbu  Discussion
1000 - 1040	Technetium uptake, localization and metabolic effects in higher plants By James W. Neel  Discussion
1040 - 1100	Coffee
1100 - 1135	The radioactive illness of pine tissues as indicator of doses of radiocontamination from Chernobyl accident By Torbjørn Sikkeland  Discussion
1135 - 1200	Plutonium deposition in soils from nuclear installations Poster by Adrian Clacher
1200 - 1300	Lunch
1300 -	Excursion
1830 -	Dinner

## WEDNESDAY, JUNE 8th

	<b>Session IV</b>	<b>Convener: Tore Lindmo</b>
0900 - 1000	Radiation risks to human health, the perspective from Hiroshima and Nagasaki By Mortimer L. Mendelsohn  Discussion	
	<b>Session V</b>	
1000 - 1100	Radiation and genetics By Anton Brøgger  Discussion	
1100 - 1130	Coffee	

	<b>Session VI</b>	<b>Convener: Steinar Westin</b>
1130 - 1230	Nuclear fallout and health effects in Norway By Jon B. Reitan	
	Discussion	
1230 - 1330	Lunch	
1330 - 1430	Attitudes and responses to nuclear threats. Results from a Norwegian National survey By Lars Weisæth	
	Discussion	
1430 - 1530	The social construction of invisible events: Case of the Chernobyl fallout in Norway By Sharon Stephens	
	Discussion	
1530 - 1600	Coffee	
1900	Banquet	

THURSDAY, JUNE 9th

	<b>Session VI cont.</b>
0900 - 1000	Ecological stress: social and psychological scales By Alexander K. Zhiritsky
	Discussion
1000 - 1100	Interpretation of radiation risk in the Norwegian population. Findings from a National survey By Arntinn Tønnesen
	Discussion
1100 - 1130	Coffee

	<b>Session VII</b>	<b>Convener: Steinar Westin</b>
1130 - 1230	Epidemiological considerations in the study of health effects of radiation By Sarah C. Darby	
	Discussion	
1230 - 1330	Lunch	
1330 - 1430	Epidemiology in radio-active contaminated areas By Rosalie Bertell	
	Discussion	
	<b>Session VIII</b>	<b>Convener: Torbjørn Sikkeland</b>
1430 - 1530	Is a termination of the uncontrolled increase of radioactive contamination in the biosphere possible in our time? By Deborah Oughton	
	Discussion	
1530 - 1600	Coffee	
1830 -	Dinner	

**FRIDAY, JUNE 10th**

	<b>Session VIII cont.</b>
0900 - 0945	Radioactive risks, past and future By John Kanwisher
	Discussion
0945 - 1030	The uncontrolled release of radioactivity into the environment: Methods of evaluating the consequences and the alternatives By Deborah Oughton
	Discussion
1030 - 1100	Coffee
1100 - 1230	Summarizing General discussion
1230 -	Lunch/departure

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**SECRETARY:**

Fredagsvik, Turid

### Location and Accommodation

The workshop will be held in the Physik-Zentrum, Bad Honnef near Cologne/Bonn, Germany, Hauptstr. 5, where accommodations is available. Unfortunately, more than half of the rooms in the Physik-Zentrum are double rooms with two single beds. Therefore it will be necessary for the majority of the participants to share one room.

### Registration fee

The registration fee will be 600.-- DM per person. This includes full accommodation (room and board) for the duration of the workshop.

### Participation

Scientists wishing to attend the workshop should return the attached registration form to:

GSF-Congress Service  
Postfach 1129  
D-85758 Oberschleissheim  
Tel. ++49-89-3187 3030 or 2669  
Fax++49- 89-3187 3362

before April 30, 1994

Travel information and further organisational details will be mailed in May 1994 to those who have been accepted as participants.

Abstracts for contributions should be submitted to the Scientific Secretariat:

Dr. Gabriele Voigt  
GSF-Institut für Strahlenschutz  
Postfach 1129  
D-85758 Oberschleissheim

before April 15, 1994

GSF / CEC / IAEA  
GAST

Workshop on

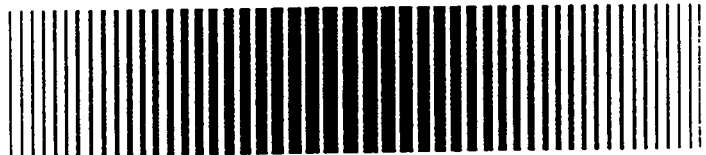
Dose Reconstruction

June 6-9, 1994

Physik-Zentrum

Bad Honnef

First announcement



GSF – Forschungszentrum  
für Umwelt und Gesundheit

**gsf**

## Objectives

In the years since the Chernobyl accident many activities studying the health effects of radiation exposures have been conducted in the countries of the CIS by various international organisations such as IAEA, CEC, and WHO. In particular the increased incidence of childhood thyroid cancers in Belarus and Ukraine has further stimulated world-wide multi- and bilateral co-operation with Belarus, Russia, and Ukraine in order to optimise benefits to those directly affected, but also to improve the current knowledge of the consequences of reactor accidents.

This workshop is addressed to scientists actively involved in dose reconstruction of the radiation exposures of population groups such as evacuees, liquidators, and occupational groups. In this context accidental and other major releases of radio nuclides into the environment as well as exposures due to explosions of nuclear weapons will be considered.

The main objective of this workshop is to bring together best professional expertise and scientific knowledge, and to achieve a better harmonisation of the scientific approaches to dose reconstruction. It is intended to stimulate discussions of urgent problems, perspectives and priorities in various fields of dosimetry. This will help to overcome present limitations for retrospective and predictive exposure assessments.

### Topics:

Reconstruction of external short-term doses from environmental data sets

Reconstruction of radio iodine exposures of the population

Dose reconstruction with Thermoluminescence dosimetry

Reconstruction of individual doses using Electron Paramagnetic Resonance

Dose reconstruction using Biological Dosimetry

Models for prediction of long-term external exposures

Models for prediction of long-term internal exposures

Validation of models used for reconstructing doses

Conference language will be English only

### Organisation of the workshop

The workshop is organised by GAST (German Association of Radiation Research)

Secretariat: GSF-Forschungszentrum Neuherberg, Institut für Strahlenschutz,  
D-85758 Oberschleissheim, Germany

The workshop will start on Monday 6 June at 14:00

Registration will be on Monday 10:00 - 12:00.

### Programme Committee

L. Ansbaugh (LLNL)	Y. Kemnig (Belarus)
M. Balanov (Russia)	I. Likhatchev (Ukraine)
M. Crick (IAEA)	H. Menzel (CEC)
P. Jacob (GSF)	H.G. Paretzke (GSF/IARR)
Chr. Reiners (Univ. Essen/GAST)	
Chr. Streffer (Univ. Essen/SSK)	

### Scientific Secretariat

G. Voigt (GSF)

GSF/CEC/IAEA/GAST

**Workshop on Dose Reconstruction****Bad Honnef June 6 to 9, 1994****Programme****Monday, June 6**

- 10:00 -12:00      Registration
- 13:00**              **Lunch**
- 14:00              Welcome (*P. Jacob, H. Menzel*)  
Presentation of the first draft of a 'recommendation paper for reliable dose reconstruction' (*H. Menzel*)  
Establishment of a drafting committee
- 14:30              **Session I**  
Experimental physical methods for dose assessments: I-129 measurements  
Chairman: *M. Crick*  
*T. Straume* (USA): Status report on I-129 measurements  
*K. Heinemann* (FRG): A method of retrospective reconstruction of children's thyroid gland dose using I-129 soil contamination
- 15:30**              **Coffee break**
- 16:00              **Session II:**  
Experimental physical methods for dose assessments: Thyroid measurements  
Chairman: *Chr. Reinert*  
*G. Gulko* (Ukraine): Retrospective thyroid dose reconstruction  
*I. Zvonova* (Russia): Methods of thyroid dose estimation for the population of Russia following the accident at Chernobyl NPP  
*A. Ulanovsky* (Belarus): Influence of measurement geometry to the estimate of I-131 concentration in the thyroid  
*V. Khrouch* (Russia): Key problems of individual thyroid dose reconstruction due to the Chernobyl accident

Tuesday, June 7

- 9:00           **Session III:**  
Experimental physical methods for dose assessments: Thermoluminescence  
Chairman: *E. Haskell*  
*I. Bailiff* (UK): The use of luminescence with ceramic materials  
*Y. Göksu* (FRG): The limits of luminescence techniques with domestic materials for retrospective dosimetry  
*D. Stoneham* (UK): The use of TL of porcelaine for retrospective dosimetry  
*L. Brodski* (Estonea): Vitreous materials: prospects in retrospective dosimetry  
*L. Heide* (FRG): Retrospective dosimetry by chemiluminescence measurements on sorbite
- 10:30           **Coffee break**
- 11:00           *T. Maruyama* (JPN): Dose assessment by means of TL techniques using ceramic materials  
*V. Polyakov* (Estonia): Absorbed dose depth profiles for the radionuclide composition in Pripyat
- 12:00           **Session IV:**  
Experimental physical methods for dose assessments: Electron Paramagnetic Resonance  
Chairman: *I. Bailiff*  
*A. Wieser* (FRG): Potential and limitations of retrospective EPR dosimetry  
*G. Liidja* (Estonia): Temperature and frequency effects in tooth enamel by electron spin resonance dosimetry  
*G. Hünt* (Estonia): Some aspects of absorbed dose evaluation using tooth enamel by ESR spectroscopy
- 13:00           **Lunch**
- 14:00           *P. Fatibene* (I): Dose reconstruction in bones using Electron Paramagnetic Resonance  
*E. Haskell* (USA): Combined ESR dosimetry using dentine and enamel of teeth  
*A. Brik* (Ukraine): About new approaches to EPR and luminescent retrospective dosimetry of objects from Chernobyl accident zone
- 15:30           **Coffee break**
- 16:00           **Session V:**  
Experimental biological methods for dose assessments  
Chairman: *Chr. Streffer*  
*T. Straume* (USA): Dose reconstruction from reciprocal translocation frequencies measured by FISH

*M. Bauchinger* (FRG): Chromosome painting and conventional chromosome analysis for retrospective dose reconstruction of Chernobyl reactor personnel and liquidators

*Chr. Streffer* (FRG): Micronuclei - a method for biological dosimetry

20:00 Meeting of the drafting committee

### Wednesday, June 8

9:00 Distribution of the second draft of the 'Recommendation Paper'

#### Session VI:

Sourceterm, atmospheric dispersion and deposition

Chairman: *A. Bouville*

*G. Pretzsch* (FRG): Evaluation of the radionuclide release from the Chernobyl accident

*T. Mikkelsen* (DEN): Backfitting and data assimilation of measured exposures on the different atmospheric scales

*I. Kryshev* (Russia): A model of dose reconstruction with consideration of multiple pathways of contamination of the natural environment for the regions of Russia impacted by the Chernobyl accident

*G. Pröhl* (FRG): Deposition, interception and post-deposition retention of radionuclides by vegetation

10:30 Coffee break

11:00 Session VII:

Models for prediction of external exposure

Chairman: *M. Balonov*

*P. Jacob* (FRG): External exposure due to deposited radionuclides

*K. Andersson* (DEN): URGENT - a model for prediction of exposure from radiocaesium deposited in urban areas

*V. Chumak* (Ukraine)/*R. Meckbach* (FRG): Present state of retrospective dosimetry of external exposure to evacuees and liquidators

13:00 Lunch

14:00 Session VIII:

Food chain models: short-term exposure

Chairman: *I. Likhtarev*

*V. Minenko* (Belarus): Grounds for the necessity of clarification the the methodical approaches to the reconstruction of thyroid doses

*I. Kairo* (Ukraine): Individual thyroid dose reconstruction

*Y. Gavrilin* (Russia): The problem of internal thyroid dose reconstruction from the mathematical statistics point of view

15:30 Coffee break

16:00 Discussion of the second draft of the 'Recommendation Paper'  
Meeting of the drafting committee

**Thursday, June 9**

- 9:00            Distribution of the third draft of the Recommendation Paper'  
*Chr. Reinert* (FRG): Results of I-131 treatment in children from Belarus  
with advanced thyroid cancer  
*T. Straume* (USA): Neutron dose reconstruction for Hiroshima/Nagasaki:  
Implications for Risk Assessment for low-LET Radiation  
*M. Crick* (IAEA): Experiences from reconstructing thyroid doses due to the  
Windscale Reactor Fire - October 1957
- 10:30            **Coffee break**
- 11:00            **Session IX:**  
Food chain models: long-term exposure  
Chairman: *L. Anspaugh*  
*I. Likhtarev* (Ukraine): Models for reconstruction and prediction internal  
doses  
*Y. Kenigsberg* (Belarus): The role of ration structure peculiarities in  
estimation of radiocaesium concentration in the body  
*M. Balonov* (Russia): Overview of the problem of dose reconstruction for  
Russia and prognosis of population internal exposure after the Chernobyl  
accident  
*H. Müller* (FRG): Application of radioecological models for reconstruction  
of ingestion doses
- 13:00            **Lunch**
- 14:00            *A. Bouville* (USA): Methods of dose reconstruction being used in the US  
*V. Stepanenko* (Russia): The methodology of retrospective individual  
dosimetrical examination for residents of contaminated territories:  
approaches and problems  
*M. Hoshi* (JPN): Cs-137 concentration among children in Mogilev and  
Belarus
- 15:30            **Coffee break**
- 16:00            Summary of the workshop (*H. G. Paretzke*)  
Discussion and Adoption of the Recommendation Paper:  
Chairman: *H. G. Paretzke*
- 20.00            **Workshop Dinner**

Short contributions are welcome during discussion period at the end of each session

# LIST OF PARTICIPANTS

## Workshop on DOSE RECONSTRUCTION

June 6 - 9, 1994

Physikzentrum  
Bad Honnef, FRG

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Symp-Nr. 10905 DOSE RECONSTRUCTION  
Symp-Dauer 06.06.1994 - 09.06.1994

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DOSE RECONSTRUCTION FOR THE AREAS OF RUSSIA  
IMPACTED BY THE CHERNOBYL ACCIDENT  
(MULTIPLE MODEL ASSESSMENT)

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## INTRODUCTION

The report focuses on the methodology of dose reconstruction based on the observations of radioactive contamination and multiple model assessment in the areas of Russia following the Chernobyl accident. Special attention is given to the early stage after the accident - the period of "iodine hazard".

## 1. DYNAMICS OF RADIOACTIVE CONTAMINATION OF THE ENVIRONMENT AFTER THE CHERNOBYL ACCIDENT

### 1.1. Radioactive contamination of the air

Immediately after the accident, radioisotopes of iodine were of major radiological hazard. Also, the presence of radioiodine in the air was a good indicator of the radioactivity dispersal.

Iodine-131 was found in the fallout samples from extensive areas collected at 08 h on 26 April 1986. The plume moved mainly west and northwestward. Later on, changing meteorological conditions and, in particular, change in wind direction at different heights at the time the releases during the next 10 days led to a complicated pattern of radioactive contamination (Borsilov et al., 1989; International, 1992; Orlov et al., 1992).

The comparative analysis of maps of iodine-131 deposition and precipitation patterns shows that areas subject to precipitation during the passage of the material in 75% were the areas with highest deposition of iodine-131 (Machonko et al., 1992; Ecological, 1992).

A short-duration increase in total activity of radionuclides in the atmospheric fall-out was reported over the most part of Russia (from St.-Petersburg to Vladivostock). On separate areas, maximum

values were four order of magnitude and more above the background levels occurring before the accident.

Table 1 shows maximum concentrations of radionuclides in the air for some populated areas (Radioactive Contamination, 1986; Kryshev et al., 1994).

Of great interest for dose reconstruction is the information about the time of the formation and radionuclide composition of contaminated areas. Let us consider this problem in more detail, using as an example the most contaminated regions of the Chernobyl trace in Russia (Bryansk, Kaluga, Tula and Orel Regions). Analysis of meteorological conditions enables one to reveal several time intervals, during which the radionuclides could be transported in a north-eastward direction towards these regions (Borzilov et al., 1989; Orlov et al., 1992). First and foremost, this is April 27-29, 1986, when an intensive release of radionuclides from the accidental reactor was observed. Subsequently, the radionuclides could be carried out in a north-eastward direction on May 9, May 11-13 and May 15-17 as well. Besides, the areas under consideration could be contaminated on May 1-2, in the period of shower rains. In this particular period the radionuclides from the Chernobyl NPP were not transported in a north-eastward direction. However, the radionuclides that entered these areas as a result of a previous transport from the north-western regions could be washed out. From April 27 to April 29 the radionuclide transport in a north-eastward direction occurred at a height of 200 m. In May the height of the north-eastern transport was no more than 200-300 m.

Analysis of trajectories of the radionuclide transport shows that the contaminated area formation was predominantly associated with the transfer of radionuclides arrived at the atmosphere at 6 a.m. - 3 p.m. on April 27. In this period the radionuclides were transferred first in a north-westward direction, then eastwards due to the wind rotation and arrived at the area under consideration from the west.

Radioactive contamination of the soil in Bryansk Region is mainly due to the processes of precipitation scavenging in the atmosphere, predominantly in the period from April 28 to April 30. It should be pointed out that radioactive contamination of the trace area is highly inhomogeneous. This is associated with

inhomogeneity of the atmospheric fallouts during the cloud passage. Another reason was the presence of areas with strong and weak winds. Thus at a height of the release the wind velocity was about 10 m/c, whereas in the areas under consideration it was 1-2 m/s at the same height. This slowed down the radionuclide transport and, together with the atmospheric fallouts, resulted in a patchy pattern of radioactive contamination.

Unfortunately, in the early period following the accident the data on the radionuclide concentrations in the air of the area under consideration are practically lacking. Nevertheless, these concentrations can be reconstructed on the basis of model calculations, data of measurements in the adjacent regions and data of radiation monitoring of the air in the years which followed. As an example, we present in the table 2 the estimated content of radionuclides in the air of Novozybkov district of Bryansk Region in April-May 1986. The maximum radionuclide concentrations in the air were observed on April 28-30. In May-June, radioactive contamination of the air was reduced considerably. In April-June 1986 (Table 3), the effective equivalent dose from inhalation of radionuclides was, on the average, about 0.7 mSv (0.2-1.2 mSv). About 80% of this dose was accounted for by the radionuclide inhalation on April 28-30 and 15% on May 1-13. Consequently, the first two weeks following the accident make a contribution of about 95% to the dose from inhalation. About 60% of the inhalation dose is accounted for by I-131. The most significant of the other radionuclides were Ru-106 (12%), Cs-134,137 (11%) and Ce-144 (9%). The contribution of short-lived radioisotopes of iodine and tellurium (I-133, Te-132 and I-132) to the inhalation dose was about 4%.

The absorbed exposure dose from inhalation of I-131 (aerosol and gas phases) for thyroid gland of children was 10- 40 mGy.

After the decay of short-lived nuclides the radioactive contamination of the air over the largest part of Russia was due to Cs-137 and Cs-134. The dynamics of concentrations of long-lived radionuclides in the near-surface air for various regions is illustrated in Table 4.

## 1.2. Radioactive contamination of soil

Immediately after the accident, the soil was contaminated with short-lived nuclides: iodine-131 and other. Table 5 indicates maximum accumulation of iodine-131 in some locations.

To reconstruct soil contamination fields for I-131, a more detailed data base for Cs-137 was helpful to use. The correlation coefficient for these values over the European part of Russia was  $r = 0.91$  (Machonko et al., 1992).

After the decay of I-131 and other short-lived nuclides since the mid 1986 the predominant radionuclides were Cs-137 and Cs-134 for the most part of contaminated areas in Russia and Sr-89 and Sr-90 in some areas. The highest levels of I-131, Cs-137 and Cs-134 in Russia occurred on the patch lying in Brynsk-Orei-Tula-Kaluga regions.

It should be noted that the "patchy" pattern of Cs-137 contamination is characteristic of not only extensive territories, but some localities as well, in particular populated areas, Cs-137 density could differ by dozens of times. For illustration, the results from measurements of soil contamination with Cs-137 in Novozybkov district of Bryansk Region are listed in Table 6.

Of major importance to radiological situation are processes of radionuclide redistribution due to both geophysical and ecological mechanisms. Geophysical aspects of radionuclide migration are associated with wind transport (horizontal migration) and movement along the soil profile (vertical migration). According to observations on the contaminated Russian areas, horizontal migration does not cause any significant shift in the isolines of the contamination fields. However, special consideration should be given to transport of Cs-137 under emergency meteorological and ecological situations (dust storms, forest fires). The vertical transport of radionuclides in the soils goes by the mechanism of "slow" and "fast" migration. The mechanism of fast migration causes easily mobile species to move to deeper layers (10-20 cm) as soon as the first months after the accident. By the degree of mobility, given fast migration, the radionuclides can be placed in the order: Sr-90 > Ru-106 > Cs-137, 134 > Ce-144, i.e. the highest mobility is characteristic of Sr-90 (Izrael et al., 1990).

Ecological aspects of radionuclide migration involve

accumulation and transfer of radionuclides in trophic chains of ecosystems, transformation of physical and chemical forms of radionuclides and changes in their migration characteristics as a result of ecological metabolism of organisms. To describe ecological aspects of radionuclides redistribution a concept of "Radionuclide Ecological Ring" was proposed to account for bioaccumulation of the contamination ("biogenic capture" of radionuclides) (Kryshev et al., 1992).

### 1.3. Radioactive contamination of surface waters

The highest contamination of aquatic ecosystems occurred in the first period after the accident: late April-early May 1986. Of major radioecological significance at that time were short-lived radionuclides, above all iodine-131 whose maximum concentration in the surface water of some areas was in excess of permissible concentration in drinking water (37 Bq/L) by dozens of times (Izrael et al., 1990; Kryshev et al., 1992).

## 2. MULTIPLE MODEL FOR DOSE RECONSTRUCTION AND RISK ASSESSMENT

### 2.1. The procedure of risk assessment of radioactive contamination of the environment

In the general case, the risk assessment includes the following elements.

#### 1) Analysis of the contamination sources.

Assessment of the radionuclide intake in the environmental components, both primary (accidental atmospheric depositions) and secondary (wind-driven resuspension, washoff from catchment areas, etc.).

#### 2) Analysis of the contaminant transport in the environment (air, soil, water and sediments). Determination of the radionuclide accumulation factors in trophic chains. Research on the transformation processes of physical-chemical forms of contaminants accompanied by an increase of their migration capacity and toxicity. Revealing the critical pathways of the radionuclide transport.

#### 3) Analysis of the exposure. Assessment of internal and external doses. Revealing the critical pathways of the dose

formation and the critical population groups.

In a practical implementation of this methodology we used: the data of radiation monitoring in the regions impacted by the Chernobyl accident (these data were reviewed in Section 1); the dynamic models of radionuclide transport and accumulation in the environmental components and biota (Kryshev and Sazykina, 1986, 1990); the data on demography and diet of the population.

## 2.2. Dose reconstruction and risk assessment of radioactive contamination of the environment with iodine-131

The dose was estimated with the following formula:

$$D_a = R_a \sum_p \sum_t A_p^*(t_i),$$

where  $R_a$  is the dose factor of conversion for the age group  $a$ , Gy/Bq;  $A_p^*(t_i)$  is the radionuclide intake through the pathway  $p$  on the day  $t_i$  for persons of the age group  $a$ . Bq.

The calculation results show that young children under 1 have the highest thyroid exposure doses. A major contribution to the dose formation for the children is the consumption of milk. Next, in order of importance, is the consumption of water, vegetables, bread and baked goods of home manufacture. The doses through the food pathway exceed the highest estimates of the doses from inhalation almost by an order of magnitude.

For some regions the individual expected internal dose for thyroid gland through the food pathway was estimated with the following empirical formula:

$$D_a = K_a R_a A_s$$

where  $K_a$  is the iodine-131 transfer coefficient from ground depositions with food to a human organism, m<sup>2</sup>;  $R_a$  is the dose factor of conversion for the age group  $a$ , Gy/Bq;  $A = A_s = \sum_t A_s(t_i)$  is the total daily depositions of I-131, Bq/m<sup>2</sup>.

Measurements of I-131 depositions from the atmosphere were taken in the territory of Russia at the points relatively few in number. Therefore we used for the dose assessment the estimates of soil contamination with I-131 obtained on the basis of statistical relationship between depositions of I-131 and Cs-137 as well as from a more detailed data base on soil contamination.

with Cs-137 (see Section 1.2).

The values of  $K_a$  were estimated from the data of monitoring over the content of I-131 in the local foodstuffs and drinking water as well as using the model of multiple pathways for the iodine-131 migration in food chains. In this case, the density of soil contamination with I-131 was recalculated for 15 May 1986.

These estimates of dose are very rough because of a number of factors introducing a considerable uncertainty into the dose calculations. Among these factors are: rather little direct data on the content of I-131 in the environmental objects and food chains; errors in the recalculation of the density of soils contamination with Cs-137 to that with I-131; errors in the assessment of the transfer coefficients; inaccurate knowledge of the diet; the assumption that essentially the local foodstuffs were used; the assumption of no countermeasures taken.

The calculations based on direct measurements of the content of I-131 in thyroid gland are more accurate. However, these data are lacking for most regions of Russia. Table 7 presents the weighted averages over the contaminated areas of the exposure dose for thyroid gland from the data of direct measurements and using the model of multiple pathways of the iodine-131 migration through trophic chains. Comparing the two methods of assessment shows that the method of indirect assessment based on the model of multiple pathways provides higher values of the exposure dose as compared to the estimates from the data of direct measurements of I-131. However, on the whole, agreement between the two methods of dose assessment is satisfactory.

This suggests that the proposed method of estimating the exposure dose for thyroid gland based on the model of multiple pathways is efficient. Note that the estimated doses are averaged over sufficiently large territories. For persons living in the "patches" of radioactive contamination the individual exposure doses for thyroid gland can substantially exceed the average values.

The collective dose distribution throughout various contaminated areas in the Bryansk Region is characterized by the following special features. The greatest contribution to the collective dose (about 50 %) is made by the area of strict

radiation control with a density of soil contamination by Cs-137 of 555- 1480 kBq/m<sup>2</sup>, where about 6 % of the population of Bryansk Region lives. The second contribution (about 20 % of the collective dose) is made by the areas with moderate contamination levels (37-185 kBq/m<sup>2</sup> for Cs-137). The areas with low contamination levels (below 37 kBq/m<sup>2</sup> for Cs-137), account for about 15 per of the collective dose.

The highest levels of radiation risk ( $R=5E-$ ), exceeding the spontaneous risk of thyroid cancer, are characteristic of the young children under 5 living in the strict radiation control area. For the other groups of children the level of risk is somewhat lower but still remains fairly high. In the other contaminated areas (below 555 kBq/m<sup>2</sup> for Cs-137) the values of radiation risk are lower than the spontaneous risk of thyroid cancer but considerably in excess of the risk of the natural background radiation.

Note that the risk assessments were made on the basis of the risk coefficient  $r = 8 \times 10(-4)$  Sv-1 (ICRP 60) postulated without resort to the Chernobyl data. It seems very important to assess the risk coefficients, using the models of dose reconstruction and the data of medical monitoring.

### CONCLUSIONS

Radioisotopes of iodine presented the most serious hazard immediately after the accident. A combined analysis of the maps of daily I-131 depositions and rainfall areas showed that approximately in 75% of the cases the rainfall areas coincided with the regions of maximum I-131 depositions.

A rather close correlation was found between atmospheric depositions of I-131 and soil contamination with Cs-137 ( $r = 0.91$ ). Therefore a considerably more detailed data base on soil contamination with Cs-137 can be used for the reconstruction of the fields of soil contamination with I-131. A model of multiple pathways of the I-131 migration through food chains was developed and verified against the observational data. Exposure dose and radiation risk assessments were made for various age groups of the population living in the contaminated areas of Russia. Children under 1 were found to have the highest exposure doses of thyroid gland. A major contribution to the dose formation for children is

the consumption of milk. Next, in order of importance, is the consumption of water, vegetables, bread and baked goods of home manufacture. The doses through the food pathway were shown to exceed considerably (by an order of magnitude) the highest estimates of the doses from inhalation. For the most contaminated areas of Russia the levels of radiation risk for children resulted from the Chernobyl accident are comparable with or exceed the spontaneous risk of thyroid cancer. In the majority of contaminated areas the values of radiation risk lower than the spontaneous risk of thyroid cancer but exceed the natural background radiation risk.

Comparing the direct and indirect methods of dose assessment showed that the method of indirect assessment based on the model of multiple pathways provides higher values of the exposure dose which remain, however, within the confidence intervals.

It is very significant that the models of dose reconstruction and the data of medical monitoring in the areas of the Chernobyl accident also enable one to solve inverse problems on the assessment of radiation risk coefficients. This can lead to a certain reassessment of their values in the future, taking into consideration the Chernobyl data.

Table 1

Concentration of radionuclides in the near-surface air, Bq/m<sup>3</sup>

Radionuclide	Minsk 28-29 April	Baryshevka (Kiev region) 30 April-1 May	Obninsk (Kaluga Region) 30 April- 1 May	St.-Petersbu 28-29 April
I-131 (aerosol)	320	300	6.7	1.1
Te-132	74	3300	3.7	0.15
Cs-137	93	78	3.3	0.14
Cs-134	48	52	1.5	0.08
Ba-140	27	230	0.4	0.11
Ce-141	-	26	0.7	0.08
Ce-144	-	26	0.7	0.01
Zr-95	3.0	24	0.7	0.08
Ru-103	16	24	0.4	0.08

Table 2

Assessment of radionuclide concentrations in ground level air  
of Novozybkov area (Bryansk Region), Bq/m<sup>3</sup>

Radionuclide	28-30.04	1-10.05	11-20.05	21-31.05	1-30.06
Sr-89	1-5E-1	3-15E-2	8-46E-3	8-36E-4	6-30E-5
Sr-90	1-5E-2	3-17E-3	1-5E-3	1-4E-4	1-5E-5
Zr-95	3-25	2-12E-2	1-4E-2	6-24E-3	4-16E-4
Mo-99	6-34	-	-	-	-
Ru-103	5-35	1-7	1-9E-1	4-20E-2	3-14E-3
Ru-106	2-10	4-20E-1	4-16E-2	1-6E-2	2-10E-3
I-131*	200-1500	14-90	5-30	1-6	3-26E-2
I-133*	40-300	-	-	-	-
Te-132	20-180	-	-	-	-
Cs-134	10-50	4-16E-1	1-3E-1	5-15E-2	2-6E-2
Cs-137	20-100	8-32E-1	2-6E-1	1-3E-1	4-12E-2
Ba-140	10-70	2-12E-1	1-4E-2	1-5E-3	-
Ce-141	4-24	2-14E-2	3-20E-3	6-50E-4	1-5E-4
Ce-144	2-16	2-14E-2	5-30E-3	1-7E-3	1-6E-4
Np-239	20-120	-	-	-	-

Note: \* aerosol and gas forms.

Table 3

Dose reconstruction from inhalation of radionuclides in May-June 1986 (the area of Novozybkov, Bryansk Region), SvE-6

Time	28-30.04	1-10.05	11-20.05	21-31.05	1-30.06
Dose	200-900	40-170	9-30	3-11	1-3

Table 4

Concentrations of radionuclides in the surface air in Russia and adjoining states, (E-6)Bq/m<sup>3</sup> (1986)

Radio-nuclide	Observational area	May	June	July-December
Cs-137	I	>E+6	E+5	5E+3
	II	3E+5	1.8E+3	3.6E+2
Cs-134	I	>E+6	5E+4	3E+3
	II	1.5E+5	8.8E+2	1.6E+2
Ce-144	I			3.4E+4
	II	3E+5	3E+3	5E+2
Ru-106	I			1.3E+4
	II	3E+4	4E+3	4.4E+2

Note: The data are averaged over the observational areas:  
 I-Chernobyl, II-Mogilev, Gomel, Minsk, Kiev, Bryansk, Kursk.

Table 5  
Maximum accumulation of I-131 on soil after  
the Chernobyl accident of 1986, kBq/m<sup>2</sup>

City	Data	I-131
Baltiyisk	30.04 - 1.05	315
Brest	29 - 30.04	160
Gomel	28 - 30.04	2440
Kaliningrad	29 - 30.04	350
Kerch	2 - 3.05	17
Kiev	2 - 3.05	500
St.-Peterburg	1 - 2.05	8.5
Mariupol'	2 - 3.05	24
Minsk	30.04 - 1.05	30
Mogilev	28 - 29.04	60
Moscow	2 - 3.05	5
Obninsk	2 - 3.05	3
Odessa	2 - 3.05	70
Pinsk	28 - 29.04	810
Feodosiya	3 - 4.05	11
Khar'kov	1 - 2.05	14
Cherkassy	1 - 2.05	290
Chernobyl	1 - 2.05	2400

Table 6

The density of contamination with Cs-137  
and composition of population in the settlements  
of Novozybkov district (as to 1 October 1991)

Subarea	Samples	Cs-137, kBq/m <sup>2</sup>			Population		
		Min:	Aver.	Max.	Total	Male	Female
AGRO 1-1	143	136	380	1380	778	324	454
AGRO 1-2	36	44	460	655	857	382	475
AGRO 1-3	95	107	610	1890	785	346	439
AGRO 1-4	118	255	730	1470	776	322	454
AGRO 1-5	124	320	980	2290	874	381	493
AGRO 1-6	112	290	860	2160	1316	567	749
AGRO 1-7	73	170	700	1310	399	384	515
AGRO 1-8	49	70	280	470	995	441	554
AGRO 1-9	95	130	530	940	990	420	570
AGRO 1-10	34	190	1700	2670	681	275	406
AGRO 1-11	85	460	900	1750	985	419	566
AGRO 1-12	107	160	600	1140	1435	617	818
AGRO 1-13	51	125	310	550	769	323	446
AGRO 1-14	50	100	700	1200	746	325	421
AGRO 1-15	75	55	470	1030	1666	747	919
AGRO 1-16	118	150	1020	1560	622	249	373
AGRO 1-17	165	155	920	2460	1102	485	617
AGRO 1-18	24	110	420	620	432	181	251
AGRO 1-19	53	300	910	1400	144	61	83

Table 7

Comparison of the estimated exposure doses for thyroid gland of the population with the estimates based on direct measurements of the I-131 content in thyroid gland (The Near, 1987; Proceedings, 1991; Chernobyl, 1992; International, 1992; Kryshev et al., 1994)

Region	Age group	Weighted average of individual dose, cGy	
		From the data of direct measurements of I-131	Assessment based on the multiple model of the I-131 migration in trophic chains
Gomel Region	Children	100	160 ± 80
Gomel Region	Adults	42	55 ± 20
Gomel Region	Children	100	160 ± 80
	Adults	65	55 ± 20
Bryansk Region	Children	37 - 80	90 ± 40
	Adults	10 - 24	30 ± 15
Tula Region	Children	40 - 50	35 ± 15
	Adults	5 - 14	10 ± 4
Orel Region	Children	10 - 20	33 ± 18
	Adults	2 - 7	10 ± 4
Kaluga Region	Children	25 - 43	36 ± 18
	Adults	6 - 14	11 ± 5

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**URGENT - a model for prediction of  
exposure from radiocaesium deposited  
in urban areas.**

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**Abstract**

*In the event of a severe accident at a nuclear power plant, in which significant fractions of the core inventory are released to the atmosphere and subsequently deposited in urban areas, the long term external radiation hazard is mainly determined by the amount of deposited  $^{137}\text{Cs}$ . Mainly on the basis of field measurements, the computer code URGENT models the behaviour of this radionuclide subsequent to deposition on outdoor surfaces in an urban area. With the use of a library of pre-calculated dose factors, the dose-rate can be calculated as a function of time for a limited number of urban environments. The validity of model predictions has been investigated by comparison with field measurements of Chernobyl debris in different European countries. The doses received from indoor deposition are also estimated on the basis of experiments. This modelling can be used to facilitate the formation of clean-up strategies for urban environments.*

## 0. Introduction

Prior to the Chernobyl accident in 1986 very little thought had been given to the behaviour of radioactive fallout deposited in an urban environment or indeed as to how the contaminated area might be cleaned. The reason for this may be the erroneous assumption that the consequences of credible accidents would be relatively short-term and restricted to rural areas. As a result of the Chernobyl accident a need has emerged for contingency strategies which enable the consequences of radioactive contamination of large urban areas to be identified and dealt with as early as possible following contamination. The URGENT (URban Gamma Exposure Normative Tool) model has been developed in order to facilitate the decision-making in such cases. The aim of this work is to use experimental data from investigations reported by other workers together with measurements made by the Contamination Physics Group at Risø to describe the system of retention/migration loss processes which might occur on outdoor surfaces in a radioactively contaminated urban environment. The resulting gamma doses can then be calculated for four different urban or suburban environments using the dose conversion factors presented by Meckbach et al. (1988). The model is restricted to cover the behaviour of the single most important radionuclide concerning external dose from urban contamination - namely  $^{137}\text{Cs}$ . Further, a semi-empirical model has been included to estimate the relative importance of radiocaesium deposition on internal surfaces of buildings.

## 1. Methods

### 1.1. Calculations of dose from outdoor sources

The model URGENT, which runs on a personal computer, is based on the TAMDYN code in TURBO PASCAL (Kanyar & Nielsen, 1988) for radioecological modelling. It is mainly based on the linear compartment model theory. Thus, the transfer rate for radioactive matter following deposition on a given type of surface,  $m$ , can be written as:

$$\frac{dX_m}{dt} = \sum_{n=1}^P S_{nm}X_n - \left( \sum_{n=1}^P S_{mn} \right) X_m - L_m X_m + F_m$$

in which  $X_m$  and  $X_n$  represent the radioactive matter in compartments  $m$  and  $n$ , respectively, at a time  $t$ .  $S_{nm}$  is the transfer coefficient from compartment  $n$  to  $m$ .  $L_m$  is the transfer coefficient for flow of radioactivity out of the system, etc. (for instance, loss by radioactive decay), while  $F_m$  is the initial input to compartment  $m$ .

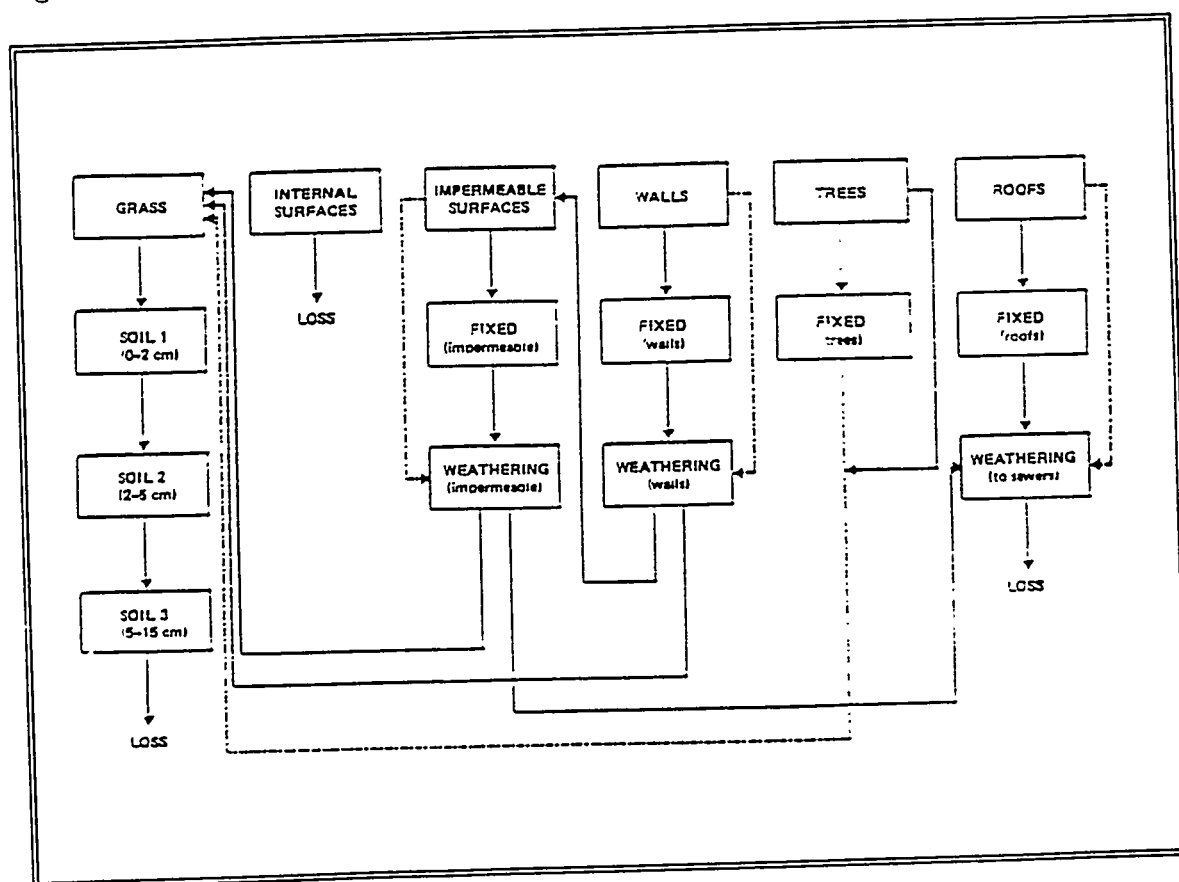
To provide dynamic solutions, the system is time integrated, employing the 4th (5th) order Runge Kutta method (included in the ODEPACK from Risø computer library), in which the coefficients introduced by Fehlberg (1969) have been implemented.

In principle, an accurate model would take into consideration the conditions for migration of all radionuclides that might plausibly arise from any accident fallout and on any possible

urban surface. To do so, however, one would need an immense amount of data. Further, since the running time for the present code structure is proportional to the square of the number of compartments, it is recommendable that certain generalizations be made. In any case, the field measurements are somewhat site-specific, and there is little to be gained by going into further detail.

In its present version, the model comprises 16 compartments, each representing a state in which  $^{137}\text{Cs}$  may be found on an urban surface. The flow diagram (Figure 1) shows the principle of the migration model with its assumptions. The dotted lines indicate that the processes taking place are discrete events. The term 'impermeable surfaces' means all horizontal surfaces that are not easily penetrated by water, such as asphalt and concrete.

Figure 1. URGENT contamination flow chart.



The 'internal surfaces' compartment contains the amount of radioactive matter deposited on the internal surfaces of buildings and on furniture and furnishings. In this paper the internal surfaces have been dealt with separately in section 1.2.

For those 'hard' surfaces on which weathering processes are likely to cause a migration of caesium contamination from one type of surface to another (paved horizontal surfaces, walls and roofs), the migration /retention is accommodated by splitting the activity into three 'pools'. These represent three different states at which radioactive matter may be found on

the particular surface. The first is the mobile phase representing part of the initially dry-deposited material. The second state is the more strongly bound. Weathering processes will however mobilize the material in this state, and it is here the third state arises, representing the remobilized material. It is suggested that the mobile fraction is so loosely bound to the surface that a heavy rain shower giving at least 3 mm of rain within a few hours (depending on the time of year, porosity, etc. (Roed 1988-a)) can displace the entire content of this compartment (Ritchie et al. 1976). This, though, is likely to be important only in cases where heavy rain falls shortly after contamination.

Naturally, this sort of subdivision is only approximate, since it is made without regard to the specific processes causing the fixation and thus yields no information on the degree of the fixation. However, the fixation processes are highly material dependent, and since the task was to make evaluations for typical European urban and suburban areas, the choice of distinct materials would make the model less widely applicable. In the model, the term 'fixed' means insoluble or not easily displaced.

For the activity deposited on trees the model structure is different. Based on published data, it is difficult to evaluate the effect of heavy rain or other weathering processes on the activity deposited on the trees. However, a slow transfer of activity from the trees to the grass due to the effects of wind and rain is taken into account in the model. A large fraction of the fixed activity will be removed from deciduous trees by leaf fall in the first autumn. It is assumed that all the leaves fall on a grassed area during the month of October and that a variable fraction is left on the ground to moulder.

The subdivision of the soil into three different depth compartments allows a simulation of removal of layers of top soil, or normal or deep ploughing. It also permits shielding calculations. In principle, it is possible in this model to simulate any decontamination procedure at any time following deposition by removing a part of the activity in a number of compartments.

The input parameters in URGENT are, where possible, based on experimental results. These parameters are clearly connected with considerable uncertainties since they represent a mean value of a number of results of independent measurements obtained under different conditions and on different materials, all of which fall within the same model category.

The transfer coefficients used in the present version of the model are listed in Figure 2 in the manner in which they are read into the main program.

Figure 2. URGENT input file.

```

test-data-URGENT-wet-depos
17 18 18 0 6
roof wall imps tree gras ints wfix wrun ifix irun rfix sewr tfix
soil1 soil2 soil3 loss
ints>loss G 1.1500E-01 3.0000E-01 1.0000E-02 4.0000E-01
wall>wfix U 2.3000E-01 1.0000E-01 1.0000E-01 4.0000E-01
imps>ifix U 2.3000E-01 1.0000E-01 1.0000E-01 4.0000E-01
roof>rfix U 2.3000E-01 1.0000E-01 1.0000E-01 4.0000E-01
sewr>loss N 2.3000E-01 1.2000E-01 1.0000E-01 4.0000E-01
tree>tfix U 2.3000E-01 1.0000E-01 1.0000E-01 4.0000E-01
wfix>wrun N 1.0000E-04 8.0000E-05 1.0000E-05 5.0000E-04
ifix>irun N 1.0000E-03 8.0000E-04 1.0000E-04 5.0000E-03
rfix>sewr N 4.6000E-04 4.0000E-04 2.0000E-04 1.2000E-03
wrun>gras N 8.0000E-01 8.0000E-01 4.0000E-01 9.0000E-01
irun>gras N 2.0000E-02 2.0000E-02 1.0000E-02 5.0000E-02
irun>sewr N 8.0000E-01 8.0000E-01 4.0000E-01 9.0000E-01
wrun>imps N 8.0000E-01 8.0000E-01 4.0000E-01 9.0000E-01
gras>soil1 N 4.6000E-02 4.0000E-02 2.0000E-02 1.0000E-01
soil1>soil2 N 4.0000E-04 3.8000E-04 2.0000E-04 5.0000E-04
soil2>soil3 N 3.0000E-04 2.5000E-04 1.5000E-04 4.5000E-04
soil3>loss N 6.0000E-05 5.0000E-05 3.0000E-05 1.0000E-04
tfix>loss N 1.0000E-03 8.0000E-04 1.0000E-04 5.0000E-03
grassconc :=gras.
soil1conc :=soil1.
soil2conc :=soil2.
soil3conc :=soil3.
roofscconc :=roof+rfix.
imperconc :=imps+ifix+irun.
0.0 0.2E+6 5.0E+3 2.0E+5 0.1E+6 2.0E+5 0.0 5.0E+3 0.0 3.0E+5 0.0
2.0E+5 0.0 0.0 8.0E+5 0.0 0.0 0.0 {initial t, konc.{Bq/m2}}
EEEE

```

In the first row is given the data file head. The second row states the number of compartments (17, including the loss compartment accumulating the flow out of the system), the number of transfer parameters in the input file (18), the number of input-defined parameters (also 18), the number of input-defined constants (0) and the number of outputs (6). In the third row follows a listing of the compartment names. The compartments are numbered in this order. Then follows the transfer parameter definitions. Starting in the fourth row in Figure 2, the first column indicates that the parameter deals with the transfer of activity from one compartment to another. The next column holds a single letter indicating the statistical function which the parameter variations follow. This variation by indicating the statistical function which the parameter variations follow. This variation by indicating the statistical function which the parameter variations follow. This variation by indicating the statistical function which the parameter variations follow. The letter 'N' means that the distribution is normal. 'U' means that it is uniformly distributed over an interval, while 'G' indicates a log normal distribution simulation. The third column gives the mean value which is used by itself in deterministic simulations. The fourth column shows the standard deviation for the distribution. The last two columns represent the minimum and maximum values of the 'random' parameter produced for the Monte Carlo analysis.

These parameters are written in the dimension of days<sup>-1</sup>, as the model time step has been chosen to run in units of days.

The following parameters define the output combinations for dynamic solutions of surface concentrations [Bq/m<sup>2</sup>].

In the last line the initial concentrations in the compartments (in [Bq·m<sup>-2</sup>]) are listed in the order given by the first line of the input file.

The transfer coefficient for fixation of activity dry deposited on walls. 'wall > wfix', like that for impermeable horizontal surfaces (imps), roof material and trees has been set to 0.23 days<sup>-1</sup>, corresponding to the assumption that 90 % of the material would be 'fixed' within 10 days if no radioactive matter were removed by weathering processes. At present, little information is available on the subject and the parameterisation in URGENT has been based on coarse experiments by Sandalls et al. (1986), Warming (1982), and experiments carried out at Risø (Andersson, 1991).

It is suggested that the residence time of sewage in sewerage systems is also about 10 days; hence 'sewr > loss' has been given the value 0.23 days<sup>-1</sup>. The velocity with which radiocaesium is typically removed by weathering processes varies widely depending on the surface type, mode of deposition and weathering conditions. The weathering processes on "hard" surfaces were modelled by two component functions (only one component is given in the input file, the other - marked + in the list below - is varied accordingly):

	Fraction	Half-life	Fraction <sup>+</sup>	Half-life
Roofs :	0.5	1.5 · 10 <sup>3</sup> d	0.5	3.4 · 10 <sup>2</sup> d
Imperm.:	0.5	6.9 · 10 <sup>2</sup> d	0.5	6.9 · 10 <sup>1</sup> d
Walls :	0.8	6.9 · 10 <sup>3</sup> d	0.2	6.9 · 10 <sup>1</sup> d

The weathering process on roofs was modelled according to the recommendations of Roed (1988-b), with slight modifications based on later measurements made at Risø. The weathering coefficients for impermeable horizontal surfaces were based on analytical expressions by Jacob et al. (1987), while the coefficients for walls were based more loosely on Risø measurements in Gävle, Sweden (campaigns in 1987, 1988, 1990, 1991 and 1993) and the findings of Sandalls et al. (1986).

It is assumed that all material weathered off roofs will eventually be lodged in the sewerage systems. The flow velocities of washed-off <sup>137</sup>Cs from 'impermeable' horizontal surfaces and walls to grassed areas are considered to be equal in magnitude. In the absence of any measured data, the time constant for the flow of loosened activity has been estimated to be about 1 day<sup>-1</sup>. The behaviour of <sup>137</sup>Cs deposited on a grass cover has been modelled on the grounds of recommendations from Krieger & Burman (1969). It is advisable to adjust the relationship between the fraction initially deposited on the ground and that deposited on the rougher grassed surface in the light of the assumed wet/dry deposition relationship. The migration of <sup>137</sup>Cs in soil has been modelled according to Andersson & Roed (1994). For dose calculations, the shielding factors for caesium in the different soil layers have been based on the work of Jacob & Paretzke (1986).

Where possible, the standard deviations on the input parameters have been based on the

variations in the individual experiments which led to the parameterisation. For further information on the URGENT model the reader is referred to the URGENT model user's guide.

## 1.2. Calculations of dose from indoor sources

From the assumption of a constant aerosol concentration outside a building, and the knowledge of the rate coefficient of ventilation (the fraction termed  $\lambda_r$  of air exchanged per unit time), the rate coefficient of deposition (the fraction termed  $\lambda_d$  of aerosols in the building deposited per unit time), the filtering factor  $f$  (the fraction of aerosols in air entering the building which is not retained in cracks and fissures of the building structure), the relationship between the equilibrium indoor aerosol concentration ( $C_i$ ) and the outdoor aerosol concentration ( $C_o$ ) can be calculated as:

$$C_i / C_o = f \lambda_r / (\lambda_r + \lambda_d).$$

If the average local indoor deposition velocity ( $v_d = \lambda_d V/A$ , where  $V$  is the indoor volume and  $A$  is the indoor surface area), and  $V_{dg}$  (the average deposition velocity on a grassed outdoor surface) are also known, a relationship can be established between the average deposited contaminant concentration on indoor surfaces ( $D_i$ ) and the deposited contaminant concentration on a smooth, cut lawn (the common reference surface for outdoor contamination) here termed  $D_o$ :

$$D_i / D_o = (V_d / V_{dg}) f \lambda_r / (\lambda_r + \lambda_d).$$

Field investigations by Roed (1990) showed the caesium aerosol to have a typical deposition velocity of  $4.3 \cdot 10^{-4}$  m/s on cut grass surfaces ( $V_{dg}$ ). A representative value of the relationship  $V/A$  for a furnished room is 0.5 m. Following the Chernobyl, a series of experiments (Roed and Cannell, 1987) were made in which the typical values of  $\lambda_r$ ,  $\lambda_d$  and  $f$  were determined for the Chernobyl  $^{137}\text{Cs}$  aerosol in a furnished Danish house. These values were used in the calculations of the mean indoor deposition ( $\text{kBq/m}^2$ ) that form the basis for the calculations of doses received from indoor relative to outdoor deposited  $^{137}\text{Cs}$ .

## 2. Results

The following doses from external surfaces in urban environments (Table 1) accumulated over 1 and 10 years following a wet or dry deposition on the 26th of April were calculated with the URGENT model assuming a deposition on grass of  $1\text{MBq/m}^2$   $^{137}\text{Cs}$ . The relative deposition on other outdoor urban surfaces was assumed to be as given by Roed et al. (1990). It was further considered that the average person living in one of the four urban environments, for which dose conversion factors are available, spends 85 % of the time at indoor locations, equally distributed between the different residential floors, 10% of the time in the garden and 5 % on the streets.

**Table 1.** External location averaged doses (mGy) from different contaminated outdoor surfaces accumulated over 1 and 10 years following a wet or dry deposition on 26. April of 1 MBq/m<sup>2</sup> <sup>137</sup>Cs in four different environments described by Meckbach et al. (1988). Contamination on indoor surfaces is not included here.

Wet dep. 1 y	ROOFS	WALLS	ROADS	TREES	GRASS
Prefabricated	0.72	0.034	-	0.098	8.20
Semidetached	0.39	0.010	-	0.026	3.13
Terrace-house	0.15	0.008	0.320	0.022	1.89
Multistorey	0.006	0.008	0.434	0.011	1.34

Wet dep. 10 y	ROOFS	WALLS	ROADS	TREES	GRASS
Prefabricated	2.58	0.250	-	0.133	55.6
Semidetached	1.39	0.076	-	0.036	22.3
Terrace-house	0.54	0.061	0.822	0.031	13.1
Multistorey	0.022	0.057	1.119	0.015	9.55

Dry dep. 1 y	ROOFS	WALLS	ROADS	TREES	GRASS
Prefabricated	1.79	0.34	-	2.93	9.01
Semidetached	1.16	0.13	-	0.79	3.53
Terrace-house	0.37	0.08	0.26	0.68	2.04
Multistorey	0.015	0.07	0.37	0.34	1.45

Dry dep. 10 y	ROOFS	WALLS	ROADS	TREES	GRASS
Prefabricated	6.41	2.48	-	3.98	68.7
Semidetached	3.44	0.76	-	1.08	27.4
Terrace-house	1.34	0.61	0.75	0.93	14.9
Multistorey	0.054	0.57	1.11	0.46	10.9

In order to verify the dynamics of the model, results of URGENT simulations have been compared to experimental data from different parts of Europe. A reasonable agreement was found for all surfaces. An example is given in Figure 3 for pavings (roads). Here comparison was made with field measurements in Gävle, Sweden by Risø (DK) and Karlberg (S, 1988) and with measurements in Germany (D, Roed & Jacob, 1990). A weakness of these comparisons is that almost all available data for the weathering of caesium on urban

structures has been obtained from in situ measurements of Chernobyl fallout.

The assumption of a 1 to 10 relationship between the caesium concentrations on external walls and grass immediately following dry deposition and 1 to 100 immediately following wet deposition was verified by a series of measurements in 1993 in the contaminated areas of the former Soviet Union. In the town of Pripyat, where radiocaesium was dry deposited, the contamination level on sandstone walls was found to be in the range of 119-350 kBq/m<sup>2</sup>. Here, the level on a grass cover was found to be 2.9 MBq/m<sup>2</sup>, or about 10 times that on the walls. In other, more remote towns, where deposition occurred with rain, the level on sandstone walls was found to be about 0.9-28 kBq/m<sup>2</sup>, while the corresponding levels on grass were about 100 times as high. It is known that the caesium level both on grass and on vertical surfaces decreases very slowly without intervention, so the measured values are in agreement with what has been assumed in the model. In Pripjat, the level on the more impervious horizontal surfaces, such as roads and pavements, had decreased much more significantly, due to 'natural' decontamination by traffic and surface water flow, from presumably about 1.5 MBq/m<sup>2</sup> to 30-350 kBq/m<sup>2</sup> (or 1-10 % of the initial contamination level on grass).

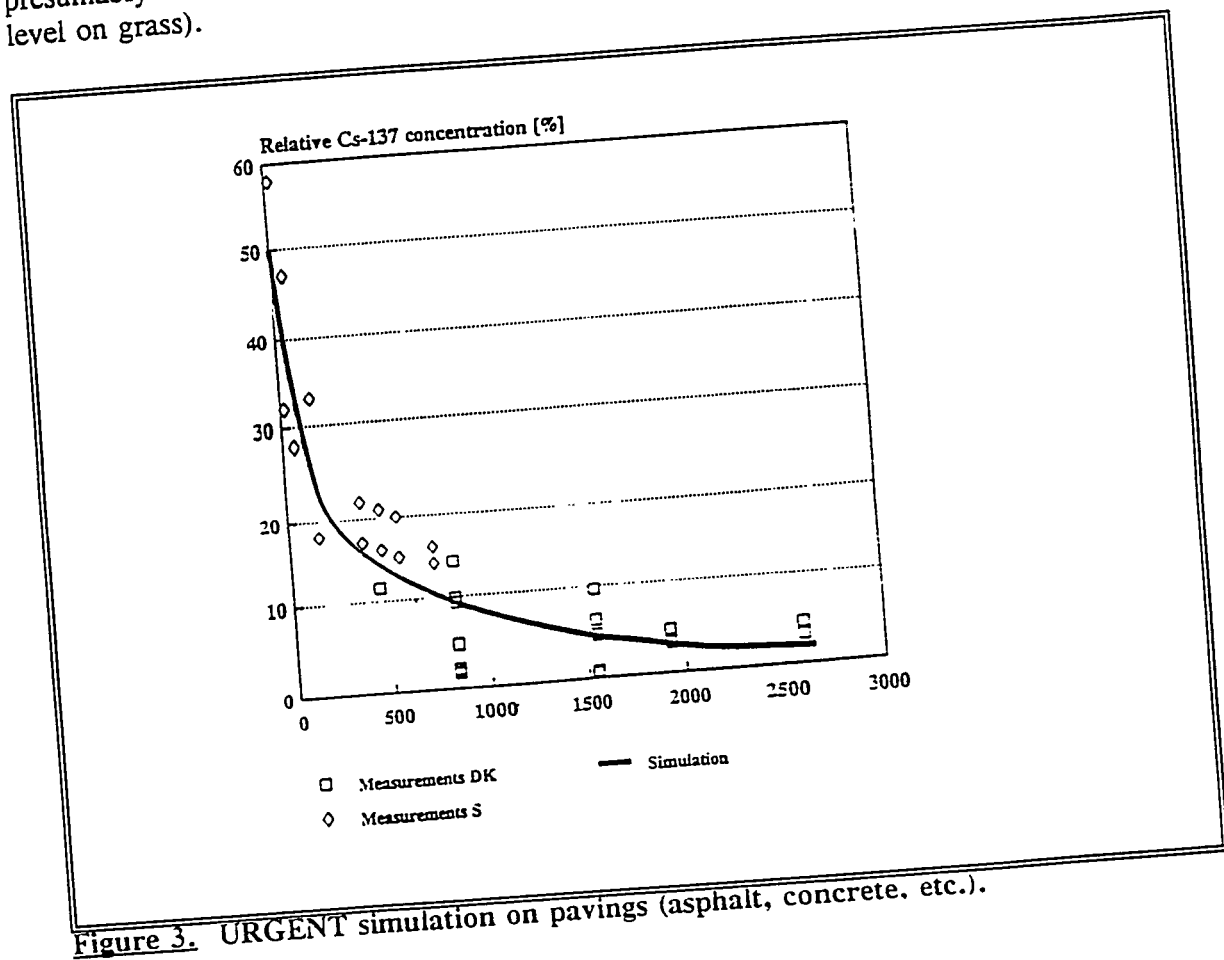


Figure 3. URGENT simulation on pavings (asphalt, concrete, etc.).

The calculated mean indoor depositions are given in Table 2 for a variety of what are considered to be realistic values of  $f$ ,  $\lambda_d$  and  $\lambda_r$  concerning aerosols of the Chernobyl <sup>137</sup>Cs size.

**Table 2.** Calculated mean indoor deposition ( $\text{kBq/m}^2$ ) under different circumstances relating to an outdoor deposition on grass of  $1 \text{ MBq/m}^2$ .

$f = 0.4$	$\lambda_a = 0.36 \text{ h}^{-1}$	$\lambda_a = 0.60 \text{ h}^{-1}$	$\lambda_a = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	21	26	30
$\lambda_r = 0.4 \text{ h}^{-1}$	24	30	37
$\lambda_r = 0.6 \text{ h}^{-1}$	29	39	48

$f = 0.6$	$\lambda_a = 0.36 \text{ h}^{-1}$	$\lambda_a = 0.60 \text{ h}^{-1}$	$\lambda_a = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	32	39	45
$\lambda_r = 0.4 \text{ h}^{-1}$	36	45	56
$\lambda_r = 0.6 \text{ h}^{-1}$	44	58	72

$f = 1.0$	$\lambda_a = 0.36 \text{ h}^{-1}$	$\lambda_a = 0.60 \text{ h}^{-1}$	$\lambda_a = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	53	65	75
$\lambda_r = 0.4 \text{ h}^{-1}$	60	75	93
$\lambda_r = 0.6 \text{ h}^{-1}$	73	97	120

The corresponding dose estimates for indoor surfaces were made equivalent to a target position 1m above the ground in a room with height 3m and in the centre of a ground area of 4m by 4m. The dose contribution from scattered radiation and deposition on internal surfaces of neighbouring rooms was not included. It was stipulated in the dynamic calculations that the caesium level on the floor decreases with a half-life of 1 month due to hoovering, and that the effective half-life on walls, furniture and ceiling is 5 years, as these surfaces are usually only rarely treated.

Recent experiments carried out by Lange et al. at the Contamination Physics Group at Risø using porous silica particles of various monodisperse size distributions ranging from 0.7 to 20 microns and labelled with neutron activatable tracers have shown that the deposition velocity to the floor approximately equals the sum of the deposition velocities to the four walls and the ceiling (Table 3). This distribution pattern was applied in the dose modelling.

**Table 3.** Mean deposition velocities ( $10^{-4} \text{ m/s}$ ) of monodisperse 0.7 micron particles collected on hard pressed Whatman 542 filters on surfaces of different orientation in a room.

Ceiling	Wall (N)	Wall (S)	Wall (E)	Wall (W)	Floor
0.189	0.235	0.230	0.117	0.249	1.581

Table 4 shows the dose estimates relating to the deposited radiocaesium concentrations given

in Table 2.

**Table 4.** Estimated received doses the first year following contamination (mGy), equivalent to a target position 1m above ground in a room with height 3 m and in the centre of a 4m by 4m ground area assuming the above mean indoor concentrations and that 50 % of the total amount of caesium is deposited on the floor, while the rest is equally distributed on the walls and ceiling.

$f = 0.4$	$\lambda_1 = 0.36 \text{ h}^{-1}$	$\lambda_1 = 0.60 \text{ h}^{-1}$	$\lambda_1 = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	0.19	0.23	0.27
$\lambda_r = 0.4 \text{ h}^{-1}$	0.22	0.27	0.33
$\lambda_r = 0.6 \text{ h}^{-1}$	0.26	0.35	0.4

$f = 0.6$	$\lambda_1 = 0.36 \text{ h}^{-1}$	$\lambda_1 = 0.60 \text{ h}^{-1}$	$\lambda_1 = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	0.29	0.35	0.41
$\lambda_r = 0.4 \text{ h}^{-1}$	0.32	0.40	0.51
$\lambda_r = 0.6 \text{ h}^{-1}$	0.39	0.53	0.65

$f = 1.0$	$\lambda_1 = 0.36 \text{ h}^{-1}$	$\lambda_1 = 0.60 \text{ h}^{-1}$	$\lambda_1 = 1 \text{ h}^{-1}$
$\lambda_r = 0.3 \text{ h}^{-1}$	0.48	0.59	0.68
$\lambda_r = 0.4 \text{ h}^{-1}$	0.54	0.68	0.84
$\lambda_r = 0.6 \text{ h}^{-1}$	0.66	0.88	1.08

### Discussion/conclusions

A dynamic model has been formed for calculation of dose from external surfaces in housing environments. In the examined environments, ranging from suburban single family house areas to urban centres, the location averaged dose contribution from the grassed areas was found to be dominant (65 % - 90 % of the total first year dose and 83 % - 95 % of the total ten years dose from outdoor surfaces). However, it would be dangerous to make decisions alone on the background of the location averaged figures, as dose contributions to people living on specific floors of tall buildings may be very different. For instance, the first year dose contribution from contamination on roofs to people living on top floors of multistorey buildings is dominant according to these calculations. Later on the relative importance of roofs will decrease due to weathering.

As can be seen from Table 4, the first year doses from deposition on internal surfaces of buildings may be rather large compared with those from the outdoor surfaces. In buildings with a high ventilation rate, a high deposition rate, and a low degree of filtration of caesium aerosols passing through the building, the first year dose from indoor surfaces may in certain

cases be almost as much as that from outdoor surfaces.

Together with the available information on decontamination efficiencies, strategies for clean-up of contaminated areas could be deduced from such computer modelling. A limitation in the applicability of the calculations is, however, the small number of housing environments available for dose estimates. It would be a clear advantage if dose calculations for more housing environments, typical of different parts of Europe, were included in the dose factor library.

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# **WORKSHOP ON "DOSE RECONSTRUCTION"**

**Bad Honnef**

**06.06. - 09.06.1994**

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**ABSTRACTS**

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URGENT - a model for prediction of exposure from radiocaesium deposited in urban areas

Kasper G. Andersson, Riso National Laboratory

In the event of a severe accident at a nuclear power plant, in which significant fractions of the core inventory are released to the atmosphere and subsequently deposited in urban areas, the long term external radiation hazard is mainly determined by the amount of deposited  $^{137}\text{Cs}$ . Mainly on the basis of field measurements, the computer code URGENT models the behaviour of this radionuclide subsequent to deposition in an urban area. With the use of a library of pre-calculated dose factors, the dose-rate can be calculated as a function of time for a limited number of urban environments. The validity of model predictions has been investigated by comparison with field measurements of Chernobyl debris in different European countries. The model has been used in the formation of clean-up strategies for urban environments.

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Chromosome painting and conventional chromosome analysis for retrospective dose reconstruction of Chernobyl reactor personnel and liquidators

M. Bauchinger, K. Salassidis, E. Schmid and H. Braselmann, Institut für Strahlenbiologie, GSF-Forschungszentrum, Germany

Chromosome analyses were carried out in peripheral blood lymphocytes from 15 persons exposed to ionizing radiation from the Chernobyl nuclear power plant accident. Nine subjects were exposed as working personnel within or nearby the reactor immediately after the accident and three as members of teams of technicians participating in rescue and clean-up operations (so-called liquidators). For all, a history of acute radiation syndrome is reported. Three received a bone marrow transplantation. Currently they are examined and treated in the Department of Dermatology, University Clinic, Munich for symptoms of the delayed stage of cutaneous radiation syndrome.

Biological dose estimates were determined, either by measuring the frequency of dicentric and ring chromosomes in first division unstable cells from conventional preparations (Qdr-method), or by measuring the frequency of stable translocations using two-colour fluorescence in situ hybridisation (FISH) with painting probes for human chromosomes 1, 4 and 12 and a pancentromeric DNA probe.

With both methods fairly comparable individual estimates between 1.1 to 5.8 Gy were obtained for 12 of 15 individuals. For three patients consistently no elevated aberration frequencies were found with conventional scoring and FISH analyses. In each of these cases we have clear evidence for the occurrence of various clonal abnormalities. Perspectives and limitations of chromosome dosimetry for past radiation exposures are discussed

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About new approaches to EPR and luminescent retrospective dosimetry of objects from Chernobyl accident zone

A. Brik, V. Radchuk, V. Degoda, Yu. Marasuev, O. Scherbina  
(Institute of Geochemistry, Mineralogy and Oreformation of Academy of Science of the Ukraine)

After the Chernobyl accident had appeared a range of problems that need the reconstruction of doses which different objects have received for the last years. Among these problems are restoration of the radiation history of the territory, technical and biological objects including population. For to solve this problems, it is necessary to apply complex of instrumental methods, working out new approaches and scientific ground of retrospective dosimetry. We have studied the process of forming and accumulation radiation defects in quartz (associated with aluminium impurity), the radiation properties of EPR signals in different part of mollusc shells.

We have worked out a new approach in luminescence retrospective dosimetry. This approach is based on kinetic effects in X-ray luminescence. It was found that X-ray luminescence signals (at 380 nm) depends on the initial state of defects determined by the dose taken before by the object under investigation. This method has a high sensitivity and needs only a few quantity of sample we have worked out a new method of registration of EPR signals with external electric field as well. By means of this method we have registered EPR signals of aluminium centers in samples irradiated by dose (0.3 - 0.4) Gy. The mentioned above methods we have applied to dose reconstruction of objects from Chernobyl accident zone.

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Vitreous materials: prospects in retrospective dosimetry

L. Brodski and G. Hütt

Widely spreaded vitreous materials may prove very useful in retrospective dosimetry in case of accidents connected with radiation pollution of an area or premises without systematic monitoring. Different kinds of vitreous materials produced by different factories in the former Soviet Union were studied by thermoluminescence (TL) method. Samples were treated in the form of powder. TL reader designed in Tallinn was used. Almost all samples measured had rather intensive TL in wide temperature region. Some of them (decorative wall tile, car headlight glass etc.) proved to be very dose sensitive. Disadvantage of this type of material is fading. Nevertheless, residual signal remains dose dependent. Therefore these materials can successfully be used for purposes of retrospective dosimetry. Dose response curves, fading and minimal detectable doses for different vitreous materials are discussed.

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Present state of retrospective dosimetry of external exposure to evacuees and liquidators

V. Chumak, USCRM Kiev, Ukraine

R. Meckbach., GSF-Neuherberg, FRG

Models are being developed for the calculation of individual external radiation exposures received by the population evacuated from the city of Pripjat and the settlements of the 30 km zone. Input parameters of the models are a data set of gamma dose rate measurements performed after the accident, information on the location and behaviour of evacuated persons, obtained by a population survey with questionnaires involving 15.000 people evacuated from Pripjat and 18.000 from the 30 km zone and location (shielding) factors for typical housing buildings. The location factors are calculated by Monte Carlo simulation of the photon transport for different source energies, deposition areas and radioactive cloud configurations. Methods for the assessment of the uncertainty distributions of the input parameters are developed. Using Monte Carlo methods, uncertainty distributions for the individual external exposures are calculated in the model from the uncertainty distributions of the input parameters.

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Experience from reconstructing thyroid doses due to the Windscale Reactor Fire -  
October 1957

M. J. Crick

On the 10 and 11 October 1957 a fire in the No. 1 Pile at the Windscale establishment in Cumbria led to an uncontrolled release of activity to atmosphere. The resultant cloud was subsequently dispersed and radionuclides could be detected over England, Wales and parts of northern Europe. The extensive environmental measurements which were made during and after the release enabled a fairly accurate estimate to be made of the radiation doses to the most exposed individuals in the local population. The author was involved in a study that made estimates of the thyroid doses to the population as a whole. The methods used for estimating these doses will be outlined and some insight into the problems of dose reconstruction from environmental measurements given.

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Dose reconstruction in bones using Electron Paramagnetic Resonance

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The knowledge of the dose distribution inside the body is extremely important in situations as accidental internal contamination and radiopharmaceutical administration for therapeutic and palliative purposes. Notwithstanding the attention internal dosimetry has been receiving, a lot of problems are still open, such as the knowledge of metabolism of radionuclides and the irregular geometry of organs. The presently accepted dosimetry relies on the MIRD (Medical Internal Radiation Dosimetry) scheme, which combines physical properties of the radionuclide with physiological data. Unfortunately metabolism data are known only for a few radioisotopes. Therefore there is a great demand for experimental techniques apt to provide dose distribution and hence to confirm theoretical expectations.

Electron Paramagnetic Resonance (EPR) spectroscopy can be a tool for validation of models, and for providing information about activity distribution of radioisotopes when unknown. Some tests have been carried out up to now on bones from people involved in nuclear accident, in order to provide the average dose they received.

In this paper a first attempt of mapping the dose distribution in bones is presented. The method was tested on an animal bone tissue treated with a radiopharmaceutical. The experiment was carried out *ex vivo*, that is the radionuclide was administered *in vivo*, then the animal was sacrificed and the dose in bone detected. The radiopharmaceutical was Holmium-166 chelated with ethylenediaminetetramethylene phosphonate (EDTMP) and the administered activity was 20 mCi/kg. After the animal was sacrificed, a humerus was cut in about 60 fragments and, for each fragment, the dose was assessed by the dose additive method. Efforts are still required to quantify the absorbed dose, but first data show that the dose distribution in the bone is not uniform and the radionuclide seems to be more concentrated in the ends than in the midshaft with a concentration ratio of about 5:1.

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The limits of luminescence techniques with domestic materials for retrospective dosimetry

Y. Göksu, GSF - Institut für Strahlenschutz

The dose reconstruction after radiation accidents by use of building material like bricks, tiles and porcelain with luminescence methods is well established. However, at certain conditions especially in rural areas where the wood is used as a construction material, there is a necessity to find alternative material. In these studies various household materials like, the fluorescence lamp coatings, pot scale, the anhydride fraction of table salt and blackboard chalk are investigated.

The radiation induced thermoluminescence response of the above mentioned material is investigated to establish the type and the form of suitable natural and household materials offering the best potential for retrospective dosimetry. The thermal and optical stability of the radiation induced centres are measured. The trap parameters are calculated to determine the applicable time range of the method after accidents. The determination of lower limits are based on the precision required for dosimetry being  $\pm 20\%$ . Unirradiated standard, commercially available material or known source material are used for this measurements.

Among the materials studied here, the pot scale is found to be the most suitable material for doses assessment above 0.3 Gy. It has no internal activity like bricks and tiles. The internal dose accumulated due to the age of the sample need not to be assessed by additional measurements of uranium, thorium and potassium content.

The fluorescent lamp coating are found to be very sensitive, lower detectable limit is found to be 0.01 Gy. The material consist of fluorapatite therefore can be used as bone equivalent material.

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### Retrospective thyroid dose reconstruction

G. Goulko, I. Kairo, I. Likhtarev, G. Pröhl, B. Sobolev

Thyroid exposure is one of the most important consequences of the Chernobyl accident. The thyroids of the population (especially children) from the Northern part of the Ukraine were highly exposed due to the  $^{131}\text{I}$  release. There are some possibilities for the retrospective thyroid dose reconstruction some years later after the accident. For this purpose it is possible to use:

- direct measurements of the radioiodine activities in the thyroids or in different environmental media;
- $^{129}\text{I}$ ,  $^{137}\text{Cs}$  or  $^{14}\text{C}$  deposition;
- questionnaire and
- release scenario and meteorological information.

These data could be used separate or in the different combinations. Some of these possibilities are used for the thyroid dose reconstruction in the Ukraine. In this paper the thyroid exposures of different groups of population for the three most contaminated regions (Kiev, Gitomir and Chernigov) are estimated.

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Combined ESR dosimetry using dentine and enamel of teeth

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V.I. Polyakov, Institute of Geology, Tallinn, Estonia

Retrospective dosimetry in humans exposed to radiation accident situations can be done using the radiation sensitive EPR signal in calcified tissues, including bone and teeth. Teeth are particularly attractive as dosimeters because in a given population they are continually being extracted. Ongoing work in our laboratory has shown that doses well below 1 Gy can be quantitated in crushed enamel. Until recently the presence of organic material has prevented similar quantitation of dentine. We have recently applied an extraction technique to dentine which removes most of the organic material of the dentine leaving a predominately hydroxyapatite preparation. Using this technique, we have found that results similar to those mentioned above for enamel are readily obtained. A problem in accurately assessing the long-term health risks to victims of radiation accidents is that both ingestion of radionuclides and exposure to external gamma emitters can occur. By combining EPR measurements from both enamel and dentine of the same teeth it should be possible to determine dose due to internal versus external emitters in an individual exposed in an accident situation. Such determination would be possible due to the greater uptake of circulating radionuclides experienced by dentine versus enamel. The lack of remodelling in dentine would further insure that the exposed hydroxyapatite would retain a history of exposure for an extended period of time.

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A method of retrospective reconstruction of children's thyroid dose using  $^{129}\text{I}$  soil contamination

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Research Centre Jülich GmbH

In the last years, an increase of children's thyroid diseases has been observed in those areas which were strongly contaminated by the Chernobyl accident. A critical thyroid dose might have been caused by the releases of short living iodine nuclides in the first few days after the accident. In order to prove an assumed correlation between the iodine intake and the growing number of thyroid diseases, a retrospective reconstruction of children's thyroid doses is necessary because only insufficient data from measurements of the short living iodine nuclides are available.

The most important contribution of the thyroid dose is expected from  $^{131}\text{I}$ . The dose of which can be reconstructed on the basis of the measured net  $^{129}\text{I}$  soil contamination because (1) of an established relation between the long living  $^{129}\text{I}$  and the short living iodine inventory of the reactor which only depends on the reactor's working time and (2) all radioiodine nuclides behave in the same manner during release from the reactor, during dispersion in the atmosphere and during deposition onto vegetation and soil.

Assuming the deposition only by fallout with an effective deposition velocity will result in an upper limit for the inhalation dose and an approximately equal contamination of soil and vegetation. If the deposition is caused only by washout contamination of vegetation is about a factor of 3 less compared to soil contamination, and the inhalation dose will be smaller. To get the thyroid dose for ingestion there is a straight forward calculation from the known contamination of vegetation using parameters such as: iodine transfer factor for grass to milk, grass consumption rate by cows, yield of grass per square meter, consumption rate of milk by children and dose factors.

Due to countermeasures, e.g. by prohibition of milk consumption, the resulting ingestion dose is expected to be smaller than the calculated one. The assessed thyroid dose values will be compared e.g. with  $^{131}\text{I}$  soil contamination data and measured  $^{131}\text{I}$  thyroid gland burdens in few selected villages.

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$^{137}\text{Cs}$  concentration among children in Mogilev and Gomel oblasts, Belarus

M. Hoshi, Hiroshima University

Chernobyl Sasakawa Health and Medical Cooperation Project began in April, 1991 as a five year project. The project planned to examine from 0 to 10 years old children at the time of the Chernobyl accident in the fallout area of the accident. The cooperation placed five medical centres for examination. They are Mogilev and Gomel centres in Belarus, Kiev and Korosten (Zitimir) centres in Ukraine and a Klincy centre in Russia. The terms of the examination included those concerning  $^{137}\text{Cs}$  whole body counting, thyroid and hematological examinations. Here, we report concerning the level of radiation exposure in Belarus on the basis of whole body  $^{137}\text{Cs}$  count. The subjects were 10,062 children (4,762 boys and 5,300 girls) in Mogilev and Gomel, Belarus who received the project's health examinations during the period from May 1991 to December 1992. The median levels of whole body  $^{137}\text{Cs}$  count per body weight varied from 21-48 Bq kg<sup>-1</sup> and from 28-126 Bq kg<sup>-1</sup> in Mogilev oblast and Gomel oblast, respectively. Corresponding annual effective dose equivalents were all less than the public dose limit of 1.

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Some aspects of absorbed dose evaluation using tooth enamel by ESR-spectroscopy

G. Huett and V. Polyakov: Institute of Geology, Tallinn, Estonia

Different kinds of dental enamel were investigated, including samples extracted from human (milk and permanent) and cow teeth. It was shown, that the radiation sensitivity of the relevant ESR-signal at  $g=2.0018$  varies in an wide range depending on the specimen, even for the set of tooth enamel samples, taken from one person.

The influence of the background signal on the absorbed dose estimation have been carried out too. This signal appears to be radiation sensitive, that leads to the enhancement of its contribution to the reference signal with higher dose irradiation. Moreover, the width of the background signal changes depending on the grain size of a sample, that causes either a "positive" interference with the reference signal for smaller grain size or "negative" one for larger grains. This feature, in turn, leads to over- or underestimation of absorbed dose, respectively.

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Key problems of individual thyroid dose reconstruction  
due to Chernobyl accident

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The content of the main presentation (30 minutes)

1. The history of the problem for the former Soviet Union.
2. Peculiarities of the thyroid dose estimations for personnel of the Chernobyl station and for other 'liquidators'.
3. Peculiarities of the radioiodine thyroid measurements of inhabitants in May and at the beginning of June 1986, who lived in the contaminated areas.
4. The models of individual internal dose calculation on the basis of iodine content measurements. (The main features and peculiarities obtained by different teams of researchers)
5. Group characteristics of internal thyroid irradiation of inhabitants of settlements with sufficient number of direct measured people. The passports of such settlements.
6. The relation between group characteristics of internal thyroid irradiation of inhabitants and radionuclides deposition density: The main semi-empirical regularities and their using for thyroid dose reconstruction.
7. Basic unsolved problems and ways for looking for the answers.

The content of the additional presentation (20 minutes)

(The problem of internal thyroid dose reconstruction from the mathematician statistics point of view)

1. Functions of individual internal thyroid dose distribution and the problem of adequate descriptions of such functions by several parameters.
2. Common requirements to the ideal model for internal thyroid dose predictions on the basis of data of radioactive release source applying to semi-empirical models of thyroid dose reconstruction on the basis of limited number of measured parameters of the radiation situation.
3. About the using the thyroid dose reconstruction results for ascertainment of the possible radiation dependence of thyroid diseases.

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Problems of dose reconstruction and prediction for the public in the territories affected by radioactive contamination

V.O. Konstantinov, Institute of Radiation Hygiene, St. Petersburg, Russia

Decision making in restoration of normal economic activity and living of people on the territories affected by radioactive contamination should be based on the assessment of radiological risk on an actual situation. The reconstruction of past doses and the prediction of future doses need a knowledge or suggestions on a time-scale dynamics of the main parameters of radiation situation. Exposure to external radiation and intake of radionuclides by human organism is influenced by a range of technological (source term), environmental and social factors, that implies the need for specific dose assessment methods for each particular situation under consideration. The generic scheme for assessment of doses to the public in the territories affected by radioactive contamination is presented in this paper. The scheme is illustrated by examples of dose reconstruction applying to specific radiation situation. The methodology of dose assessment should be dependent on essential features of decision making system, namely:

- a concept and wording of criteria for implementation of radiation protection and social protection measures and for regulation of economic activities on the radioactive-contaminated territory,
- interrelation between primary (dose) and secondary (irradiation and contamination) radiological criteria,
- specification of dose under consideration (projected - averted - residual, collective - individual, effective - equivalent).
- degree of realism and conservatism in assumptions suggested for use in dose calculations.

The methods for reconstruction and prediction of doses are dependent also on the completeness and uncertainties of a needed radiometric, ecological and social information. Doses assessment methodology, in turn, implies requirements to standardisation or comparability of procedures for measurements, analyses, sampling and interpretation of radiometric data.

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Reconstruction of internal doses from caesium radionuclides

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In the Russian Federation territories most affected by radioactive contamination following the Chernobyl accident are the western districts of the Bryansk Region. A radiometric examination of the population to determine the body content of caesium radionuclides was undertaken in the "strict control zone" (SCZ) with a caesium-137 contamination level (S) of  $>0.56 \text{ MBq/m}^2$ . During the first two years after the accident about 90.000 people were examined. Most of them twice and some of them three times or more. With the aim to reconstruct mean individual doses for all settlements as well as personal doses for residents in the SCZ a computerised information system is developed. The system contains data bases of radiological and social information, software modules for cross-checking, verification and correction of primary records from radiometric and questionnaires surveys of population, software for production and processing of secondary radiological information. In view of essential change (mainly decrease) of radiocaesium body contents after the early summer 1986, simplified model was employed to calculate personal doses taking into consideration the time points of single or several whole body measurements during a period of dose accumulation. Reconstructed internal dose distributions are presented for rural settlements with S of 1.2 to  $2.4 \text{ MBq/m}^2$ . The factors influencing frequency distribution are considered in the light of their relevance to dose reconstruction.

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Realistic approach to reconstruction of thyroid doses to population following the Chernobyl accident

Y.O. Konstantinov, G Nikolaeva, Institute of Radiation Hygiene, St. Petersburg, Russia

Personal dose (PD) is considered here as individual dose ascribed to an identified personal. Uncertainties in calculation of PD from data on measurements of radioiodine content in thyroid after the Chernobyl accident are assessed. Degree of uncertainty depends on the time of a single measurement after the start of radioactive contamination of terrain, on time course of radioiodine fallout on the availability of relevant ecological and social information. The error in numerical value of PD from a single thyroid examination performed during a month after the accident ranges from several ten percent (the best case) to hundreds percent. For persons without individual measurements data, the error in PD value may reach order of magnitude when dose reconstruction is based on environmental radiological data and food habits data.

This unhappy conclusion leads to a feeling that stochastic (statistical or probabilistic) presentation of PD is more reasonable than a deterministic one. The specific form of presentation of PD values is a matter of choice derived from the kind of application of dosimetric data for medical, scientific (e.g. epidemiology) or/and social purposes.

Some examples of this realistic approach is presented in the report, based on data bank compiled from as trial to reconstruct thyroid doses for about 60 thousands of people living in the most contaminated region of Russia after the Chernobyl accident.

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Temperature and frequency effects in tooth enamel electron spin resonance dosimetry

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Electron spin resonance spectra of  $\text{Co}_3^{3-}$  molecule ions in human tooth enamel have been studied at various temperatures between 4 and 350 K and at various microwave powers in the 9 GHz (X) band. Signal saturation during cooling due to slowing down of the electron spin relaxation has been established. 35 GHz (Q) band spectra of tooth enamel, irradiated with various  $\gamma$ -ray doses, are also presented. Q band ESR dosimetry offers some advantages over the X band dosimetry due to signal enhancement from the spin level population difference and especially due to a better filling factor which is important when minute quantities (a few mg) of enamel are available.

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Dose assessment by means of TLD techniques using ceramic materials

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The epidemiological study of inhabitants in some sites of relatively high contamination due to the Chernobyl accident will propose valuable data on the biological effects of ionising radiations. The best possible estimates of radiation dose received by the organs or tissues of survivors are extremely required as a basic data for the epidemiological study. In the past, gamma doses from the atomic bombs in Hiroshima and Nagasaki have been determined with thermoluminescence (TL) measurements of ceramic materials, such as bricks and decorative tiles, which were collected from buildings that remain as they were at the time of the explosions. The TL measurements were performed using TL dating techniques generally used in archaeology. Annual background doses from natural radionuclides in the ceramic materials and from environmental radiation including cosmic-rays were evaluated with commercially available TL detectors. A time-zero point at the original firing of the ceramic materials was estimated from the age of the buildings in given in the register book. Total background dose was evaluated by multiplying the period between the time-zero point and the time of measurement by the annual dose rate. The resultant gamma doses were determined as a function of distance from ground zero and were compared with the Dosimetry System 1986 (DS86) gamma doses.

The present paper describes the methodology of dose assessments with the TL techniques of ceramic materials in Hiroshima and Nagasaki, and discusses the applicability of TL measurement for the evaluation of cumulative doses after the Chernobyl accident on the basis of preliminary results with TL measurements of ceramic samples collected from buildings in several areas highly contaminated between Kiev and Gomel.

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Application of radioecological models for reconstruction of ingestion doses

Heinz Müller: GSF - Institut für Strahlenschutz

## Summary

Reconstruction of ingestion doses of the population long time after an accidental release of radioactivity requires a lot of knowledge about the time dependent activity concentrations in human foodstuffs. If these data are not available from measurements it is possible to estimate them by radioecological models.

In this paper the basic features of such a model are presented with emphasis on the needs of input data. The problems arising, and the main sources of uncertainty of the resulting doses are discussed. Comparisons of predicted with actually measured whole body burdens of caesium after the Chernobyl accident are shown to demonstrate the possibilities and the limitations of dose reconstruction by means of radioecological models.

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Dose assessment to evacuees Pripyat-city using sugar ESR measurement

Toshiyuki Nakajima, National Institute of Radiological Sciences, Japan

An electron spin resonance dosimeter using sugar was studied for the purpose of evaluation the external dose to the exposed inhabitants in the vicinity of the radiation accident. Proportionality of the ESR absorption intensity of sugar to the dose was maintained in a range from about 20 mGy to  $6 \times 10^4$  Gy. A survival fraction of free radical created in sugar by radiation was approximately 100% at about six months after irradiation. If sugar left in and/or around the house since the occurrence of the Chernobyl reactor accident is obtained, it will be possible to estimate from them the integrated external dose to people who were exposed.

It was estimated the absorbed dose to evacuees at Pripyat-city using ESR measurement of sugar, which were collected from Pripyat-city, and exposure rate calculations. It was concluded that the absorbed dose to those people was estimated with  $0.042 \pm 0.016$  Gy. In this workshop, it will be also reported that the present result on the estimated dose at Pripyat-city obtained from the sugar ESR dosimeter, and a comparison between the present result and one reported to IAEA by exo-USSR.

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Absorbed dose depth profiles for the radionuclide composition in Pripjat

V. Polyakov, L. Brodsky, G. Hutt: Institute of Geology, Tallinn, Estonia

Depth profiles of absorbed gamma-dose were obtained by numeric calculations in the frame of the model proposed. In this model the contributions to the total absorbed dose, originated from both primary and secondary gamma-emissions were taken into account. The radionuclide composition, characteristic for polluted regions in the town of Pripjat as well as specific geometry of sample location were used on model calculations. The results obtained testify good shielding characteristics of main building materials and correlate closely with the data obtained by experimental methods of retrospective accident dosimetry on the basis of building materials. The variation of the absorbed dose with the height of the detection point above the ground level is also presented.

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Evaluation of the radionuclide release from the Chernobyl accident

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In this paper, source term data on radioactivity release after the Chernobyl accident are presented. Based on own fuel burn-up calculations using the GRS computer code OREST84, the resulting radioactivity inventory of the reactor core was compared with the data originally published in 1986 by the Kurtchatov-Institute Moscow. The amount and content of the radioactive release were evaluated on the basis of this comparison as well as on new results from investigations on the radioactivity content of the fuel containing mass inside the shelter. Originally, a release for e.g. Cs 137 of 13% of the total inventory was assumed. Recently, however, a ratio of about 30% was published. Furthermore, the emission as a function of time was reviewed. The release was not terminated on May 6, 1986 as published earlier but proceeded some days longer. On May 16, 1986, e.g. a peak emission of a considerable amount of radioactivity was stated after analyses of filters deposited above the reactor building.

# **WORKSHOP ON "DOSE RECONSTRUCTION"**

**Bad Honnef**

**06.06. - 09.06.1994**

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Deposition, interception and post-deposition retention of radionuclides by vegetation

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The processes of deposition and interception represent the link between the atmospheric dispersion of radionuclides released to the atmosphere and the transport in foodchains. This paper gives an overview about these processes and its dependence on the characteristics of the deposit and the environmental conditions.

For dry deposition, the most important factor is the particle size spectrum which depends on the characteristics of the release and the distance to the release point. Furthermore, the development of the vegetation, whether the plants are dry or wetted, as well as the actual weather conditions have a considerable impact on the dry deposition of radionuclides. For iodine isotopes the chemical form has a dominating influence on the deposition.

The interception of wet deposited activity by vegetation depends on the chemical form of the radionuclide, the amount of rainfall during which the deposition occurs and the development of the vegetation.

The loss of radionuclides from plants after deposition is due to removal by wind, rain fog, and abrasion of waxy particles from the leaves and loss of leaves. If the decrease of the activity concentration of the plant is considered, the diluting effect of the increase of biomass is very important. The loss rate depends on the particle size and the stage of development. In some experiments the loss rate decreases with time after deposition.

The processes deposition, interception and retention are described and discussed, and examples for the dependencies are presented.

## WORKSHOP ON "DOSE RECONSTRUCTION"

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Results of I-131 treatment in children from Belarus with advanced thyroid cancer

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The incidence of thyroid cancer in children from Belarus has increased after the Chernobyl reactor accident from 2-4 cases in 1986 to 66 cases in 1992. In April 1993, we started the joint Belarussian-German project "Scientists Help Chernobyl Children" on optimization of childhood thyroid cancer, which is sponsored by German electricity companies. From 1.4.93 to 31.3.94, 49 children with advanced thyroid cancer from Belarus have been treated with I-131 in Essen. The 29 girls and 20 boys aged 7 - 18 years (mean age  $9.4 \pm 2.8$  years at the time of diagnosis). Histology had shown 47 papillary and 2 follicular cancers. 42 cases had to be classified as pT4, 46 as pN1 and 34 as pM1 cancers respectively. Distant metastases were localised in the lung in 33 patients and in 1 patient in bone. Pulmonary metastases mainly were of disseminated, miliary type.

Up to now 79 courses of high dose I-131 treatment have been given to the children. Despite the fact that fractionated I-131 treatment has not been finished, in all but one cases at least a partial response could be observed. However, in childhood thyroid cancer with disseminated lung metastases I-131 induced pulmonary fibrosis may limit the maximum cumulative activity of I-131.

## WORKSHOP ON "DOSE RECONSTRUCTION"

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The use of thermoluminescence of porcelain for retrospective dosimetry

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The TL signal obtained from domestic porcelain, such as bathroom and kitchen fittings and external porcelain such as electrical and telephone insulators has been used for retrospective dosimetry measurements in the Exclusion zone around Chernobyl. Although thermoluminescent measurements have been made on lower fired materials such as bricks, it was found that these were often contaminated with several radioisotopes and the measurements were unreproducible and sometimes unreliable. Porcelain, being vitreous, does not absorb radionuclides from fallout but records the integrated absorbed gamma dose.

The TL signal is emitted by unreacted quartz in a vitreous matrix with is a mixture of feldspars and reacted quartz. The absorbed dose is measured using the pre-dose technique and is the sum of the internal self dose (due to naturally occurring radionuclides in the porcelain body), the environmental dose prior to the accident and the fallout dose. The internal self dose can be calculated if the date of manufacture of the porcelain is known and the environmental contribution estimated from information regarding the value prior to the accident (however it is a small component compared with the internal dose).

This method was used successfully in retrospective dose estimates for Hiroshima and Southern Utah and some initial results have been obtained for Zone 1 in Pripyat. Current work is focussing on samples obtained from Byelorussia and evacuated villages in the Ukraine as well as more samples from Pripyat.

## WORKSHOP ON "DOSE RECONSTRUCTION"

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### Potential and limitations of retrospective EPR dosimetry

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The solid state dosimetry methods like Thermoluminescence (TL) and Electron Paramagnetic Resonance (EPR) are suitable for retrospective dosimetry. It makes use of the capability of some natural materials to act as dosimeters and store the absorbed dose in the crystal lattice for long time in the form of trapped electrons or stable radicals. It is known that generally both methods are using different centres created by irradiation for dosimetry. As a rule it was found that in materials which are suitable for both methods, TL possesses relatively higher sensitivity to radiation than EPR. However, the advantage of EPR dosimetry is that it can also be applied for biological material in contrast to TL dosimetry. Individual dosimetry can be performed by EPR measurement of human teeth. It makes use of the formation of  $\text{CO}_2$  radicals in the mineral component of the tooth. The formation of the radicals is independent on dose rate and the half-life of the radicals is about  $10^7$  years at room temperature.

Traditionally, EPR dosimetry was used for high-dose applications. However, in the field of retrospective dosimetry after radiation accidents and incidents the dosimetry needs to be done at a dose level around 1 Gy and below. At this level EPR dosimetry suffers from the interference with signals which have insufficient dosimetric properties and are due to organic and inorganic impurities in the sample. Therefore, precise dosimetry below 1 Gy requires an intensive pre-treatment of the samples and the optimization of parameters of the EPR measurement.

## **WORKSHOP ON "DOSE RECONSTRUCTION"**

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**Methods of thyroin dose estimation for the population of russia following the accident at Chernobyl npp**

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**Methods of thyroid dose estimation based on J-131 measurements on the thyroid glands of inhabitants of Russia in 1986 after the Chernobyl accident are discussed in this report.**

**Methods of dose reconstruction based on regression analysis of the relationship between the measured thyroid dose and some parameters of environmental radioactive contamination are suggested for the estimation of thyroid dose in settlements and individuals which were not measured in 1986.**

**The limits of uncertainty for the received dose estimations are discussed in this report.**



# Scientific Recommendations for the Reconstruction of Radiation Doses due to the Reactor Accident of Chernobyl

Prepared by the participants of the workshop on 'Dose Reconstruction'  
Bad Honnef (Germany) June 6 to 9, 1994

## 1. Purposes

For people affected by radiation, the health effects of the Chernobyl accident depend on the dose accumulated since the start of exposure. The purpose of this report is to give recommendations on the reconstruction of radiation exposures of workers and the public due to the accident of the reactor in Chernobyl. The purpose of dose reconstruction is to serve as a basis for optimization of

- a) medical surveillance,
- b) social protection of affected people,
- c) epidemiological studies,
- d) information of the public, and
- e) research.

In the course of dose reconstruction new data will be obtained which are of importance for the development of radioecological and environmental dosimetry.

## 2. Addressees

Results of dose reconstruction are prepared for use by medical bodies, authorities and institutes managing population health surveillance, medical treatment, epidemiological and radioecological studies, for authorities in charge of the population social protection, and for information of the affected persons, of the general public, media, etc.. The accuracy required for dose reconstruction depends on its purpose and the exposure level.

## 3. Methods

The reconstruction of radiation doses should and will inevitably involve a combination of various measurements supplemented by model calculations. Primary measurements are those closely related to the dose quantity of interest, e.g., activity measurements in the whole body or the thyroid, or in urine and feces of individuals, and direct individual external doses. These measurements have the potential to provide the most accurate assessments of individual doses and must be subjected to rigorous analysis and evaluation of their nature, extent and quality. Although many primary measurements exist, the data are necessarily only available for a small fraction of all the individuals in the exposed population. Moreover, there will be some uncertainty in the dose estimates even using these primary data. Depending on the purposes of the reconstruction process, additional information has to be used in order to substantiate and increase confidence in the individual doses estimated. These fall into two groups:

- those based on further *individual* measurements (e.g., by electron paramagnetic resonance of tooth enamel, or other means of biological dosimetry), and
- those based on measurements in the environment, from which perhaps individual dose estimates are made through the application of radioecological and dosimetric models.

This second approach allows extrapolation and interpolation to be made to geographical areas, times, nuclides, organs and population groups for which no primary measurements exist or no additional individual measurements can be made. Care must be taken, however, to ensure that the models are appropriate for the circumstances, that model parameters are reasonable, based on our general knowledge of such models, and that for locations where both primary and environmental data exist the dose estimated by both sets are consistent.

An important consideration in the development, validation and tuning of these models is the scope and timing of countermeasures, which include both officially controlled ones and spontaneous ones arising from increased public awareness. This consideration is extremely important not only for interpretation of primary and supplementary individual measurements, but also in the process of attempting to interpolate and extrapolate from environmental measurements. Information on the geographical and temporal distribution and of the efficiency of applied countermeasures, preferably on an individual basis, is necessary if confidence is to be established in the estimates derived from environmental measurements.

This principle of interpolating and extrapolating can be extended to areas, time, radionuclides and populations for which even environmental measurements do not exist. This can be achieved through the use of information on the meteorology, and on the composition, time-dependence and magnitude of the source term. The atmospheric dispersion models and source term assumptions used for these purposes must again be validated against the environmental measurements available.

Thus the dose reconstruction process will be a dynamic one of re-assessing model predictions against measurement data, refining models to fit data, and even making further measurements or obtaining additional information on countermeasures, for example, to test model assumptions. Thus the procedure is one of 'boot-strapping' with the aim of making a sufficiently reliable and self-consistent dose assessment. Because of the potential for confusion and misinterpretation of results during this 'boot-strapping' process, particularly between institutes of different disciplines, it is *essential* that the methodology (including corrections for countermeasures) and data sets used are clearly specified when reporting results.

In making the assessments careful consideration needs to be given throughout to estimating uncertainties in measurements and predictions. This is in order that the validation and tuning of the models for interpolation/extrapolation purposes is rationally based. Moreover some estimation of the uncertainty in the final results is needed for epidemiological and litigation purposes, as well as to assist in directing future efforts.

### 3.1 Measurements of body burdens and of individual exposures

#### 3.1.1 Measurements during exposures

Among the short term exposures, the intake of radioactive iodine is of main concern. After the Chernobyl accident a large number of thyroid contamination measurements were performed. For example, data bases in Ukraine, Belarus, and Russia contain dosimetric measurements for more than 310 000 individuals from contaminated areas. Before using these data the quality and the calibration of the measurements need to be evaluated. In particular, the non-spectrometric measurements need careful quality assurance. In general, thyroid measurements have been performed for individuals only once or twice. Additional information will be needed to assess the time dependence and the total thyroid exposure for individuals together with more details of countermeasures, consumption of food (milk, vegetables etc.), time of fallout, condition of fallout (rainfall etc.)(see section 3.3.2). However, in some areas the evaluated thyroid measurements may yield distributions of thyroid exposures in population groups and will be a key part of a dose assessment which is based on a combination of more methods. With such information semi-empirical or extrapolation models for dose calculations related to contaminated areas where direct measurements were not performed, may be developed.

Whole body measurements with NaI- or Ge-detectors allow a determination of activities of  $\gamma$ -emitting radionuclides which are distributed in human bodies. Data bases exist in 3 countries of

the former SU containing the results of WBC measurements for 1 400 000 individuals exposed between 1986 and 1993. For evaluation and application to dose assessments due to the incorporation of radioactive caesium, the same items are valid as those mentioned above for thyroid measurements and radioactive iodine.

External radiation exposures of the population have been monitored by thermoluminescence dosimeters that should have been worn for several weeks close to the body. Here, the quality assurance of the measurements includes the determination of the energy dependence of the detector response and other dosimetric properties. In addition, for these measurements there must be an assessment of the potential bias due to the fact that at least some of the dosimeters will not have been continuously worn close to the body of the measured person. Furthermore, the individual TLD measurements did not start before end of 1986, so they cannot contribute to dose assessments for the first months after the accident. Nevertheless, these measurements belong to the important class of direct measurements during the exposure.

In principle, external radiation exposures of the personnel of the nuclear power plant and of many liquidators, were at least controlled by film badges. Unfortunately, the degree of information which can be gained from the records of these measurements seems to be limited.

### 3.1.2 Retrospective individual dosimetry

A promising method for individual retrospective dosimetry for external exposures is electron paramagnetic resonance (EPR) measurement of tooth enamel. This method can now, after the extraction of organic parts from the enamel, achieve detection limits of the order of 100 mGy. The use of the method requires further development and optimization. In particular, the procedures for pretreatment of tooth enamel and EPR evaluation needs to be standardized. It has the advantage that the signal in the enamel for the accumulated dose is very stable and no corrections need to be performed due to the time between the radiation exposure and the analysis of the enamel. Currently, it has the disadvantage that a tooth or part of it must be extracted.

Chromosome translocations measured by fluorescence in situ hybridization (FISH) techniques have now been demonstrated to achieve detection limits of the order of 100 mGy. Recent validation measurements have shown that this method is stable with time after exposure and can therefore be used to reconstruct dose received many years, even decades, previously. An advantage of this and other cytogenetic methods described below is that only a small blood sample is required.

Chromosome dicentrics are unstable with time after exposure, but, even so, dose reconstruction can be done by measuring the frequencies of dicentrics exclusively in first division cells (representative of the irradiated cell fraction) from conventional preparations of blood lymphocytes (Qdr method). As with FISH, this method is applicable to external exposures and internal exposures due to radionuclides that are distributed relatively homogeneously in the body.

The micronucleus assay in blood lymphocytes is very unstable with time after exposure and cannot be used today for *individual* dose reconstruction. However, it has the advantage of being simple and rapid to perform and could potentially (after additional validation) be useful as a population screening tool to evaluate relative exposure levels among groups. In contrast to blood lymphocytes, micronuclei in the lens of the eye may be useful for individual retrospective dosimetry because these cells do not divide. This approach should be explored as a biodosimeter for those individuals who have cataract surgery.

The glycophorin mutation assay (GPA) may also be useful as a screening tool because it is relatively simple and rapid. However, due to the unavailability of *in vitro* or other model systems for calibration, it may not be useful for individual dose reconstruction and may not be useful for doses below ~ 500 mGy.

All these methods are not routine methods. It will be very helpful to perform intercomparison of the results obtained by different methods including results achieved by modelling and direct individual measurements.

### 3.2 Environmental measurements

#### 3.2.1 Radionuclide concentrations and gamma dose rates in air

Measurements of radionuclide concentrations in air during the passage of the cloud are of primary importance for assessments of inhalation doses. The results for the relative air concentrations of radionuclides may be used at other locations where only the gamma dose rate has been measured and for an assessment of the deposition, if it has not been measured early enough to detect possibly important short-lived radionuclides. Unfortunately, the radionuclide concentrations in air could not be measured sufficiently at many points during the accident. A larger part of the samples has been measured relatively late so that short-lived radionuclides could no longer be detected. The evaluation of the results needs special care for gaseous iodine, since the fraction retained on the filters is an uncertain parameter.

Series of gamma dose rate measurements in air can be very helpful to assess external exposures of the public. The extensive data obtained after the reactor accident of Chernobyl need to be evaluated with respect to the calibration of the devices, their energy dependence and possibly with respect to the environments where the measurements have been performed. In general, the data will not be dense enough to directly describe the full temporal development and spatial distribution of the outdoor gamma dose rates. Geostatistical methods may be used to derive from the measured data more complete data which are necessary for dose assessments. Besides the measurements over open fields - where most of the measurements have been performed to allow an easy comparability - measurements at other outdoor locations and indoors have been performed and are needed for assessments of external exposures.

#### 3.2.2 Deposition of radionuclides and food contamination

Activity measurements in a large number of soil samples have been made after the Chernobyl accident. These measurements give valuable information on the spatial distribution of caesium, strontium, plutonium and other radionuclide deposition, as well as on the radionuclide ratios in the deposition. Unfortunately most of the measurements were made too late to detect short-lived radionuclides. Moreover the deposition is relatively inhomogeneous even over quite small distances and care must be taken to ensure that adequate sampling has been performed before generalisation. Nevertheless the data are useful for validating atmospheric dispersion model predictions, for comparing with any activity concentrations measured in local foodstuffs, e.g. milk, green vegetables, to validate radioecological model assumptions, and with gamma dose rates measured over open fields, to check consistency with calculations. Information on the depth distribution in soil is needed for validating predictions of dose-rate with time.

The I-131/Cs-137 ratio is known to have varied considerably in space and time depending on the different physico-chemical forms and release characteristics. As mentioned above, relatively few measurements were made of short-lived isotopes in soil. Because of this the measurement of I-129 activity in soil is potentially a promising method to assess the deposition of short-lived iodine isotopes. Comparison of I-129 activity in the relatively few samples of soil for which I-131 measurements were previously made would be extremely useful to give confidence in the

use of this method. If the method is proven reliable, soil samples should be taken primarily in areas for grazing animals and where people live to calculate doses from milk ingestion and inhalation more reliably.

The incorporation of radionuclides by ingestion of food in many cases represents the largest component of dose from the Chernobyl accident. Measurements of I-131 activity in milk are of particular importance in the reconstruction of thyroid doses. There may also be archived food samples (e.g. powdered milk) for which I-129 measurements may now yield some estimates of the original I-131 contamination. This information should be compared with predictions of concentrations in milk for areas where deposition is known. Caesium and other long-lived isotopes may be incorporated over many years after the accident. For these isotopes a much larger number of measurements in milk, other agricultural products, food from forests and fish are available, and measurements can still be made to validate transfer models from deposition. However attempting to compare individual doses assessed from food with whole body or thyroid measurements requires detailed information on the source of food, its level of contamination with time, and whether countermeasures were applied or not. This validation process is complicated further by the fact that the importance of different foodstuffs varies with time after deposition and also from region to region. Special attention has to be given to population groups relying for part of their food supply on game, fish, berries and mushrooms.

### 3.2.3 Retrospective environmental dosimetry

The measurement of long-term integrated dose in populated areas can be achieved by the use of solid-state dosimetry methods. Luminescence techniques have been developed for use with ceramic materials and previous studies of A-bomb dose at Hiroshima and Nagasaki and fall-out dose from the Nevada Test Site have shown that the method is capable of producing accurate (better than  $\pm 10\%$ ) evaluations of accumulated transient dose many years after the radiation event.

Preliminary work in the polluted regions within the Exclusion Zone has demonstrated that samples suitable for application of the method are available. Ceramics materials can be obtained from the external faces of buildings, within walls, on interior surfaces or as interior fixtures. They provide a range of sampling locations which can yield both evaluations of: external dose for particular habitation or workplace locations; information related to shielding coefficients and a measure of the time averaged incident energy spectrum. Multi-storey buildings also provide a means of differentiating ground and airborne dose contributions.

The minimum detectable dose is currently  $\sim 10$  mGy and doses in excess of several Gy are well within the range of the method. In addition, new techniques under development based on thermally- and optically- stimulated luminescence may offer improved sensitivity and extend the range of materials which can be used.

The method has the potential to provide: 1) benchmark dose evaluations for modelling calculations and comparisons with other techniques used in dose reconstruction for populated areas 2) integrated dose evaluations for areas continuously populated since the accident but which lack monitoring data.

The use of the method in dose reconstruction requires further development and optimization. In particular the following areas need to be addressed: procedures for standardisation, optimization of sample selection for comparisons with modelling calculations; uncertainty analysis; intercomparison and validation.

### 3.3 Pathway and dose assessment modelling

With the rare exception of having available complete measurement data of body burdens or of individual exposures, radioecological modelling is always needed for a retrospective assessment of radiation exposures in order to fill the gaps of information due to missing or insufficient measurements in environmental media. The kind of radioecological modelling needed depends on the case to be studied and on the data base of measurements.

Countermeasures have considerably influenced activity distributions and dose levels at several sites and checks have to be made to see if these countermeasures could have influenced the results before basing models on the measurements performed after the Chernobyl accident. If this is the case, an analysis is required to establish to what extent models for areas without countermeasures can be applied (for example, the time dependence may differ considerably from areas without countermeasures). Information gained from this area may be transferred to other areas, where the same countermeasures have been applied.

#### 3.3.1 External exposures

If the direct measurements (section 3.1) are not sufficient, the assessment of external exposures of the population is in general based on gamma dose rates in air over open fields for which the surface soil has not been disturbed since the accident. If these measurements are not sufficient, the gamma dose rate may be derived from radionuclide concentrations in air during the passage of the cloud and the type of deposition, and after the passage of the cloud, from depth distributions in soil. During the first year short-lived radionuclides and their progeny (e.g., isotopes of zirconium, tellurium, iodine, caesium and barium) and noble gases during the passage of the cloud contributed significantly to the gamma dose rate. In the modelling of gamma dose rates the different migration behaviour of fuel particles and other physico-chemical forms of the radionuclides should be taken into account. Possible contributions of the  $\beta$  radiation to the absorbed dose in the eye lens and in the skin must be considered.

The external exposures of the population are further determined by the times spent at different locations, the gamma dose rates at these locations and conversion factors to effective or organ dose. Information on the first parameter may be obtained from questionnaires. For the others, direct and retrospective measurements and photon transport calculations must be used. Model results on individual dose and dose distributions in population groups should be evaluated by comparisons with the individual dose monitoring.

#### 3.3.2 Internal exposure due to radioiodine

An assessment of an individual thyroid exposure may be based on at least one measurement of the radionuclide activity in the thyroid and an assumption about the time dependence of the exposure. This time dependence may be derived from measurements of thyroid exposures in the same age group and from the same area. Alternatively, the time dependence may be derived from modelling the iodine uptake by food consumption patterns (mainly by milk) and inhalation. The results of such modelling may vary according to food consumption patterns for rural and urban populations (e.g. local food or mixed food from shops, local vs. processed food). In the simplest case, sufficient measurements of the time dependence of food contaminations and of air concentrations are available, and the uptake can be modeled by assuming food consumption, possibly based on a response to a questionnaire, and inhalation rates. If average consumption rates are assumed, possible spontaneous changes of dietary habits have to be taken into account as well as possible differences of the radionuclide transfer data within the individual bodies. The origin of the food, for example, if it has been produced locally or in areas with other contamination levels may influence considerably the radionuclide uptake.

Special cases to be considered include the irradiation of foetal thyroid and the irradiation of infant thyroid arising from the consumption of breast milk. The estimation of dose in such cases can be based on the modelling of the transfer of radioiodine from the mother to the foetus or to the infant thyroid. The estimation of iodine intake in mother's thyroid also must be taken into account.

If the time dependence of the food contamination has not been measured, it may be modeled by using the available information on radionuclide concentrations in air, on the precipitation during the passage of the cloud and on the radionuclide depositions per unit area. In this context radionuclides of interest are short-lived and long-lived ( $^{129}\text{I}$ ) iodine isotopes and, if not available, caesium. The use of I-129 depositions per unit area is potentially important in the estimation of the fraction of iodine and caesium radionuclides during the fallout. In any case, the modelling has to be evaluated by comparing with the thyroid measurement results. The modelling may then also be applied to persons, for which no thyroid measurements have been performed.

If thyroid exposures have to be assessed in areas, where no, or insufficient measurements of thyroid contaminations have been performed, information in areas with good data sets may be extra- or interpolated, for example, that, based on data on radionuclide depositions per unit area. Such a procedure may be used for an evaluation of the radioecological modelling based on environmental data.

### 3.3.3 Internal exposures due to radiocaesium

The data base of measurements for an assessment of internal exposures due to caesium is better than for iodine, as gaseous components did not play any role for caesium and since the exposure due to caesium contamination has its main contribution in later phases, allowing more time and better organisation for measurements. Otherwise, most of the aspects discussed above for iodine also apply to caesium. Concerning modelling, a variety of foods (see section 3.2.2) and the contamination dependence on environmental parameters like soil type and agricultural practices and on food processing (such as washing or cooking) have to be taken into account.

## 3.4 Source term and atmospheric dispersion

In the reconstruction of thyroid exposures and short term external exposures, assessments based on environmental measurements may have large uncertainties. In such cases atmospheric dispersion and deposition calculations may be used to estimate the radionuclide concentration in air, including its gaseous components, and the deposition per unit area. The dependence of the deposition velocity on particle size and the resulting decrease of large particle concentrations with distance have to be taken into account, and in addition, the patchy nature of rain events during the ten days of release is an important aspect of the atmospheric dispersion and deposition. Uncertainties in the time-dependence of the radionuclide release, the unknown plume elevation, and the unstable wind conditions during the accident resulted in large uncertainties of the dispersion calculations. Applying calculations to dose reconstruction should only be done in combination with measurements.

## 4 Liquidators (Clean-up workers)

Several hundred thousand workers were involved in 'liquidating the consequences of the accident'. Many of these workers were on site for the purpose of cleaning up the radioactive

debris so that the remaining three units could be restarted as soon as possible. Workers actively participated in this process for periods that varied from a few <sup>days</sup> seconds to several months or even years. Of the approximately 30 000 to 60 000 people who worked under conditions expected to result in higher exposure, several thousands may have received doses in excess of 0.25 Gy. This high dose group is of special epidemiological interest, as they are expected to be at risk for developing leukemia and cataracts of the eye lens.

The cohort of liquidators can be subdivided into several classes with different types of the activities performed in the 30 km zone and NPP site, and consecutively received doses. These classes are:

1. Liquidators of the accident itself (NPP personnel)
2. Recruits of the army who had performed non-shielded clean-up work
3. Personnel who worked in the 30 km zone on the regular basis in 1987 - 1994
4. Visitors and temporal workers.

Classes 1 and 2 are considered to be the most exposed subcohort of liquidators (approximately 200 000 individuals), 5 to 15 % of them may have received doses in excess of 0.25 Gy.

Some of the workers wore film badges, and this dosimetric information should not be overlooked. Suggestions have been made that doses recorded for these liquidators, may have been distorted, as pressures existed to both increase and decrease the recorded levels. Some aspects of this situation might be resolved, if the original film badges could be found and re-examined to recover the information.

Another source of information is the amount of exposure-rate information recorded on site. Thus, it may be possible to perform time and motion studies for individuals, which when combined with the exposure-rate information or verified film badge data for other colleagues, could be used to estimate external doses.

Techniques of biological dosimetry may offer an opportunity for more accurate dose reconstruction. The three techniques that seem most likely to be useful are EPR of tooth enamel, analysis of stable transformation in lymphocytes, and analysis of micronuclei in lens tissue. Each of these techniques suffers from drawbacks that may limit usefulness in a particular situation, but one or more could be used in most situations.

Internal doses for this population are not likely to be of compelling interest generally. However, a small subset could have received significant thyroid or lung doses, and some consideration should be given in the future to methods for reconstructing such doses.

## 5 Evacuees

About 135 000 people were evacuated during the first two weeks following the beginning of the Chernobyl accident. The first people evacuated were those of Pripyat, a town of 50,000 inhabitants located in the vicinity of the reactor. The evacuation of Pripyat began 36 hours after the beginning of the accident. During the first 2 weeks after the accident, the entire population located within 30 km of the reactor was evacuated, as well as a number of settlements beyond the 30-km zone where elevated exposure rates had been recorded.

The main pathways of exposure of the evacuated population were external irradiation during the passage of the cloud, inhalation, and, to a lesser extent, ingestion of radionuclides. The preferred method of dose reconstruction for individuals is based upon (a) the extensive network of exposure rates that were measured during the first weeks after the accident, (b) the results of thyroid and whole-body measurements conducted within a few days after the

accident on evacuees, and (c) knowledge of the time spent by those individuals in specific locations before and during their evacuation.

The average dose from external irradiation received by the evacuees is estimated to be about 20 mGy, and 99% of that population is estimated to have received doses from external irradiation less than 250 mGy. It would be useful to apply techniques of biological dosimetry to the individuals estimated to have received the highest doses. In addition, luminescence measurements would be helpful to determine the doses from external irradiation that were avoided because of the evacuation.

The doses from inhalation received by the evacuees are estimated to be lower than those from external irradiation, while the doses from ingestion are in general lower than those from inhalation.

## 6 Children with high thyroid doses

Because of the large releases of iodine-131 and of the propensity of iodine to concentrate in the thyroid, which is much smaller in children than in adults, it was clear soon after the accident that a very large number of children could receive high thyroid doses, essentially through consumption of cows' milk. The population at risk was too large to be evacuated but it was important to identify the children with elevated thyroid doses. For that purpose, teams were sent to the contaminated areas (now located in Belarus, Russia, and Ukraine) to measure the gamma radiation emitted by the radioiodines present in the thyroids of the populations (including children and adults). The activity contents of the thyroids of more than 310,000 people were measured in this way between early May and late June 1986. In parallel, the consumption of cows' milk produced in the contaminated areas was banned, to the extent practicable.

The assessment of the individual thyroid dose is based upon the measurement of the radionuclide activity in the thyroid and upon assumptions about the time dependence of the exposure (see section 3.3.2). The method of thyroid dose reconstruction consists of (a) deriving the activity of iodine-131 (and, occasionally, of short-lived radioiodines) in the thyroid at the time of the thyroid measurement, and (b) estimating the variation with time of the activities of radioiodines in the thyroid before and after the measurement; this is done on the basis of information on the amount of radioiodines in the milk and leafy vegetables consumed, on the intake of stable iodine pills, and/or on the date of cessation of consumption of contaminated milk and leafy vegetables. The thyroid dose is then estimated from the time-integrated concentrations of radioiodines in the thyroid using <sup>appropriate model</sup> standard ICRP dose coefficients. In cases where information is available on the thyroid mass and on the biological half-time of residence of radioiodines in the thyroids of the individuals considered, this information should be used to estimate the thyroid doses received by those individuals.

↑  
intake, ho. Thyroid doses for children are estimated to range up to several tens of Gy. In general, the thyroid doses of children living in rural settlements were greater than those living in towns with the same level of fallout because the radioiodine concentrations in milk from family cows ~~was~~ <sup>were</sup> greater than those in milk obtained from shops. Thyroid biopsies on children with estimated high thyroid doses could have been carried out within one year after the accident to measure directly the I-129 content of the thyroid and to derive the thyroid dose from I-131 with better accuracy.

More than a million people either still live in contaminated areas or lived in such areas for months or years until they were relocated. The <sup>137</sup>Cs doses received by this large group are believed to vary from 0.005 to 0.15 Gy Sv.

It does not now appear likely that this entire group will be enrolled in an epidemiological study, and this group is too large to study by biological dosimetric methods. Thus, it now appears that the only realistic method is a calculation based on ecological models with <sup>137</sup>Cs deposition density as preliminary input data. However, these results must be validated against the available data on whole body contents of <sup>137</sup>Cs and on existing records on external doses. Special consideration must also be given to unique dietary situations which might have led to higher doses. For example, it is known that wild mushrooms and berries can be a significant source of <sup>137</sup>Cs to members of this group.

In some situations it may be desirable to perform special dose reconstructions for individuals. This interest may relate to individuals with specific diseases or with specific compensation requests. For a small number of individuals the most reliable technique is the analysis of stable transformations in lymphocytes, but this procedure would not be readily be applied to individuals with diseases of the blood forming organs. Alternative methods of choice would be EPR of tooth enamel and TL analysis of ceramic materials at places of habitation and working.

## 8 Summary

These recommendations were prepared by the participants of the workshop on Dose Reconstruction held in Bad Honnef (Germany) June 6 to 9, 1994.

## FOREIGN TRIP REPORT

Edwin H. Haskell, Ph.D.  
University of Utah  
Radiobiology Division  
Building 586  
Salt Lake City, UT 84112

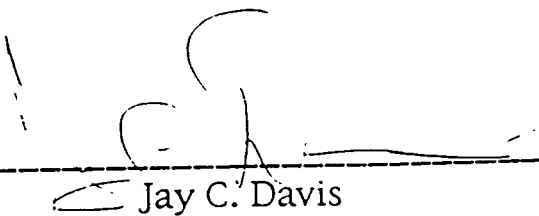
Travel under the auspices of:

Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

July 11, 1994

Approved by:



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Jay C. Davis  
Acting Associate Director  
Environmental Programs Directorate

FOREIGN TRIP REPORT  
Edwin H. Haskell  
Radiobiology Division, Bldg 586, University of Utah  
Salt Lake City, UT 84112

Travel under the auspices of

Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94550  
Contract No. W-7405-Eng-48  
30 June, 1994

**Report Summary**

I attended a workshop on dose reconstruction at Bad Honef, Germany from June 6 through 9th, 1994 which was sponsored by the GSF Center in Munich. The workshop brought together scientists engaged in all aspects of retrospective dosimetry from around the world including environmental and biological measurements as well as modeling. The purpose of the conference was to produce a list of recommendations concerning possible actions for dose reconstruction of individuals exposed to radiation as a result of the Chernobyl accident. I presented a paper entitled "Combined EPR Dosimetry Using Dentine and Enamel of Teeth", which detailed results in our laboratory concerning the effective removal of organic material from bone and dentine samples using Soxhlett extraction with diethylenetriamine. The technique may prove useful in analysis of tooth samples collected from the Chernobyl region since it has the potential of providing two independent measurements of dose using both dentine and enamel of the teeth. The workshop underscored the increasing number of laboratories engaged in retrospective dosimetry in the FSU and elsewhere. Because of the relative inexperience of some of the laboratories, the newness of the techniques being used and the fact that, to be of maximum utility, the techniques have to be pushed to their limits, a coherent research framework will be required to address the questions of precision, accuracy and the lower limits reliably detectable by the various techniques. These issues are being approached, in part, by intercalibrations and intercomparisons between several of the laboratories. However a coherent approach to understanding the limits of the techniques, EPR in particular, has not been addressed. My recommendations include the need to 1) establish a more uniform level of expertise among the laboratories performing the measurements, 2) identify the weakness of the techniques specific to the instrumentation, sample history, preparation effects, energy of irradiation, etc, 3) standardize on methodologies found to produce reliable results and 4) verify those results through blind intercomparisons. This would be achieved through initial exchange of scientists between the various laboratories, through workshops designed to address the issues of items 2 to 4 above and through subsequent intercomparisons taking into account the results of item 2 and the methodologies of item 3. Some of these concerns are currently being addressed by the work of the CEC sponsored dosimetry project ECP-10 which includes a number of laboratories from Europe and the Former Soviet Union. ECP-10 is in the process of performing a blind intercomparison of irradiated teeth which will provide a preliminary indication of the accuracy achievable among participating laboratories. A similar intercomparison between laboratories of the FSU and Japan produced disappointing results and it is likely that without a more directed approach such as that outlined above the results of the current intercomparison will not improve dramatically.

## **Statement of Trip Purpose**

The purpose of the workshop in Bad Honef was the establishment of recommendations for scientific studies related to the dosimetry and epidemiology of individuals exposed to radiation from the Chernobyl nuclear accident. A group of approximately 50 scientists from a variety of countries including those of the former Soviet Union met and discussed prior, ongoing and future research related to retrospective personal and environmental dosimetry and epidemiological investigations. The relation of this workshop to DOE interests lies in its ultimate goal of influencing research which will provide dosimetric information for correlation with health effects in one or more planned or ongoing epidemiological studies. A variety of agencies were represented at the meeting including the IAEA, CEC, and DOE. The program offered the opportunity for exchange of ideas related to the formulation of programs by each group with the potential for cooperation and collaboration between the groups and the avoidance of unnecessary duplication of effort.

## **Summary of Activities**

**Conclusions:** The trip revealed the potential for cooperation with other groups engaged in ongoing dosimetry studies. Specifically the CEC group ECP-10 which is engaged in dosimetry studies in the Chernobyl area. The group is conducting EPR studies on tooth enamel as well as Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) studies on ceramic materials. ECP-10 is comprised of a number of institutes and individuals throughout Europe and the FSU and is undertaking a series of intercomparisons and intercalibrations of the various techniques. The potential exists for U.S. and other non-ECP-10 laboratories to participate with these studies, although some of them are well underway and time constraints may make participation with non ECP-10 groups difficult. The importance of well thought out and executed intercomparisons is critical at this time since a great many samples have been collected and are rapidly being analyzed by laboratories with limited experience in the techniques. A recent intercomparison between laboratories in the FSU and Japan examining EPR of tooth enamel has apparently met with little success. Nevertheless results continue to be produced and are finding their way into the open literature. The publication of studies using questionable or inadequate methodologies has the potential of damaging the credibility of reputable studies, clouding the dosimetry picture and reducing the number of usable samples which could be accurately measured.

## **Description of the Travelers Role**

I presented a paper entitled "Combined EPR Dosimetry Using Dentine and Enamel of Teeth", Which detailed results in our laboratory concerning the effective removal of organic material from bone and dentine samples using Soxhlett extraction with diethylenetriamine. The technique may prove useful in analysis of the tooth samples collected from the Chernobyl region since it has the potential of providing an independent measurement of dose for comparison with results from the enamel of teeth.

### *Significant discussions and events:*

Albrecht Wieser, GSF Germany

#### EPR Intercomparison

I discussed with Dr. Albrecht Wieser an upcoming ECP-10 CEC sponsored EPR intercomparison using teeth from the Ukraine. The project will involve the EPR facility at GSF as well as other laboratories in the FSU which are currently performing or are planning to undertake EPR dosimetry of tooth enamel collected from dental patients who were residing in regions downwind of the Chernobyl accident site at the time of the reactor accident. The intercomparison will involve teeth taken from individuals from control regions believed to have received only ambient background radiation. The exact protocol of the study was not clear but the samples will either be irradiated prior to crushing or after crushing with doses ranging from 100 mGy to 1 or 2 Gy. There was some uncertainty as to whether or not the teeth would be irradiated at GSF or at Prof. Likterov's institute in the Ukraine. Grain sizes between 150 and 350  $\mu\text{m}$  will be distributed to the laboratories involved and will consist of approximately 65 mg of sample for each dose level. In addition to the irradiated samples an unirradiated sample will also be included. Dr. Wieser indicated that the TL/EPR laboratory at the University of Utah would be welcome to participate in the project if approval was given from the CEC.

#### Conversation with Dr. Hans Mensel, CEC program director for ECP-10.

Concerning the participation of the University of Utah in the EPR Intercomparison, Dr. Mensel indicated that U.S. - European collaboration would be welcomed from his point of view. He said that final approval would require the consent of others in addition to himself, and he indicated that there might be a reluctance among some administrators in the CEC due to perceptions that U.S. obtained agreements for research with FSU republics without informing the CEC in advance. We both agreed that the international association on the intercomparison as well as other dosimetric aspects of the studies would be of benefit to all of the projects.

#### Conversation with Dr. Vadim Chumak, Institute for Radiological Medicine, Kiev, Ukraine.

Dr. Chumak was well aware of the upcoming EPR intercomparison but differed with Dr. Wieser as to the site of the irradiations and some other aspects of the intercomparison. For instance Dr. Chumak's impression was that there would be samples irradiated with known doses which would also be available to the participating laboratories. We also discussed the problem of energy dependence of irradiated teeth but he was not clear as to whether gamma ray energies approximating those received by the cleanup workers would be used in the studies. The problem of background EPR signal was also discussed. This is a potential problem with all EPR studies in which a residual signal due to organic material overlays the radiation related EPR signal. Without a true background sample with identical EPR properties as the samples being measured for accident dose, the uncertainty in measurement of the accident can be quite large. We speculated that the major factors responsible for background variation including fluoride uptake due to dental treatments and water fluoridation as well as a diagnostic x-rays would not be a significant problem in the teeth collected from the FSU.

Conversation with Dr. Likterov, Director of the Institute for Radiological Medicine, Kiev, Ukraine.

Dr. Likterov was quite interested in the TL/EPR capabilities of the University of Utah and expressed a desire for collaboration on both tooth dosimetry as well as TL dosimetry of ceramic materials which were being collected downwind of Chernobyl. The TL capability had not yet been established for performing pre-dose analysis at the institute but a Harshaw TL reader was apparently on order. I told Dr. Likterov that I felt a research reader such as the Riso multisample reader or the Daybreak multisample TL reader from the U.S. would be preferable since both had the capability for on-plate irradiations, multisample operation and the option of laser or IR diode input for optically stimulated luminescence measurements such as those recently reported on by the University of Utah<sup>1</sup>. The Riso TL reader will soon be capable of using the extensive library of TL analytical routines developed at the University of Utah under an agreement between the U. of Utah and ECP-10. Dr. Likterov indicated that he would stop the order upon his return to the Ukraine.

*Note: Dr. Likterov's institute is not experienced in TL of natural materials, however they plan a large scale study using collected samples. I would strongly recommend exchange of scientific expertise in this area before too many samples are analyzed using this 'destructive' technique.*

Conversation with Prof. Alexander Brik of the institute of Geochemistry and Mineralogy of the Academy of Sciences of the Ukraine.

Prof. Brik reported on an interesting variation on EPR analysis which he indicates reduces the minimum detectable dose of quartz by a factor of 30. The technique relies on the application of a varying electric field to the sample in addition to the microwave and magnetic fields normally applied. Prof. Brik gave me several references to the technique.

Conversation with Dr. Yeter Göksu, GSF, Germany

Dr. Göksu also expressed an interest in closer cooperation between the U.S. and the ECP-10 dosimetry project. She invited the University of Utah to join in an intercalibration of radiation sources which was underway with members of ECP-10 and was to be presented at the upcoming luminescence conference Lumdetr-94 to be held in Estonia in September of this year. It was not clear if the University of Utah would be able to obtain the samples and complete the study in time for inclusion in the report, however, it was agreed that the U.S laboratory would participate if at all possible.

Conversations with Dr. Masuharu Hoshi, Research Institute for Nuclear Medicine and Biology, Hiroshima University.

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<sup>1</sup> Godfrey-Smith, D. I. and E.H. Haskell (1993) Application of optically stimulated luminescence to the dosimetry of recent radiation events involving low total absorbed doses. Health Physics 65 (4):396-404

Dr. Hoshi had previously indicated that the University of Utah could have access to the large collection of ceramic materials collected for dosimetry of Hiroshima held at Hiroshima University. Dr. Hoshi apologized for failing to send requested samples some years ago but indicated that the full collection of samples would now be available if they were still desired. Based on the recent publications by Dr. Hoshi and others concerning doses at distances greater than 1.4 km from the Hypocenter at Hiroshima, it may be advisable to perform a limited number of replicate analyses.

#### **Conversations with Dr. Vladimir Polyakov, Institute of Geology, Estonia**

Dr. Polyakov indicated that he was nearing completion on an article based on his work while a visiting scientist at the University concerning characteristics of the EPR signal of dentine and effects associated with various methods of sample preparation. Dr. Polyakov provided a copy of the manuscript which is jointly authored by members of his laboratory and the University of Utah.

#### **Recommendations concerning future or follow-up studies.**

It is important that samples be analyzed by groups and individuals who are adequately experienced in the various measurement techniques, that methodologies be established which can be shown to produce reliable results and that the accuracy of the techniques can be demonstrated through blind intercomparisons with results published in the open literature. These can best be done by increasing the expertise of less experienced laboratories through joint scientific exchanges, through a workshop held to identify the weakness of the techniques specific to the instrumentation, sample history, preparation effects, energy of irradiation, etc. and through a subsequent workshop aimed at standardizing on methodologies found to produce reliable results.

An equally important aspect concerns the need to determine the accuracy with which samples collected from Chernobyl-exposed regions can be analyzed using EPR, TL and OSL techniques. This can be done through interlaboratory comparisons and calibrations, although such studies should be well thought out and include factors unique to the techniques, materials and regions from which the samples are collected. For instance in design of an EPR intercomparison the effect of gamma ray energy should be considered and designed into the experiment. Dental x-rays as a confounding background source must be considered, and variations in EPR background in the absence of a radiation induced signal must be studied. The establishment of a 'standard background' EPR signal would be extremely useful in any dosimetry studies since the background signal of an undosed sample is not zero. On studies of teeth collected from the U.S. we have observed large variations in background due not only to the extent of dental x-ray dose but to other factors possibly due to the incorporation of fluoride from dental applications or water fluoridation. Such practices are apparently uncommon in the FSU, as are routine dental X-rays, so the establishment of a 'standard background' may be feasible in this case. Nevertheless an important step will be the identification of confounding factors and the determination of their degree of influence on measurements.

## 7.1C – EXTERNAL DOSE

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
**(1,000 Dollars)**

LLNL No: 6288-08  
 DOE No: 94-ES-1031

Project:

7.1C External Dose [Harold Beck—EML] (Lynn Anspaugh / Sheilah Hendrickson)

Cost Item	Months												Year-to-Date
	1993			1994									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits												0.0	0.0
Travel												0.0	0.0
Procurement and Expenses*												0.0	0.0
Technical Information Department												0.3	0.3
Facility/Service/Distributed Charges												0.0	0.0
LLNL Overhead+/Taxes**												0.0	0.0
TOTAL				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Liens/Preliens													
Budget				122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	0.0	0.0
Funds Available				122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	0.0	-0.3
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts													
** General & Administrative (G&A)													
+ LDRD: Division and Directorate Burdens, etc.													

# EH-40 Monthly Report

March—September 1994

**Project Title:** Chernobyl Studies  
7.1C External Dose

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-08

**Principal Investigator:** (Harold Beck, Environmental Measurements Laboratory)  
**M&O Contractor:** Lawrence Livermore National Laboratory  
Lynn Anspaugh / Sheilah Hendrickson

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

With the agreement of Mr. Beck this report has been prepared by Lynn Anspaugh and Sheilah Hendrickson.

## I. Project Objective

To improve and validate methods of forecasting doses and dose commitments from external exposure. This is of major importance, as the external dose from the Chernobyl accident (and most other releases of radioactive materials to the environment) is a major contributor to dose. As  $^{137}\text{Cs}$  is now the dominant radionuclide and it has a half-life of 30 years, this is a long-term problem that cannot be adequately resolved within a short time period.

## II. Current Project Status / Monthly Progress

The central goal of this project is to validate models of projecting external dose far into the future—at least 30 years. This project has not yet been very active, as we have awaited the accumulation of significant data sets against which models can be tested.

A formal workshop was being tentatively planned for August 1994 in New York City. However, it has been indefinitely postponed at this time. It will most likely occur in FY 95.

When the workshop is set, we hope to have the best external dose modelers in the world who will analyze the existing data and test their models against it. The expected result is the development of a consensus model of projection of external exposure rate with time.

At the conclusion of the workshop and a report prepared, it is presumed that this activity will be considered completed. However, it is hoped that data on external gamma-exposure rate will continue to be collected, and that model predictions can again be tested against real data at a future time.

### III. Significant Problems/Issues/Concerns

We had planned to hold this Workshop early in FY 94 from funds carried over into FY 95. However, the FY 94 funds were taken back by EH at the end of FY 94. It is not now clear that this Workshop is sufficiently high on our priority list to be funded within the FY 95 year. The topic is still very important, but much of the needed work is being accomplished by other people or by other means.

### IV. Assistance Required of EH-40 Staff

We need to have a specific discussion about this topic and reach a decision on future direction.

## 7.1F – HYDROLOGICAL TRANSPORT

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
**(1,000 Dollars)**

**Project:** 7.1F Hydrological Transport (Yasuo Onishi—PNL)      \$\$\$ DIRECT FUNDING TO PNL      LLNL No: none      DOE No: 94-ES-1031

Cost Item	Months												Year-to-Date
	1993			1994									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits				14.0	2.9	0.7	11.8	0.5	1.2	1.0	3.1	1.1	36.3
Travel				0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	-0.2
Procurement and Expenses*				1.3	-0.6	0.0	-0.1	0.1	0.0	0.5	0.1	0.1	1.4
Technical Information Department				0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Facility/Service/Distributed Charges				3.4	-2.2	0.1	0.0	0.1	0.2	8.1	0.1	5.0	14.8
LLNL Overhead+ /Taxes**				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0
TOTAL	0.0	0.0	0.0	18.7	1.0	0.8	11.7	0.7	1.5	9.6	3.3	5.1	52.4
Liens/Preliens													
Budget	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	65.0	65.0	65.0	
Funds Available	50.0	50.0	50.0	31.3	30.3	29.5	17.8	17.1	15.6	21.0	17.7	12.6	
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts													
** General & Administrative (G&A)													
+ LDRD; Division and Directorate Burdens, etc.													

## EH-40 Monthly Report

### March 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi

**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

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*Address each item, if applicable.*

- I. **Project Objective**
- II. **Current Project Status / Monthly Progress**  
Administrative (meetings organized).  
Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).  
Travel. Include copy of foreign trip report.
- III. **Significant Problems/Issues/Concerns**  
Substantial changes in project expectations, protocol, funding.  
Problems occurring or anticipated (corrective actions).
- IV. **Assistance Required of EH-40 Staff**  
Identify EH-40 staff member(s) with each requests.

#### I. Project Objectives

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

We have been collaborating our Landsat data analysis for the Iput River basin with Dr. Tim Warner at the Geology and Geography Department, University of West Virginia. Dr. Warner participated on the DOE NORCUS program working with us on the Landsat Data analysis at PNL for most of last summer as a NORCUS faculty. We have reduced the project cost for this portion of the study significantly by collaborating with him and his university associate on the Iput River watershed Landsat data analysis.

By working jointly, we produced a land use map for the small southern catchment within the Iput River basin by combining Landsat data analysis results with land use/groundcover information, pictures and maps provided by TYPHOON, our Russian counterpart organization for Program 7.1F. We used seven bands to classify soil, forests, natural vegetation, farms, fields, wet land, cities, water, cloud and cloud shadow. By interpreting what was possibly below the cloud and cloud shadow, we eliminated cloud and cloud shadow since they were relatively small. The resulting land use map is then to be supplied to the watershed/groundwater model for this catchment in order to identify potential runoff and soil erosion areas, thus identifying areas of potentially large migration of radionuclides. The Landsat data analysis approach calibrated with this small catchment will then be applied to the overall Iput River watershed to obtain a computer-generated/interpreted land use map for the entire Iput watershed. Enclosed is an example of Landsat data analysis results superimposed with roads (yellow lines). Rivers are shown here with a blue color. Because there are some errors on the radionuclide-level contour map we obtained from TYPHOON, we reinterpreted  $^{137}\text{CS}$  levels on the ground in the Iput River Basin with finer intervals to superimpose with the land use map we generated.

Also enclosed is Dr. Y. Onishi's paper, "Environmental and Remediation Assessment Around Chernobyl", published in the Japanese Journal, Energy Review (Vol. 14, No. 3, pp. 23-26, March 1994.) This paper is based on our Chernobyl study. One hundred and forty one dollars was received from the publisher for preparing this paper. It is in the process of being put in to our Chernobyl project funds.

## III. Significant Problems/Issues/Concerns

Just recently, we were asked by Dr. Oleg Voitsekhovitch of the Ukrainian Hydrometeorological Institute and the Ministry of Chernobyl Affairs, and Dr. Mark Zheleznyak of the Cybernetic Centers to buy and process Landsat data covering the first week of March or April of this year to analyze a severe Spring flooding of the Pripyat River now occurring in Ukraine and Belarus. But, we do not have the necessary funding (about \$4,000) to purchase and to process these new Landsat data. This is obviously outside of our currently funded scope of work.

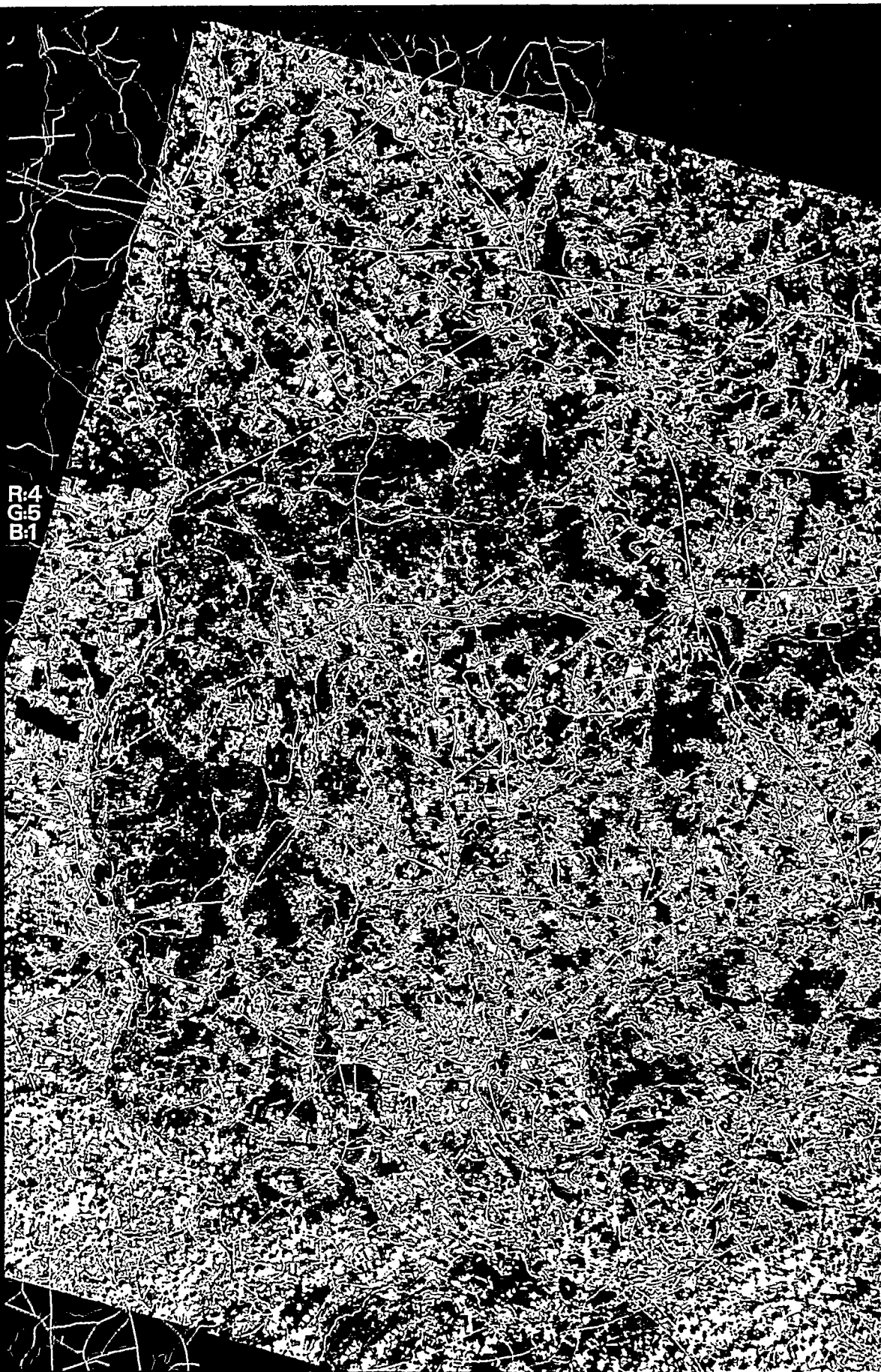
#### IV. Assistance Required of EH-40 Staff

We would like to know how DOE-EH wants us to respond to this urgent request from Ukraine.

##### *Response from EH-40 Staff*

*On May 2, 1994, Sheilah Hendrickson, Lawrence Livermore National Laboratory (LLNL) received approval from EH-40 to purchase Landsat data from existing Chernobyl funds at LLNL for Dr. Onishi. On June 8, 1994, Dr. Onishi advised that after further inquiry, the U.S. Government did not take Landsat data over the Pripyat River in the Ukraine during the period of March-May 1994. After advising the Ukrainians of the above, it was agreed that Dr. Onishi would enhance (by digital enhancement methods) the Ukrainian photographs taken from a helicopter during this flood period.*

R:4  
G:5  
B:1



広く詳しく正確な情報・評論

# エネルギー・ビズ

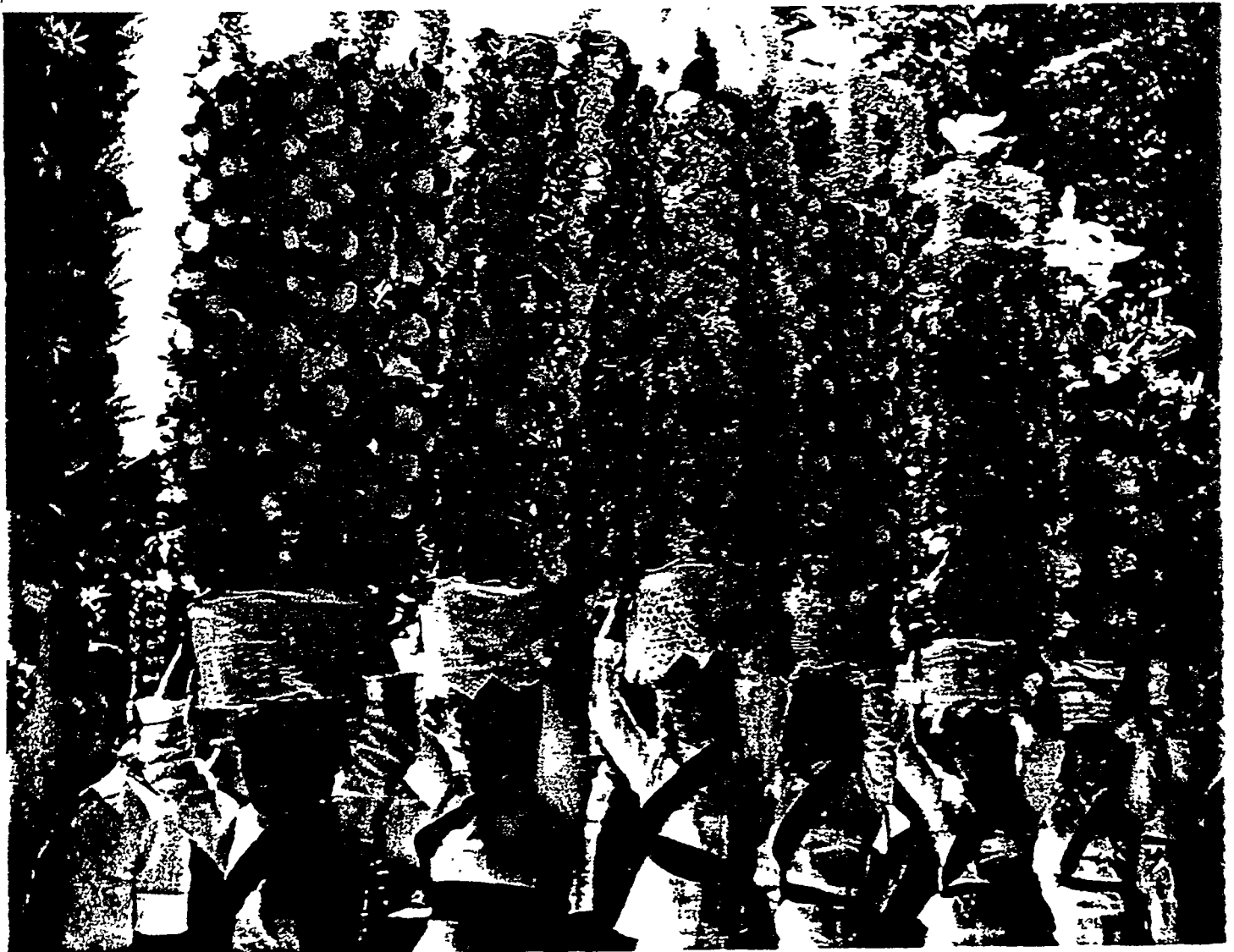
特集

エコサイド・旧ソ連における  
環境破壊の現状

徹底分析

シドニー・オリンピックの環境対策

3



▲聖盃を譲る三年ごとの祭「タブレイ

特集

# チェルノブイル周辺の 環境修復アセスメント

(パシフィック・ノースウェスト研究所) 大西 康夫



## 一 はじめに

チェルノブイル事故から八年が経過しようとしている。この間、チェルノブイル事故に対してはさまざまな取り組みが行われた。

事故の実態については、国際原子力機関（IAEA）が一九八九年に旧ソ連政府の要請を受けて調査にあたった。IAEAでは、日・米・英・仏・加・旧ソ連などIAEA加盟国からの専門家、ならびに世界保健機構（WHO）、国際食料農業機関（FAO）など五つの国際機関から派遣された二〇名の専門家からなる国際諮問委員会を発足させ、その下部機関として国際チェルノブイルプロジェクト（ICP）を設けて一九九〇年に調査を開始し、一九九一年五月に調査結果を報告した。

また、被害者に対しては経済面、医療面で、政府間及び市民団体からの救済がわずかながらも始まっている。

原子力開発史の中の最大のエポック・ソ連・国外に様々な影響を

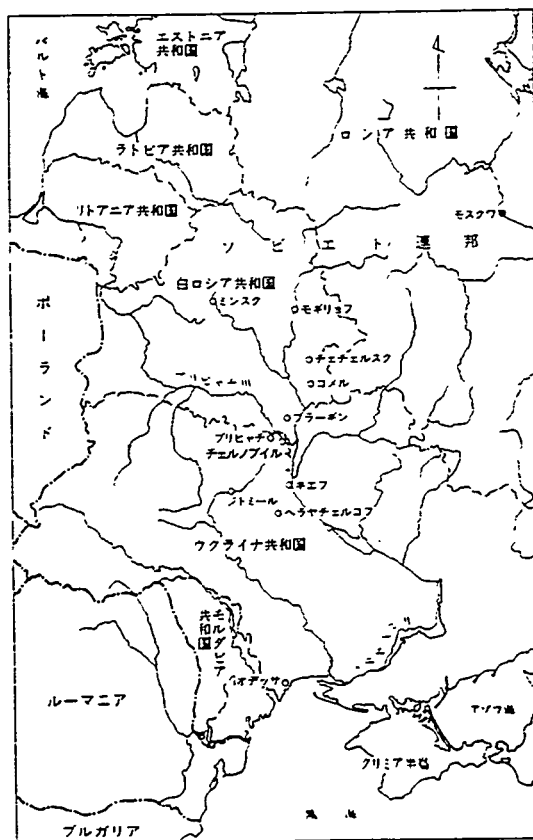
しかしながら、チェルノブイル事故後の環境修復対策は遅れており、このために被害が継続あるいは拡大することも懸念されている。

そこで本稿では、チェルノブイル発電所周辺の環境修復に向けた最新の研究開発動向について述べる。

## 二 チェルノブイル 事故の経過と影響

チェルノブイル事故は一九八六年四月二十六日未明に発生した。

旧ソ連ウクライナ共和国チェルノブイル



図一 チェルノブイル周辺

ル原子力発電所四号炉では、この日、定期検査と燃料交換のために運転を停止することになっていた。その機会を利用して、ある実験が行われていた。蒸気の供給が止まった後、慣性タービンのロータを回転させて、しばらくの間発電機が電力を出し続けることができたかどうかを確認するための実験である。

実験がほぼ終了したころ、原子炉の暴走が始まり、炉心で二度にわたる爆発が発生した。これにより、原子炉建屋の屋根が破壊され、炉心の黒鉛の約四分の一と燃料の一部が外部に放出された。核分裂生成物及びウランからなる放出された

# 放射性物質の地表から川への移行が修復策へのキーファクター

放射能量は $5.0 \times 10^6$  Ciに達すると推定されている。

この放射性物質は、おりからの西風及び北風に運ばれてウクライナ共和国から白ロシア共和国、更には東ヨーロッパ、北ヨーロッパへと運ばれた。

この事故の影響はもとより甚大であった。

この事故による被害者総数は、旧ソ連国内だけでも約四〇〇万人にも達するという。これは、白ロシアを含めてまだ比較的汚染レベルの高い地域に居住している約三五〇万人、除染作業に携わった約六〇万人、既に疎開した約一二万人などを加えたものである。

また、住民への健康被害、農業被害、電力生産への被害、住民避難など、事故の直接の影響による経済損失は、数兆円から数十兆円にも及ぶと試算されている。このような物理的な影響に加えて、社会的・政治的影響も極めて大きいものであった。おそくは、第二次世界大戦後に進められてきた原子力開発史の中でも、最大のエポックであろう。

旧ソ連国内においては、当時のゴルバチョフ政権下で進められていたペレストロイカ政策とあいまって、原子力拡大政策さらにはエネルギー政策も見直しを余儀なくされた。むしろ、ペレストロイカ政策の一環として進められていた

ラスノスチ（情報公開）とこのチェルノブイル事故が両輪となって、旧ソ連におけるそれまでの低い安全文化を徐々に向上させつつ、原子力安全対策にも取り組みがけとなった。この意味において、チェルノブイル事故はペレストロイカ促進の大きな原動力ということができ

## 三 汚染の状況

一九八六年四月二六日のチェルノブイル原子力発電所四号炉の事故において、事故発生後十一日間に、一三〇万Ciのセシウム<sup>137</sup>と、二四万Ciのストロンチウム<sup>90</sup>（イズラエルから一九八七）を含む、およそ五〇〇万Ci（あるいは四〇〇）の核分裂生成物及び核燃料が放出された。チェルノブイル原子力発電所は、ウクライナのキエフから北へおよそ一〇〇km離れた、プリピャチ川西岸沿いに位置している。プリピャチ川は三〇km下流のキエフ貯水池で、ニール川に合流する。

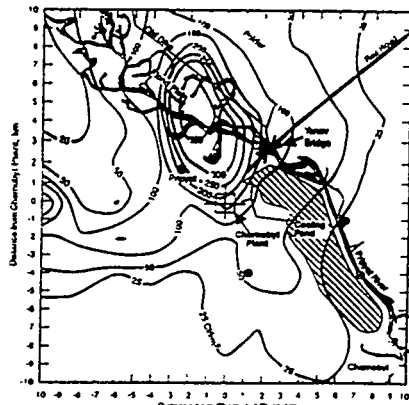
事故の結果、ウクライナ、ロシア、ベラルーシを分けるニール川・プリピャチ川分水流域は、放射性物質の降下のために著しく汚染された（大西ら一九九三）。そして汚染された地表は、プリピャチ川及びニール川にストロンチウム<sup>90</sup>とセシウム<sup>137</sup>を注ぐ、長期間の放射源となった。ニール川は、黒海へたどり着くまでの約

一〇〇〇kmの間に、六つの貯水池を通過する（コノブレフら一九九二）。

ウクライナの約二〇〇〇万人の住民は、キエフから黒海まで流れるニール川の水で生活している。従って、住民は、飲料水、かんがい、農業を通じて川に含まれる放射性物質の影響にさらされている（プリスターら一九九二、ルバンとベルコフスキー一九九二）。従って、放射性物質の地表から川への移行と川の中における「移動」が、水経路を通じた潜在的被曝量の評価、またチェルノブイル事故結果に対する現在及び将来の修復策の有効性評価にとってのキーファクターとなる。

## 四 一九九一年冬の洪水に おける水理学的評価と対応策

チェルノブイル原子力発電所と直接対面するプリピャチ川には、洪水時に埋没する平原が多数ある（以下、この平原を「洪水平原」と称す）。この洪水平原に、一m当たり一〇〇〇マイクログラム（図一）にも及ぶかなりの量のセシウム<sup>137</sup>とストロンチウム<sup>90</sup>が堆積した。それは、プリピャチ川に流入した全ストロンチウム<sup>90</sup>量のおよそ半分を占める量であった（ボツコヴィッチら一九九〇）。洪水中に、洪水平原の堆積物からプリピャチ川に流出するストロンチウム<sup>90</sup>による影響を評



図一 チェルノブイル発電所 周辺の汚染状況

価するために、不定型二次元モデルであるWATX-2（ゼルニャから一九九三）を用い、プリピャチ川及び幅約二km長さ約一〇kmにわたる洪水平原の分析をした。このモデルの予測によると、四年間の洪水では、洪水平原全体を川の水が覆い、川中のストロンチウム<sup>90</sup>の最大濃度は、川中標準濃度の二〇倍以上に増大する。また、ヤノフ橋（洪水平原の下限）における川中ストロンチウム<sup>90</sup>の予測値は、一m当たり二七〇ピコCi（図二）に上る。この値は、ストロンチウム<sup>90</sup>についての現地の飲料水基準一m当たり一〇〇ピコCiを上回ることになる。

この予測により示された、プリピャチ川におけるストロンチウム<sup>90</sup>濃度のかなりの増大に対する、有効な対策を検討した。検討した対策のうちの一つは、洪水防止のために盛り土による堤防をプリピャチ川沿いの洪水平原に設けることである。

この堤防案によると、ヤノフ橋付近で

# 93年7、8月の洪水で川の中のストロンチウム90の濃度増大

の川中のストロンチウム90濃度の予測値は、一見当たり七五ピコCi (図-3) 以下であり、飲料水基準を満たすものであった。この結果、一九九〇年にそのような堤防の建設が決定された。

一九九一年一月、堤防設置の前にプリビヤチ川のチエルノブイル町とヤノフ橋との間において「アイス・ジャム」が生じ、一九八六年の事故以来、初めて洪水平原が浸水した。この洪水の間、ヤノフ橋付近における川の中のストロンチウム90濃度の計測値は、一見当たり二五〇〜三〇〇ピコCiに増大した。この濃度レベルは、四年間の洪水を想定したシミュレーション数値に極めて近く、シミュレーションの有効性が確かめられた。結果として、一九九一年にさらなる洪水防止のために、川沿いに一〇kmに及ぶ土の堤防が設置された。

## 五 一九九三年夏の洪水における水理学的評価と対応策

前述の修復対策にもかかわらず、大規模洪水発生時のプリビヤチ川及びニパ川でのストロンチウム90の濃度上昇の問題は依然残されていた。一九九三年の七月から八月にかけて、ベラルーシ及びウクライナ両地区でプリビヤチ川流域に大量の雨が降り、支流の上方と本流の水位

が異常に高まり、洪水を引き起こした。七月の第二週から八月下旬にかけて、プリビヤチ川からの水の流出量は、チエルノブイル近辺で秒速二五〇〜一二〇〇m

に増大した。この洪水により、川の中のストロンチウム90の濃度が増大した。この川における放射性物質の濃度レベルに対する世間

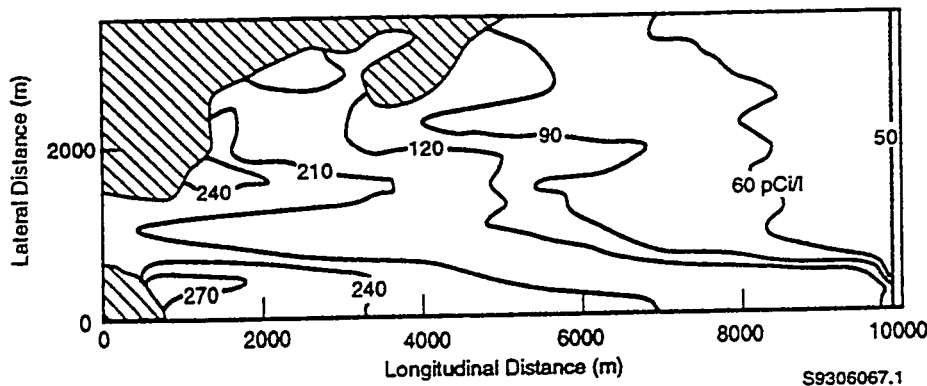


図-3 プリビヤチ川中のSr-90濃度予測値 (未対策時)

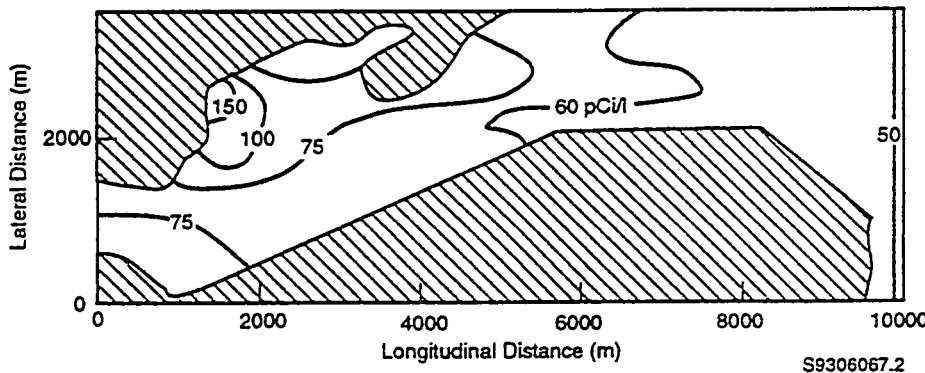


図-4 プリビヤチ川中のSr-90濃度予測値 (対策時)

の憂慮が高まってきたため、ニパ川洪水時に、緊急に放射性物質分布評価を実施した。チエルノブイル地域周辺におけるプリビヤチ川のストロンチウム90最大濃度は、八月初めに一見当たり約二〇〜二五ピコCiとなった。プリビヤチ川河口周辺では、濃度は一見当たり三五ピコCiに上昇していた。キエフ貯水池(キエフの飲料水の主用源)でのストロンチウム90濃度の最高値は一見当たり一二ピコCiであった。しかしながら、一九九三年の八月末には、黒海のニパ河口におけるストロンチウム90濃度は一見当たり六〜八ピコCiを超えない水準であった。もし一〇kmの堤防が建設されていなければ、ストロンチウム90の濃度はプリビヤチ川において、またニパ川においても、はるかに増大していたものと推察される。

ストロンチウム90と異なり、プリビヤチ川洪水時のセシウム137濃度は、洪水前の水準に比してそれほど増大しなかった。チエルノブイル事故現場周辺におけるセシウム137の川中濃度はわずかに一見当たり五・七ピコCiであった。七月中旬のキエフ貯水池とその下流にあるカネフ貯水池のセシウム137濃度は、それぞれ一見当たり二・五ピコCi、一・三ピコCiであった。

これら一連の、放射性物質の計測値、付加的なモデル結果、及び浄水場での浄水作業に基づき、キエフ市内での飲料水中のストロンチウム90濃度は一見当たり

## 発電所に対面する洪水平原に設けられた10キロの堤防が有効性発揮

ハピコCi以下と推定された。また飲料水中のセシウム137濃度は、飲料水濃度規準の一〇〇倍に達した。従って、一九九三年夏の洪水期間、キエフ市民の飲料水は安全であると判断された。

### 六 アセスメントのまとめ

夏期および冬の洪水が河川中の放射性物質濃度を増大させるクリティカルな要因であることが明らかとなった。しかしながら、チェルノブイル原子力発電所に対面する洪水平原に設けられた一〇kmの堤防が、プリピャチ川中のストロンチウム90濃度の減少に有効であることも明らかとなった。

この研究により、洪水が、河川中の放射性物質濃度を増大させるクリティカルな要因であることが明らかとなった。しかしながら、チェルノブイル原子力発電所に対面する洪水平原に設けられた一〇kmの堤防が、プリピャチ川中のストロンチウム90濃度の減少に有効であることも明らかとなった。

### 七 今後に向けて

チェルノブイル事故からほぼ八年近くが経過した。その間、そのチェルノブイル原子力発電所で火災事故が発生し、レニングラード原子力発電所での放射能洩れなどの事故が発生したが、幸いにして重大事故は発生していない。旧ソ連型の

原子力発電所は、本質的に安全性の問題を抱えているものの、チェルノブイル事故を契機として旧ソ連原子力関係者の安全意識が向上し、安全性を至上課題として努力が重ねられてきた結果であろう。その一方で、チェルノブイル事故の被災者の状況はそれほどよくなっていないようである。

むしろ、ソ連邦解体とロシアを中心とする政治と経済の混乱の中で、状況は悪くなりつつあるのではないかと考えられる情報が伝えられている。

例えば、事故直後、事故を起こした四号炉のすぐ近くで復旧作業や除染作業に身を挺してあたっていた兵士や作業員の多くが、その後十分な配慮をされずにままた放射能後遺症と思われる症状に苦しんでいる様子が伝えられている。一部の被災者は、ハンガーストライキなどの社会的な手段に訴えて当局の注意を喚起しようとしたというニュースも伝えられている。

また、チェルノブイル原子力発電所の北にあたるロシアでの放射能汚染の状況が、事故直後の当局の予測よりもはるかにひどいものであると伝えられており、そのための対策は基本的に移住のみである。チェルノブイル原子力発電所のあるウクライナ共和国では、もちろん同じ状況にある。

これらの対策には長い年月と膨大な費用を要することであろう。その間、被災地の住民は放射能にさらされることになる。

従って、現実的かつ合理的にとりうる環境修復対策が今、求められている。

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## 地球環境診断

地球環境問題に

岡本和人著



関する基礎的な知識をやさしく解説した入門書

1. 全地球的環境汚染の症状／2. どの地域、どんな症状か／3. 地球温暖化は人類にどんな影響／4. 経済成長とCO<sub>2</sub>の増加／5. エネルギーの部門別の対応／6. CO<sub>2</sub>抑制 4枚のカルテ／7. 自然エネルギーはどこまで使えるか／8. 技術開発のパワーでどこまで地球温暖化をクリアできるか／9. まとめとして

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APRIL 1994

# EH-40 Monthly Report

April 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi

**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where <sup>137</sup>Cs can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

We completed a joint PNL report, "Chernobyl Nuclear Accident Hydrologic Analysis and Emergency Evaluation of Radionuclide Distributions in the Dnieper River, Ukraine, During the 1993 Summer Flood," by O. V. Voitsekhovitch, M. J. Zheleznyak, and Y. Onishi. The report is now undergoing the internal clearance and printing process for publication. The report describes joint activities of Program 7.1F "Radionuclide Transport in Water and Soil Systems" of the USA/Commonwealth of Independent States (CIS) Joint Coordinating Committee of Civilian Nuclear Reactor Safety to study hydro-geochemical behavior of radionuclides released to the Pripyat and Dnieper rivers from the Chernobyl Nuclear Power Plant in Ukraine. The report also includes results of our rapid evaluation of the radionuclide distributions in the Pripyat and Dnieper River System with the field data evaluation and modeling for the 1993 summer flood to assist the Ukrainian Government in their emergency response, while the flooding was progressing. The brief summary of the report is as follows.

(i) The field data evaluation and modeling revealed that flooding is a critical factor that increases radionuclide concentrations in the rivers. The Pripyat River floodplain directly across from the Chernobyl Nuclear Power Plant is specially important because it received a significant amount of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  deposition with  $^{90}\text{Sr}$  concentrations of up to  $1000\ \mu\text{Ci}/\text{m}^2$ , accounting for approximately half of all  $^{90}\text{Sr}$  entering the Pripyat River. During the January 1991 flood caused by the ice jam,  $^{90}\text{Sr}$  concentrations reached  $250\text{--}300\ \text{pCi}/\text{L}$  at the bridge, exceeding the local drinking water limit of  $100\ \text{pCi}/\text{L}$ . A 10-km earthen dike in the floodplain across from the Chernobyl Nuclear Power Plant was constructed in 1991 and is effective to reduce  $^{90}\text{Sr}$  concentrations in the Pripyat River.

(ii) Despite these remediation measures, the problem of the increase of  $^{90}\text{Sr}$  concentrations in the Pripyat and Dnieper Rivers during high floods still remains. In July–August 1993, heavy rainfall over the Pripyat River catchment in the Belarus and Ukraine caused a severe flooding, significantly raising  $^{90}\text{Sr}$  concentrations in the river. Because of the heightened public concern about radionuclide levels in the river and the need of the Ukrainian Government to take an emergency response, we also conducted an emergency evaluation of radionuclide distributions in the Dnieper River while the flooding was occurring. Near the Chernobyl area, the maximum  $^{90}\text{Sr}$  concentration in the Pripyat River became about  $20\text{--}25\ \text{pCi}/\text{L}$  in early August; near the Pripyat River mouth, the concentration was elevated to  $35\ \text{pCi}/\text{L}$ . The peak  $^{90}\text{Sr}$  concentration in the Kiev Reservoir (a main source of drinking water for Kiev) was  $12\ \text{pCi}/\text{L}$ . If the 10-km dike had not been constructed,  $^{90}\text{Sr}$  concentrations in the Pripyat River, and thus also in the Dnieper River, would have been much higher. Unlike  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  concentrations in the Pripyat River during the flood did not rise significantly from the pre-flooding levels. We also conducted the radionuclide modeling with the unsteady, compartment model, WATOX. Based on these measured radionuclide levels, modeling results, and water purification

efficiency of the Kiev water treatment station,  $^{90}\text{Sr}$  concentrations in the city of Kiev's drinking water were estimated to be less than 8 pCi/L. Estimated  $^{137}\text{Cs}$  concentrations for the Kiev drinking water were two orders of magnitude lower than the drinking water standard of 500 pCi/L for  $^{137}\text{Cs}$ . Thus the water was determined to be safe for Kiev citizens to drink during the 1993 summer flood.

(iii) Field data evaluation and modeling revealed that flooding is a critical factor that increases radionuclide concentrations in the rivers. The construction of a 10-km dike in the floodplain across from the Chernobyl Nuclear Power Plant proved to be effective for reducing  $^{90}\text{Sr}$  concentrations in the Pripyat River. However, the construction of the dike makes radionuclide migration and interaction between the floodplain and the Pripyat River to be a long-term major problem. This surface and groundwater interaction must be assessed.

(iv) About 19 million people in Ukraine consume water from the section of the Dnieper River between Kiev and the Black Sea and thus are exposed to the impacts of the radionuclides in the river through drinking water, irrigation, and fishing. Eight million people consume the Dnieper River water as their drinking water. With the most current water use information available to us, we calculated collective effective equivalent dose (EED) of internal exposure to the population and expected risks due to different water usage. We estimated that during 1986-92, collective EED of 19 million people resulting from eight million people drinking the Dnieper River water and 19 million people consuming fish and irrigation food products are 216, 100, and 513 menSv, respectively, totaling 829 menSv. Thus, irrigation pathway is the most dominant pathway among the aquatic pathways for these 19 million people. The total aquatic pathway contribution constitutes about 7.0% of the total collective EED of 11832 menSv from all pathways. The equivalent radiation risks from the aquatic pathway for 19 million people are  $3.2 \times 10^{-6}$ , as compared to  $4.5 \times 10^{-5}$  for all pathways. The expected human cancer effects from drinking the Dnieper River water and consuming radioactively contaminated fish and irrigation food products are estimated to be 16, 7 and 38 people with cancers, totaling 61 people in the total population of the 19 million people. Note that the total number of people who will get cancers due to all pathways are expected to be 864 among the 19 million Ukrainians.

(v) Even though the aquatic pathway contributes only 7% of the total dose from all the pathways, radionuclide migration into and within the rivers is important for determining potential dose to people through aquatic pathways. This is mainly because most of the practical current and future remediations are expected to be within the 30-km zone to control and reduce potential radionuclide migration in the aquatic (surface and groundwater) pathways.

Thus, it is important to obtain a realistic understanding of actual aquatic pathway risks to people living outside of the 30-km zone in order to develop adequate criteria for measuring the effectiveness of current and future remediation

and water protection activities inside the 30-km zone, based on dose/risk assessment and cost-benefit analysis approaches.

As we reported in the February-1994 Monthly Report, the following three Ukrainians will be at PNL starting in May 1994, (for three to four months) to work on our joint USA/CIS 7.1F Program of the JCCCNRS with a partial assistance from U.S. Department of Commerce's Special American Business Intern Training (SABIT) Program:

Dr. Pavel V. Tklich at the Cybernetic Centers in Kiev,  
Dr. Serguei Kivva at the Cybernetic Centers in Kiev, and  
Dr. Igor Bilyi at the Ukrainian Institute of Hydrometeorology, Kiev.

SABIT will provide the travel expenses and their monthly incomes for these CIS scientists, so it will be very cost effective for us to jointly conduct the 7.1F studies in this manner.

We have been conducting two-dimensional radionuclide transport modeling for the Pripyat River floodplain around the Chernobyl Nuclear Power Plant with RMA-II and FETRA models, and one-dimensional modeling for the Dnieper River with CHARIMA and TODAM models. Dr. Bilyi will work with us to simulate the radionuclide migration in the Pripyat River and its flood plain across from the Chernobyl Nuclear Power Plant, while Dr. Tklich will be involved in radionuclide migration in the Dnieper River to its mouth at the Black Sea. Dr. Kivva will work with us (through modeling) to examine interactions of radionuclides in the groundwater and the Pripyat River water in the Pripyat River floodplain.

As we reported in our March Monthly Report, Dr. Oleg Voitsekhovitch, (Ukrainian Hydrometeorological Institute and the Ministry of Chernobyl Affairs), and Dr. Mark Zheleznyak, (Cybernetic Centers), requested that we buy and process Landsat data covering the first week of March or April of this year in order to analyze a severe spring flooding of the Pripyat River now occurring in Ukraine and Belarus. With a DOE-EH/LLNL funding approval for this work, we were to examine the availability of the Landsat data for the entire March-May 1994 period. Unfortunately, data was not collected during that period. We informed Drs. Voitsekhovitch and Zheleznyak about it.

### III. Significant Problems/Issues/Concerns

No new issues.

### IV. Assistance Required of EH-40 Staff

No new assistance requested.

MAY 1994

# EH-40 Monthly Report

May 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi

**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

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*Address each item, if applicable.*

- I. **Project Objective**
- II. **Current Project Status / Monthly Progress**  
Administrative (meetings organized).  
Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).  
Travel. Include copy of foreign trip report.
- III. **Significant Problems/Issues/Concerns**  
Substantial changes in project expectations, protocol, funding.  
Problems occurring or anticipated (corrective actions).
- IV. **Assistance Required of EH-40 Staff**  
Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status / Monthly Progress

The following three Ukrainians arrived at PNL in May 1994 to jointly conduct our 7.1F Program with partial funding assistance from U.S. Department of Commerce's Special American Business Intern Training (SABIT) Program:

Dr. Pavel V. Tkalich at the Cybernetic Centers in Kiev,  
Dr. Serguei Kivva at the Cybernetic Centers in Kiev, and  
Dr. Igor Bilyi at the Ukrainian Institute of Hydrometeorology, Kiev.

Dr. Tkalich arrived in Richland on May 1 and will stay with us for two and a half months – until July 14. Dr. Kivva arrived also on May 1 and will stay here for three months – until July 31. Dr. Bilyi arrived here on May 7 and will work with us for four months – until September 6. As we reported previously, SABIT provides both their travel expenses between Moscow, Russia and Pasco, Washington and their monthly incomes. We (Program 7.1F) cover their housing and health insurance. The cost to this project for the housing and health insurance coverage over this duration is \$14,666; thus, it is very cost effective to conduct our joint Program 7.1F in this manner.

Dr. Bilyi is now participating in our simulation of the radionuclide migration in the Pripyat River and its floodplain (covering a 4x10-km area) across from the Chernobyl Nuclear Power Plant. We are using the two-dimensional RMA-II hydrodynamic code and our FETRA sediment-contaminant transport code to simulate flow, sediment and radionuclide movements under four-year flood conditions. Resulting from this size flood, most of the contaminated Pripyat River floodplain across from the Chernobyl Nuclear Power Plant is expected to be covered by water, thus considered to be one of the worst conditions. The 1991 winter flood was caused by the ice jam that formed around the Chernobyl Plant was similar to the four-year flood in its coverage of the floodplain by the flooding water. In the month of May, we continued to calibrate the hydrodynamic model to reproduce steady-state velocity and water-depth distributions in the Pripyat River and its floodplain. Our predictions of water height and velocity are getting close to field data collected in our study area. We hope to complete the hydrodynamic model calibration in the month of June to early July. We are also participating in IAEA's BIOMOVs Program to compare our FETRA modeling results with results from other models.

Additionally we are conducting one-dimensional radionuclide transport modeling for the Dnieper River starting from Chernobyl, continuing along the Pripyat River to the Kiev Reservoir in the Dnieper River to its mouth at the Black Sea. The study area covers approximately 1000-km reaches of these rivers. We are using hydrodynamic CHARIMA code and our sediment-contaminant transport TODAM code for this modeling. Dr. Tkalich is now involved in this one-dimensional modeling. In the month of May, model calibration for the hydrodynamic mode, CHARIMA, was being conducted and this portion of the

model calibration was planned to be completed in the next month. We plan to start sediment and radionuclide transport modeling with the TODAM code in the next month. We are also participating in IAEA's VAMP program to compare our TODAM results with results from other models.

Dr. Kivva is working with us (through modeling) to examine interactions of radionuclides in the groundwater and the Pripyat River water in the Pripyat River floodplain. By using a European/Ukrainian groundwater code, Dr. Kivva previously conducted two-dimensional groundwater modeling for radionuclides in the Pripyat River floodplain in which we are currently simulating river flooding with RMA-II and FETRA, as we discussed above. With his participation, we are applying our three-dimensional subsurface code, MSTS, to the same floodplain site to assess the interactions of the Pripyat River and the groundwater, in order to assess the affect of radionuclide migration in the floodplain. We will also compare our model results with Dr. Kivva's previous modeling results. In the month of May, we first conducted two- dimensional (longitudinal and vertical) groundwater modeling. In the next month, we will conduct the radionuclide transport as well as longitudinal-lateral groundwater modeling for this area.

As we reported previously, Dr. Oleg Voitsekhovitch, (Ukrainian Hydro-meteorological Institute and the Ministry of Chernobyl Affairs), and Dr. Mark Zheleznyak, (Cybernetic Centers) requested us to process Landsat data covering the first week of March or April of this year to analyze a severe 1994 spring flooding of the Pripyat River which occurred in Ukraine and Belarus. Since we found that the U.S. Government did not take Landsat data over the Pripyat River during the March-May 1994 period, we did not further pursue this additional Landsat data analysis work. Since the Landsat Data are not available for this period, they then asked us to enhance their photograph images taken from a helicopter during this 1994 spring flood period. They indicated to us that the pictures are not very clear due to the bad weather conditions at that time. So we plan to carry out the digital enhancement of these pictures for them with our computer. Dr. Oleg Voitsekhovitch will deliver them to us in the next month.

Enclosed is our Program 7.1F topical report which is under the internal clearance/printing process. We expect PNL to print and distribute the report in late June to early July.

### III. Significant Problems/Issues/Concerns

We plan to complete the above stated modeling within this fiscal year. We requested \$80K for FY 1994 and have received \$50K to date. As we reported in our February Monthly report, we need the additional \$30K so that we can prepare reports and/or journal papers covering these modeling studies being jointly conducted by PNL and Ukrainian scientists.

IV. Assistance Required of EH-40 Staff

We hope that EH-40 can provide us the additional \$30K for this fiscal year.

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**DRAFT**

# **Chernobyl Nuclear Accident Hydrologic Analysis and Emergency Evaluation of Radionuclide Distributions in the Dnieper River, Ukraine, During the 1993 Summer Flood**

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June 1994

Prepared for  
the U.S. Department of Energy  
under Contract DE-AC06-76RLO 1830

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## Summary

This report describes joint activities of Program 7.1.F, "Radionuclide Transport in Water and Soil Systems," of the USA/Commonwealth of Independent States (CIS) Joint Coordinating Committee of Civilian Nuclear Reactor Safety to study the hydrogeochemical behavior of radionuclides released to the Pripyat and Dnieper rivers from the Chernobyl Nuclear Power Plant in Ukraine. These joint activities included rapid evaluation of radionuclide distributions in the Pripyat and Dnieper river system and field data evaluation and modeling for the 1993 summer flood to assist the Ukrainian government in their emergency response during the flood.

The Chernobyl nuclear accident released approximately 50 million curies (or 4%) of the fission products and activates in Reactor Unit No. 4 of the Chernobyl Nuclear Power Plant to the atmosphere during the 11 days following April 26, 1986, including 1.3 and 0.24 million curies of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ , respectively. The Chernobyl Nuclear Power Plant is located approximately 100 km north of Kiev, Ukraine, along the west bank of the Pripyat River, which joins the Dnieper River 30 km downstream at the Kiev Reservoir. The Dnieper passes through six reservoirs before discharging into the Black Sea, about 1000 km downstream. Subsequent to the accident, the Dnieper-Pripyat river watershed in Ukraine, Russia, and Belarus was heavily contaminated by fallout of radionuclides. The contaminated surface soil then became a source of long-term influx of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  into the Pripyat and Dnieper rivers.

About 19 million people in Ukraine consume water from the Dnieper River between Kiev and the Black Sea and thus are exposed to the impacts of the radionuclides in the river through drinking water, irrigation, and fishing; 8 million consume Dnieper River water as their drinking water. With the most current water use information available, a collective effective equivalent dose (EED) of internal exposure to the population and expected risks due to different water usage was calculated. We estimated that during 1986-1992, the collective dose (EED) for 19 million people resulting from 8 million people drinking the Dnieper River water and 19 million people consuming fish or irrigated food products are 216, 100, and 513 menSv, respectively, for a total of 829 menSv. The irrigation pathway is clearly the dominant pathway among these aquatic pathways. The total aquatic pathway

contribution constitutes about 7.0% of the total collective EED of 11,832 menSv from all pathways. The equivalent radiation risks from the aquatic pathway for the 19 million people are  $3.2 \times 10^{-6}$ , as compared to  $4.5 \times 10^{-5}$  for all pathways. The expected human cancer effects from drinking the Dnieper River water and consuming radioactively contaminated fish and irrigated food products are estimated as 16, 7, and 38 people with cancers, for a total of 61 people in the total population of 19 million. The total number of people who will get cancers due to all pathways is expected to be 864.

Even though the aquatic pathway contributes only 7% of the total dose from all the pathways, radionuclide migration into and within the rivers is important for determining potential dose to people through aquatic pathways. This is the case mainly because most of the practical current and future remediation will be confined to within a 30-km zone around Chernobyl to control and reduce potential radionuclide migration in the aquatic (surface and groundwater) pathways. It is important to obtain a realistic understanding of actual risks from the aquatic pathway to people living outside the 30-km protective zone to develop adequate criteria for measuring the effectiveness of current and future remediation and water protection activities based on dose/risk assessment and cost-benefit analysis.

The field data evaluation and modeling revealed that flooding is a critical factor that increases radionuclide concentrations in the rivers. The Pripyat River floodplain directly across from the Chernobyl Nuclear Power Plant is especially important because it received a significant amount of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  deposition, with  $^{90}\text{Sr}$  concentrations reaching  $1000 \mu\text{Ci}/\text{m}^2$ , accounting for approximately half of all  $^{90}\text{Sr}$  entering the Pripyat River. During a January 1994 flood caused by an ice jam, the  $^{90}\text{Sr}$  concentrations reached 250-300 pCi/L at Yanov Bridge (at the downstream end of the floodplain, exceeding the local drinking water limit of 100 pCi/L). The search for effective countermeasures led to the construction of an earthen dike in 1991. The construction of a 10-km dike in the floodplain across from the Chernobyl Nuclear Plant has proved to be effective for reducing  $^{90}\text{Sr}$  concentrations in the Pripyat River. However, despite construction of the dike, radionuclide migration and interaction between the floodplain and the Pripyat River are a long-term problem. Surface and groundwater interaction must be assessed in the future.

Despite these remediation measures, the problem of increasing of  $^{90}\text{Sr}$  concentrations in the Pripyat and Dnieper rivers during high floods still remains. In July-August 1993, heavy rainfall over

the Pripyat River catchment in Belarus and Ukraine caused severe flooding, significantly raising  $^{90}\text{Sr}$  concentrations in the river. Because of heightened public concern about radionuclide levels in the river and the need of the Ukrainian government to make an emergency response, an emergency evaluation of radionuclide distributions in the Dnieper River was conducted while the flooding was occurring. Near the Chernobyl area, the maximum  $^{90}\text{Sr}$  concentration in the Pripyat River reached 20-25 pCi/L in early August; near the Pripyat River mouth, the concentration rose to 35 pCi/L. The peak  $^{90}\text{Sr}$  concentration in the Kiev Reservoir (a major source of drinking water for Kiev) was 12 pCi/L. The evaluations showed that if the 10-km dike had not been constructed,  $^{90}\text{Sr}$  concentrations in the Pripyat River, and thus also in the Dnieper River, would have been much higher. Based on these measured radionuclide levels, additional modeling results and the assumption of water purification in a water treatment station,  $^{90}\text{Sr}$  concentrations in Kiev's drinking water were estimated to be less than 8 pCi/L. Unlike  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  concentrations in the Pripyat River during the flood did not rise significantly from the pre-flood levels. Estimated  $^{137}\text{Cs}$  concentrations for the Kiev drinking water were two orders of magnitude lower than the drinking water standard of 500 pCi/L for  $^{137}\text{Cs}$ . Thus the water was determined to be safe for Kiev's citizens to drink during the 1993 summer flood.

## Acknowledgments

This study has been founded by U.S. Department of Energy, Office of Environment, Safety and Health under Contract DE-AC06-76RLO 1830 as a part of the USA/CIS Joint Coordinating Committee on Civilian Nuclear Reactor Safety. Partial financial and logistical supports for CIS scientists to work at PNL were also provided by the U.S. Department of Commerce's Special American Business Internship Training Program.

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## 1.0 Introduction

Within the framework of the activities of Program 7.1.F "Radionuclide Transport in Water-Soil Systems" of the USA/Commonwealth of Independent State (CIS) Joint Coordinating Committee on Civilian Nuclear Reactor Safety, a USA/CIS working group has been studying the behavior of radionuclides in soil and water contaminated by the 1986 Chernobyl Nuclear Power Plant accident (Onishi et al. 1993). This document has been prepared during the group members' joint work at the Pacific Northwest Laboratory (PNL).<sup>(a)</sup>

The Dnieper River watershed in Ukraine, Russia, and Belarus was heavily contaminated by radionuclides accidentally released from Reactor Unit No. 4 of the Chernobyl Nuclear Power Plant in Ukraine on April 26, 1986. During the accident, approximately 4% of the fission products and actinides in Reactor Unit No. 4 were released to the atmosphere (Izrael et al. 1987, Izrael 1988). A significant portion of the radionuclides released fell onto the watershed of the Pripjat River in Ukraine and Belarus. The Chernobyl Nuclear Power Plant is located along the west bank of the Pripjat River approximately 30 km from its mouth at the Kiev Reservoir on the Dnieper River. Other areas that were heavily contaminated by  $^{137}\text{Cs}$  are in the upper Dnieper watershed in Russia and Belarus (Figure 1 and Table 1). As a result of this surface contamination, there is a long-term influx of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  into the Dnieper River, which passes through six reservoirs before discharging into the Black Sea. There has also been a significant increase in  $^{90}\text{Sr}$  concentration in the Kiev Reservoir (reaching

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(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

JUNE 1994

# EH-40 Monthly Report

June 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi  
**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

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*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies tests/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

We worked on the following three related, but separate, modeling activities in June.

(i) Radionuclide migration in the Pripyat River and its floodplain across from the Chernobyl Nuclear Power Plant for a flood condition with two-dimensional codes (PNL-developed FETRA and RMA-II).

(ii) Radionuclide migration in the same Pripyat River floodplain with PNL-developed subsurface code (MSTS).

(iii) Radionuclide migration in the Pripyat and Dnieper Rivers reaches approximately 1000-km from the Pripyat River at the Town of Chernobyl to the Dnieper River at the end of Kakhovka Reservoir with one-dimensional codes (PNL-developed TODAM and CHARIMA).

### (1) Pripyat River and Floodplain Modeling

The hydrodynamic code, RMA-II, has been applied to the Pripyat River and its floodplain across from the Chernobyl Nuclear Power Plant for a four-year flood event which is considered to be one of the worst cases to increase  $^{90}\text{Sr}$  concentrations in the Pripyat River. Figure 1 shows predicted water surface elevation, while Figs. 2 and 3 show predicted velocity distributions by RMA-II. The closely-spaced velocity distributions appearing in Fig. 2 represent those in the Pripyat River portion. The predicted results are getting closer to measured values. We will make a few more RMA-II runs to further calibrate the model. These RMA-II model results on velocity and water depths will then be supplied to sediment-contaminant transport code, FETRA, to simulate radionuclide migration in this study area.

### (2) The Floodplain Subsurface Modeling

The floodplain contains very high  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  concentrations. Their concentrations are shown in Figs. 4 and 5, respectively. Note that the river is represented horizontally along the bottoms of these figures. An earthen dike was constructed in the floodplain along the river to reduce the flooding of the Pripyat River into its floodplain across from the Chernobyl Nuclear Power Plant, thus reducing the radionuclide migration from the floodplain to the Pripyat River. With this dike, radionuclides in the floodplain will reach the river through subsurface flow under normal flow conditions, while under some flood conditions, radionuclides in the river will flow into the floodplain through subsurface flows. To simulate this river and floodplain interaction, two-dimensional (longitudinal and vertical) modeling (along the 5500-m line shown in Figs. 4 and 5) was conducted over a three year period with the three-dimensional subsurface code, MSTS. An example of the predicted hydraulic heads in the floodplain is shown in Fig. 6. The

water movements are perpendicular to iso-hydraulic head lines. Predictions of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in the floodplain after 1000 days are shown in Figs. 7 and 8, which depict general migration of radionuclides from the floodplain to the river.

### (3) The Dnieper River Modeling

Radionuclide migrations in the Dnieper River covering about 1000 km are being simulated over five years by the combination of one-dimensional hydrodynamic code, CHARIMA, and sediment-contaminant transport code, TODAM. The Dnieper River has six reservoirs, from Kiev Reservoir to Kakhovka Reservoir, before it reaches to the Black Sea. At the head of the Kiev Reservoir, the Pripyat River merges with the Dnieper River. Immediately downstream from the Kiev Reservoir (just upstream from the city of Kiev), the Desna River discharges into the Dnieper River. The modeling area covers from 15 km upstream from the Kiev Reservoir in both the Pripyat and Dnieper Rivers to the end of the Kakhovka Reservoir. Figure 9 shows the measured river discharges of the Dnieper River (at 15 km upstream of the Kiev Reservoir), the Pripyat River (at the Town of Chernobyl, about 15 km upstream of the Pripyat River mouth) and the Desna River at its mouth. Figures 10 and 11 show measured, suspended sediment concentrations of the Pripyat and Dnieper Rivers at these locations. Measured concentrations of  $^{137}\text{Cs}$  in these rivers are shown in Figs. 12 and 13. These values are supplied to the CHARIMA and TODAM as input data, as well as operational modes of these six reservoirs over the simulation period. An example of the predicted water elevation changes in the Dnieper River over six reservoirs is shown in Fig. 14. Predicted time-varying river discharges at the Kakhovka Reservoir is presented in Fig. 15 as a dotted line, while the solid line represents the Dnieper River discharge just downstream of the Desna River confluence. This figure shows the peak discharge was somewhat reduced at the Kakhovka Reservoir from the upstream values, revealing the effects of reservoir operations on the river discharge. Predicted river discharge and velocity distributions at the end of January 1991 are shown in Fig. 16. That was the time when an ice jam formed at Yanov Bridge over the Pripyat River just downstream from the Chernobyl Nuclear Power Plant. This caused the flooding of the Pripyat River floodplain, elevating  $^{90}\text{Sr}$  concentrations in the Pripyat River to exceed the local  $^{90}\text{Sr}$  drinking water limit. The predicted hydrodynamic results are being supplied to TODAM to simulate radionuclide migration in the study area.

### (4) PNL Report

We completed the following PNL report on our 7.1F Program activities. The report was printed, and now is undergoing its distribution.

O.V. Voitsekhovitch, M.J. Zheleznyak, and Y. Onishi. June 1994.

Chernobyl Nuclear Accident Hydrologic Analysis and Emergency  
Evaluation of Radionuclide Distributions in the Dnieper River, Ukraine,  
During the 1993 Summer Flood, PNL-9980, Pacific Northwest Laboratory,  
Richland, Washington.

III. Significant Problems/Issues/Concerns

None

IV. Assistance Required of EH-40 Staff

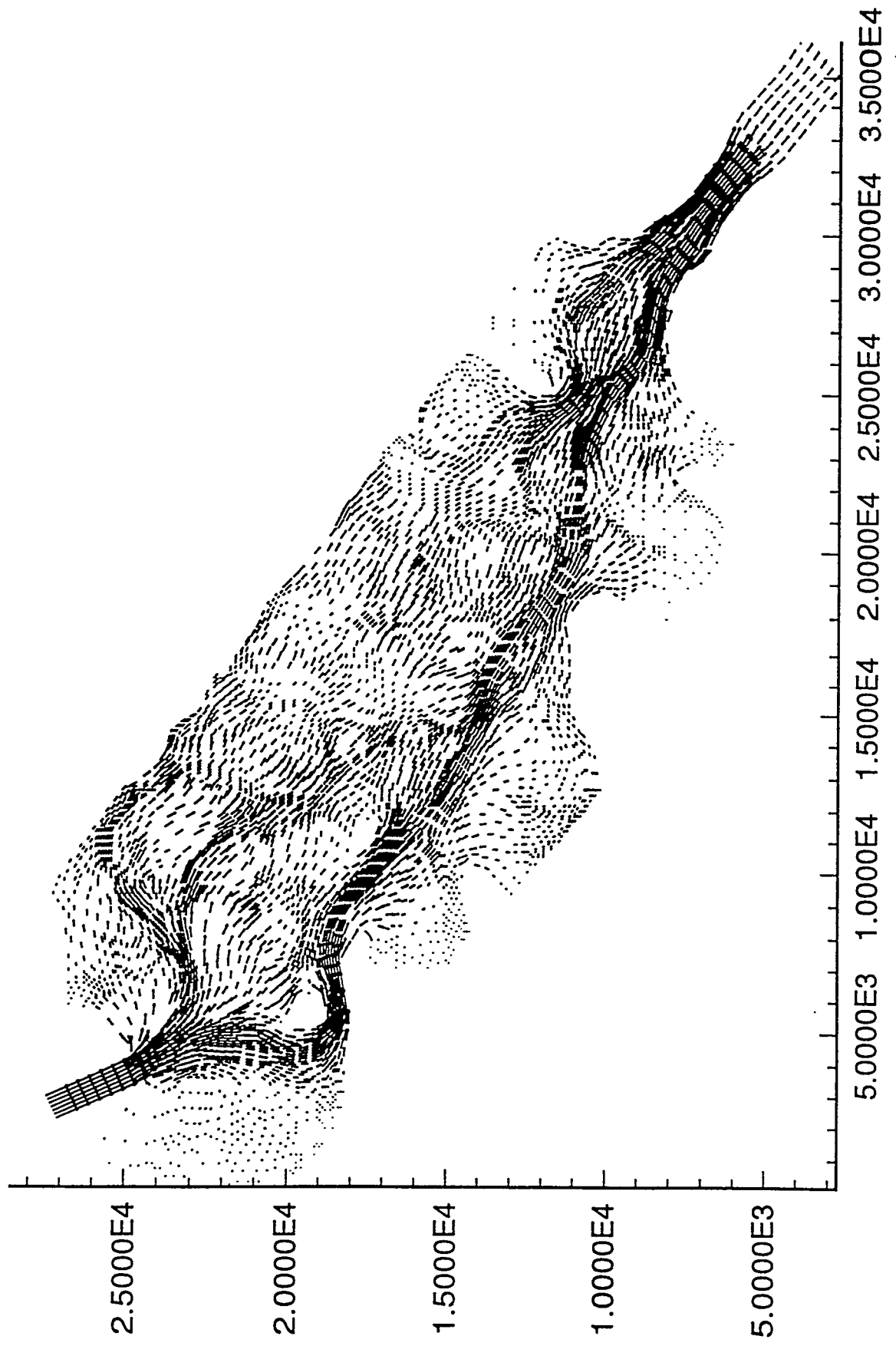
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1 Jun 1994 II fp508.plt II Flood Plane (fp508) 04/18/94

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357.5  
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356.875  
356.75



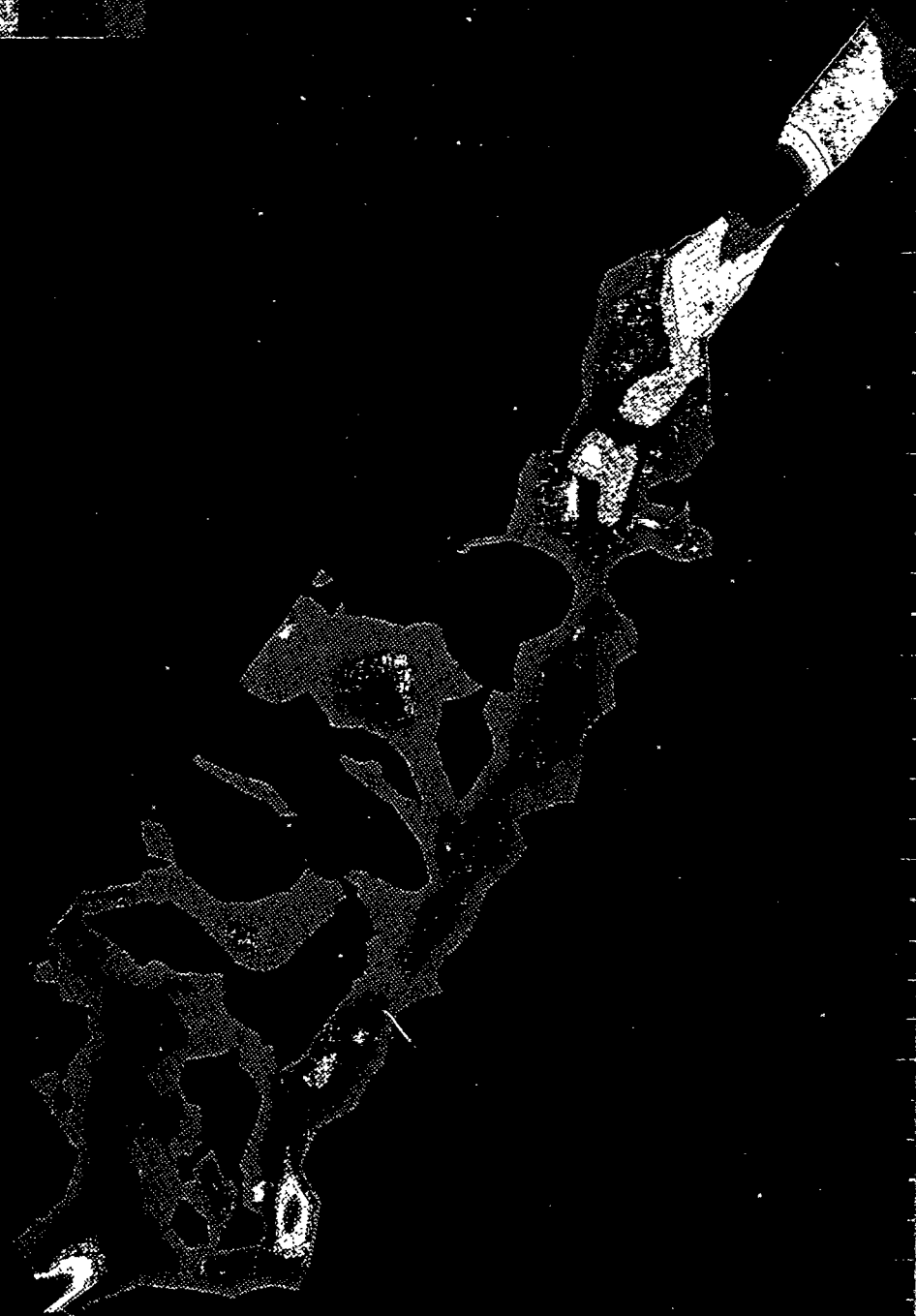
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18.2

1 Jun 1994 11 fp508.plt 11 Flood Plane (fp508) 04/18/94

vel  
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2.25  
2  
1.75  
1.5  
1.25  
1  
0.75  
0.5



5.0000E3 1.0000E4 1.5000E4 2.0000E4 2.5000E4 3.0000E4 3.5000E4

Fig 4

Surface Contamination of Floodplain by Sr-90 (Ci/km 2)

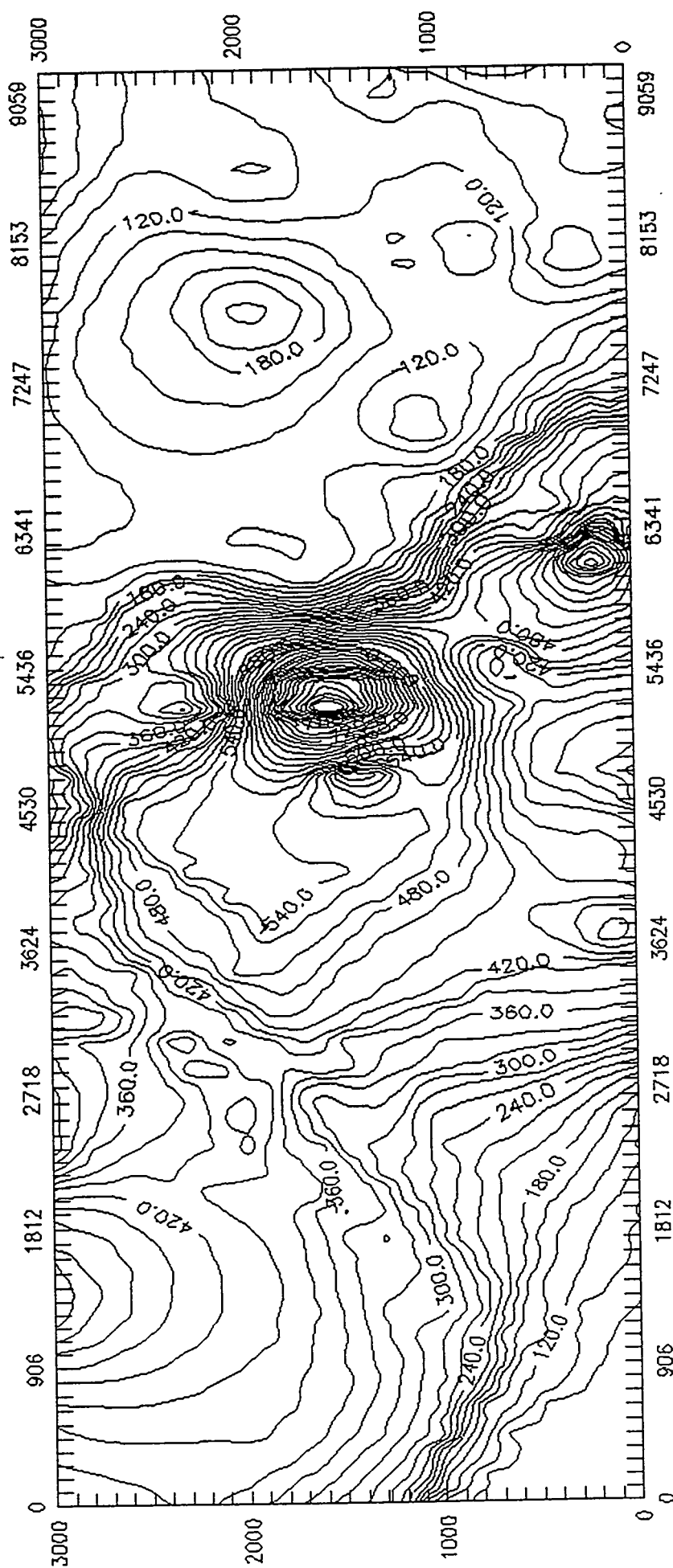


Fig. 5

Surface Contamination of Floodplain by Cs-137 (Ci/km 2)

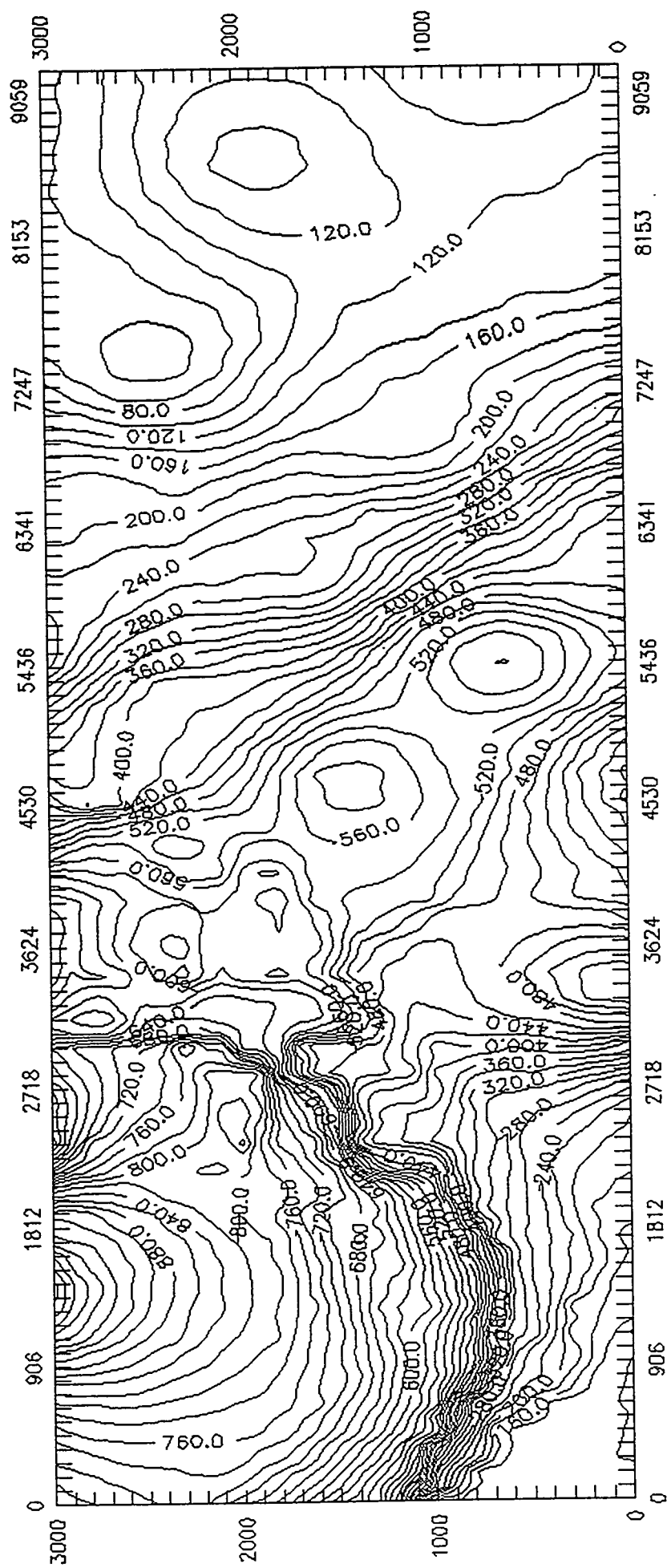


Fig. 6

Distribution of Hydraulic Heads in Floodplain Profile

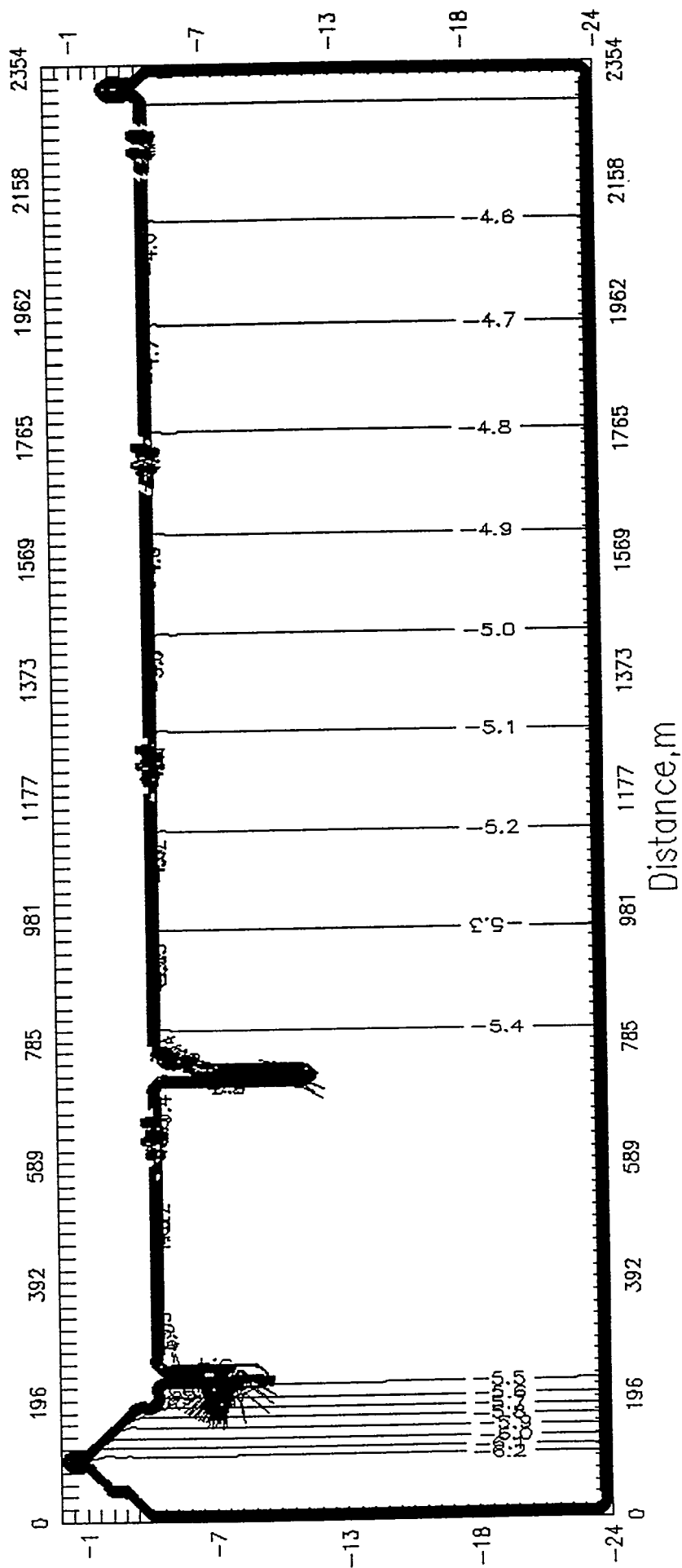


Fig. 7

Distribution of Sr-90 in Floodplain Profile  
(1100 day)

Concentration of Sr-90 in Soil Water (pCi/m<sup>3</sup>)

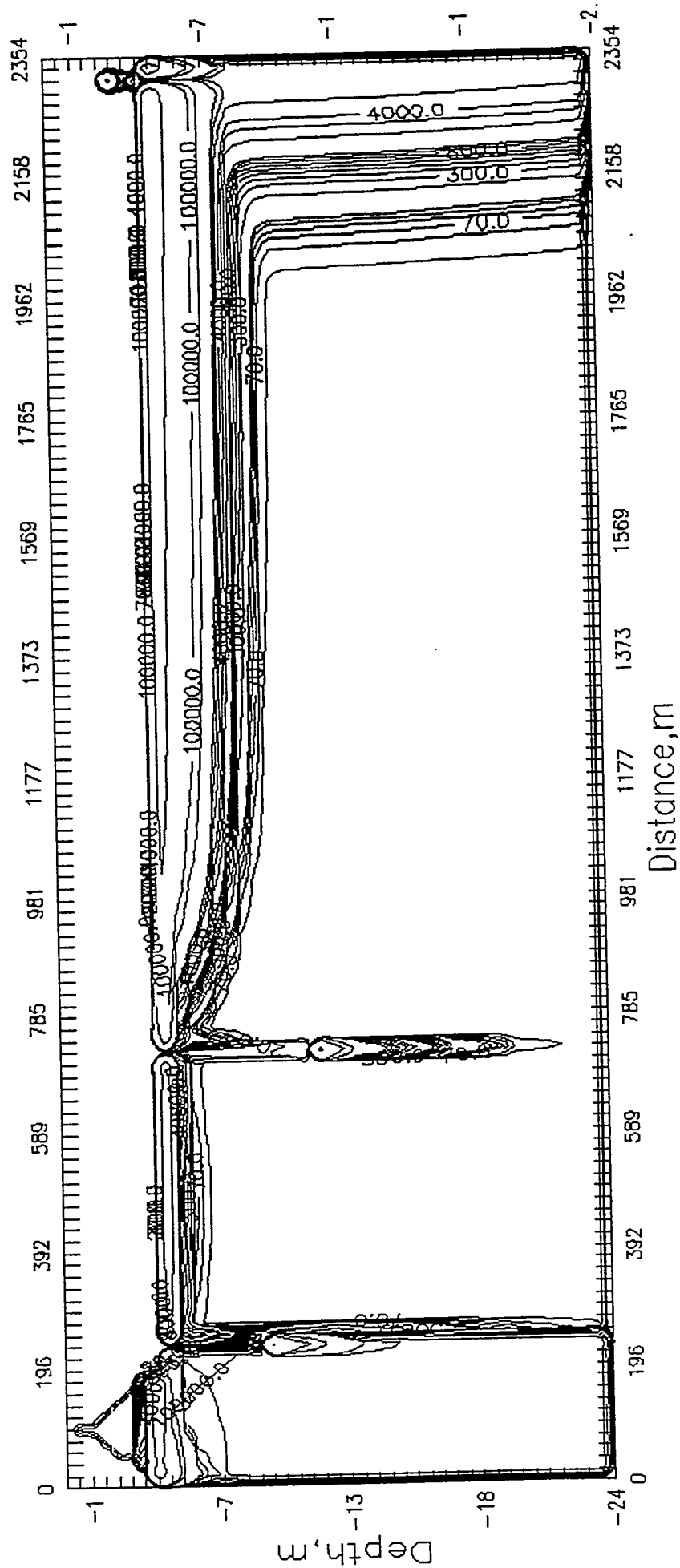


Fig. 8

Distribution of Cs-137 in Floodplain Profile  
(1100 day)

Concentration of Cs-137 in Soil Water (pCi/m<sup>3</sup>)

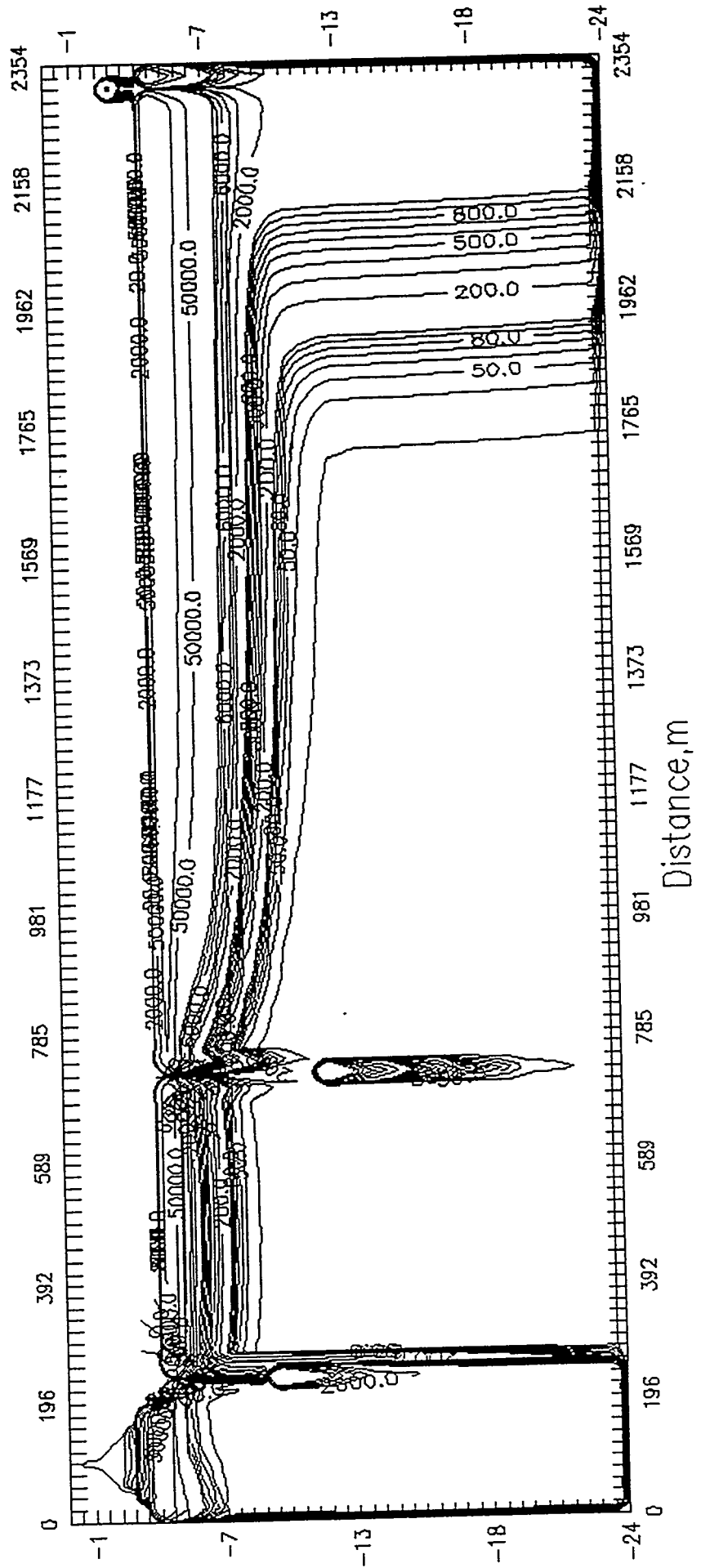


Fig 9

Chart1

### Income Discharges

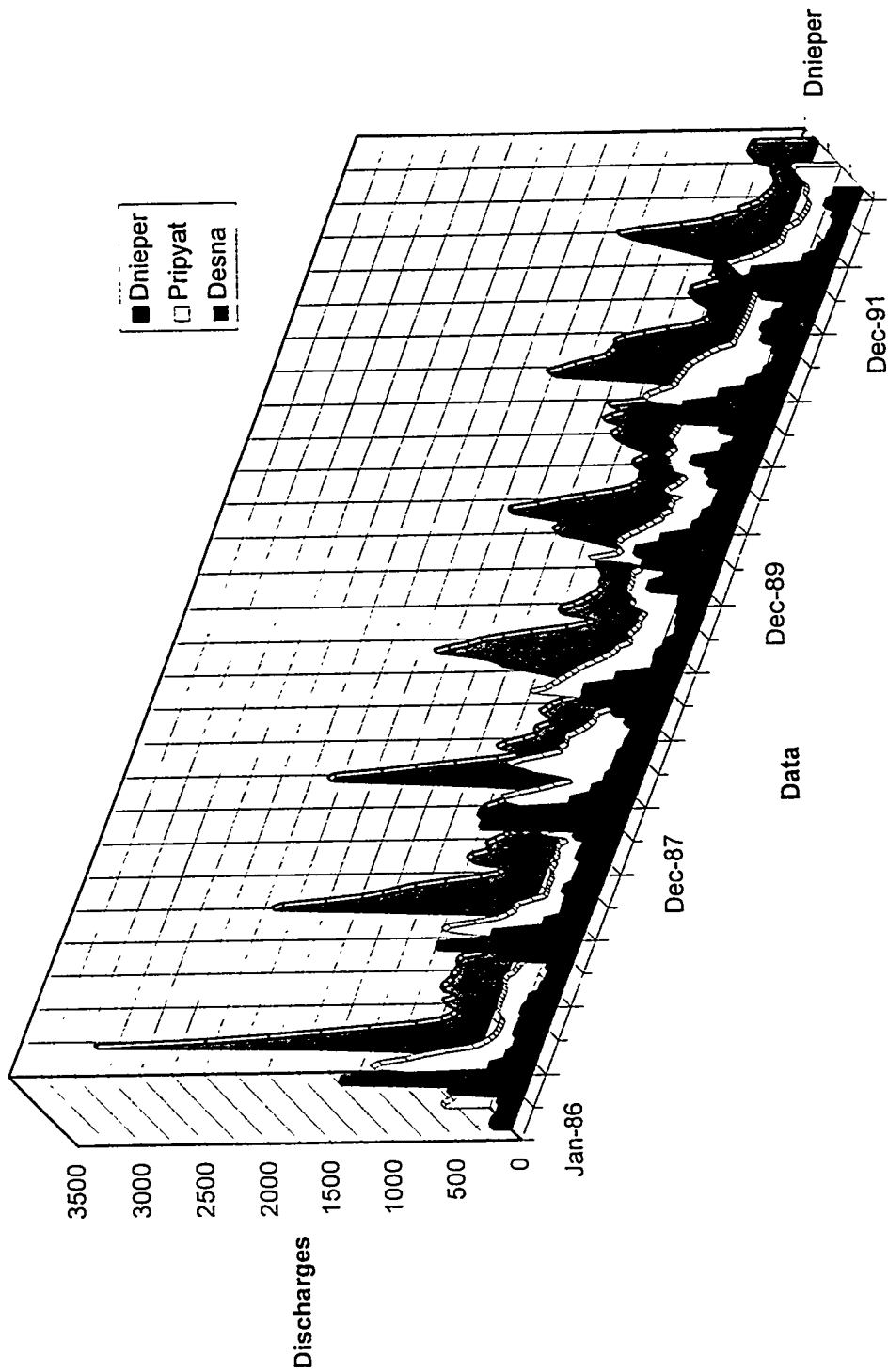
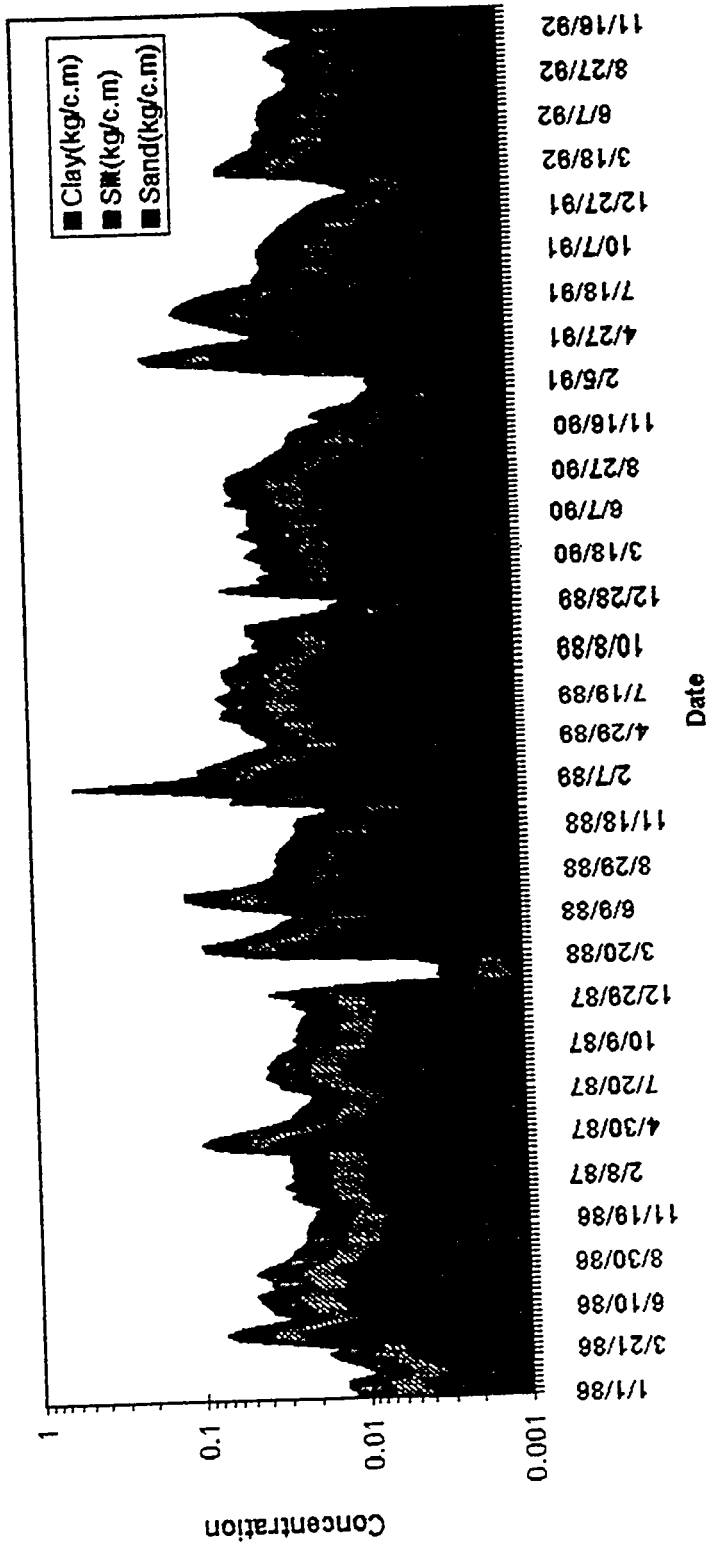


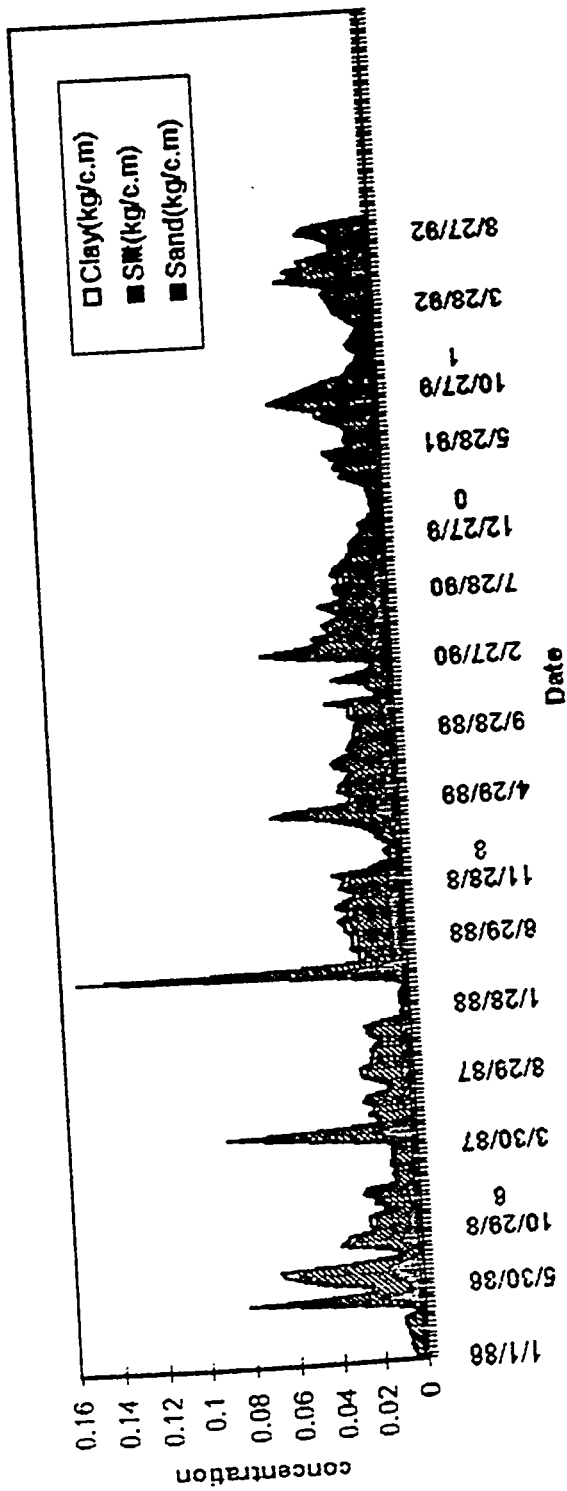
Fig 10

Sediments in Pripyat



PRIP8693.XLS

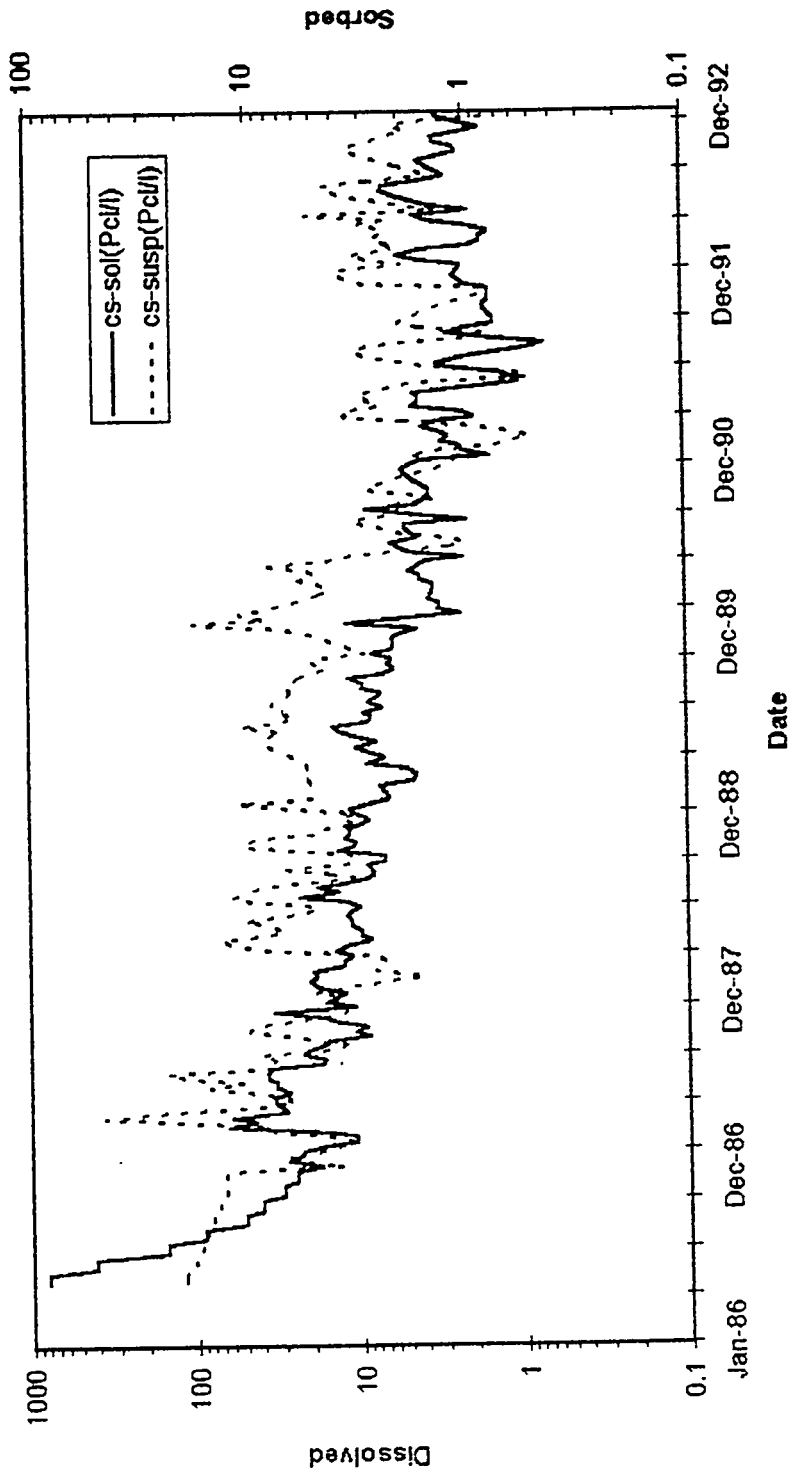
# Sediments in Dnieper



DNEP8693.XLS

F 2.12

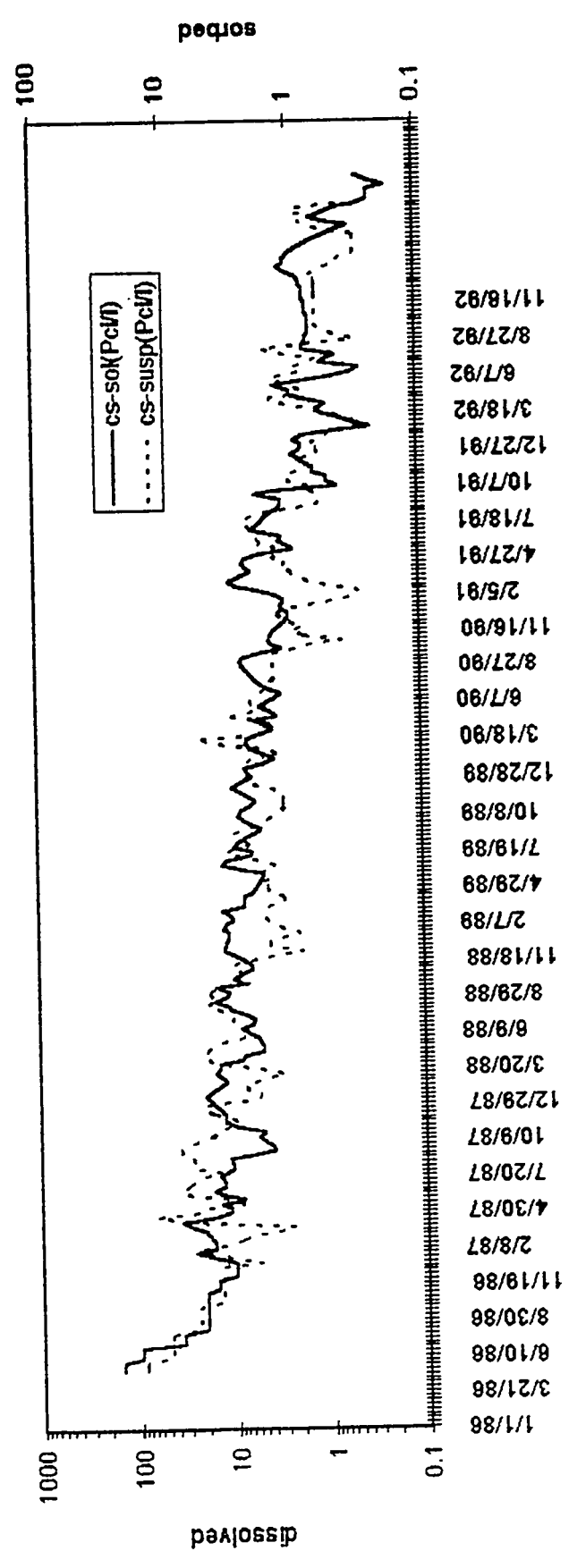
# Contamination of Pripyat



PRIP8693.XLS

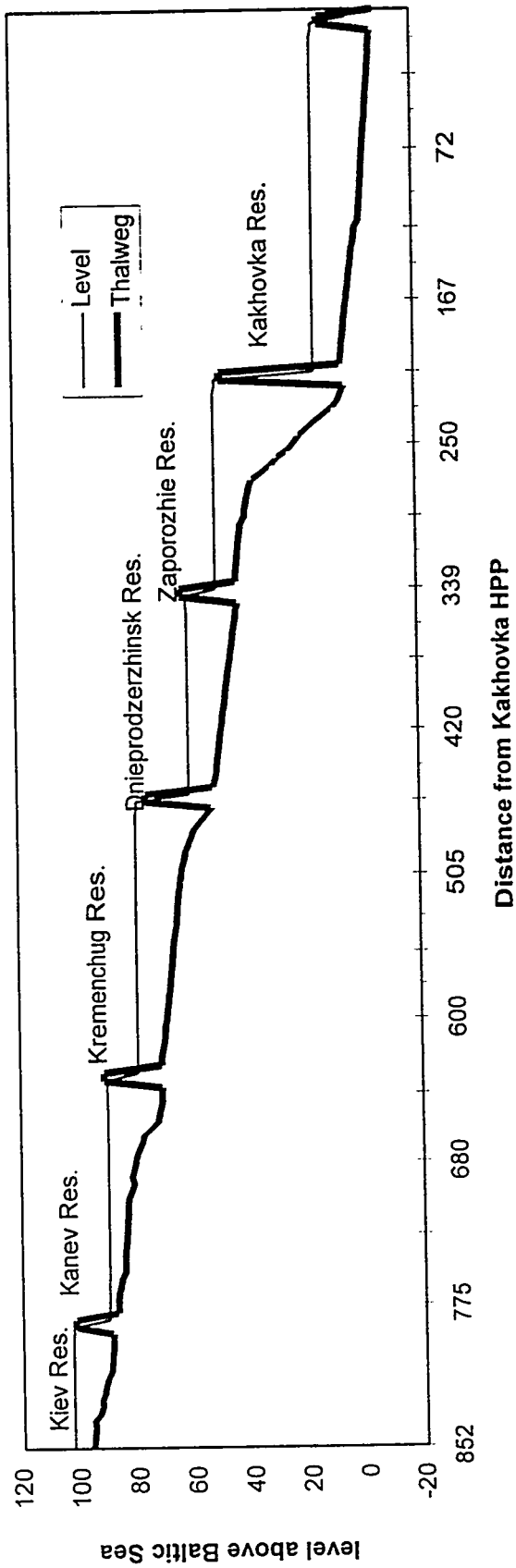
Fig. B

# Contamination in Dnepro



DNEP8693.XLS

# Profile of Dnieper Reservoirs



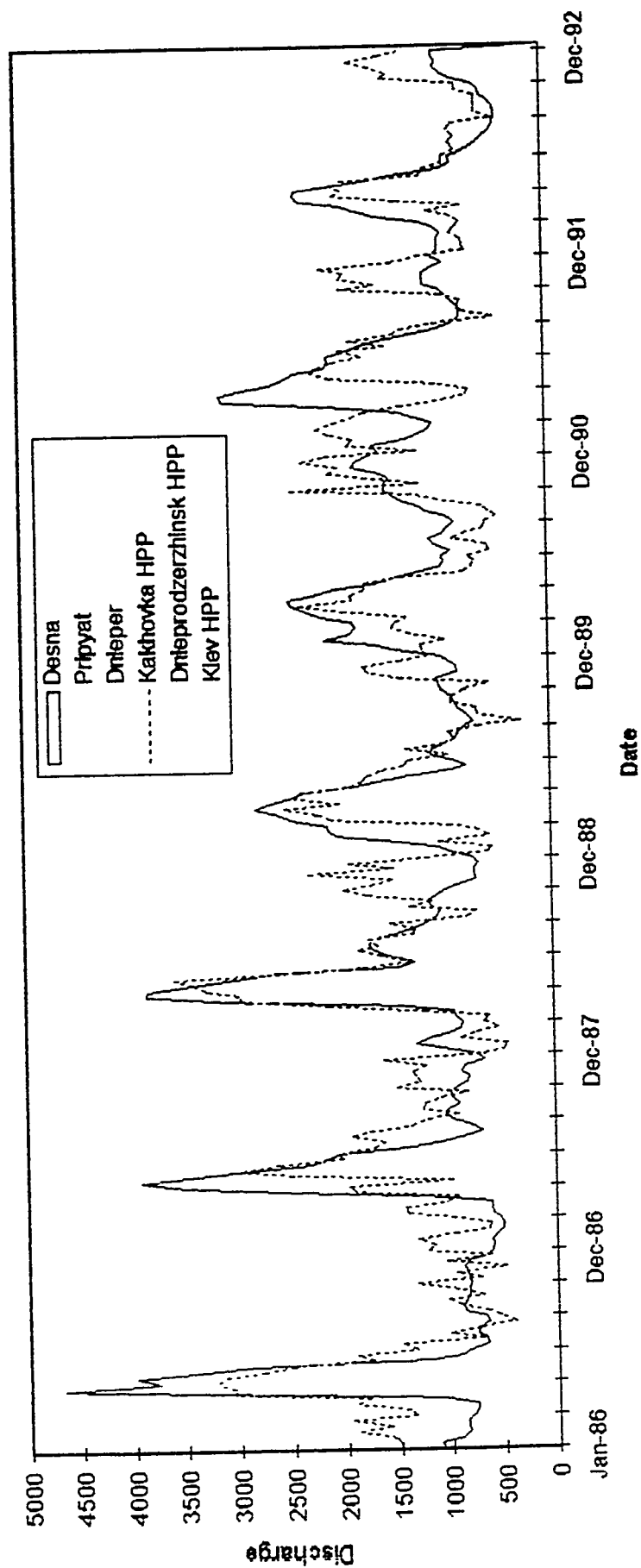
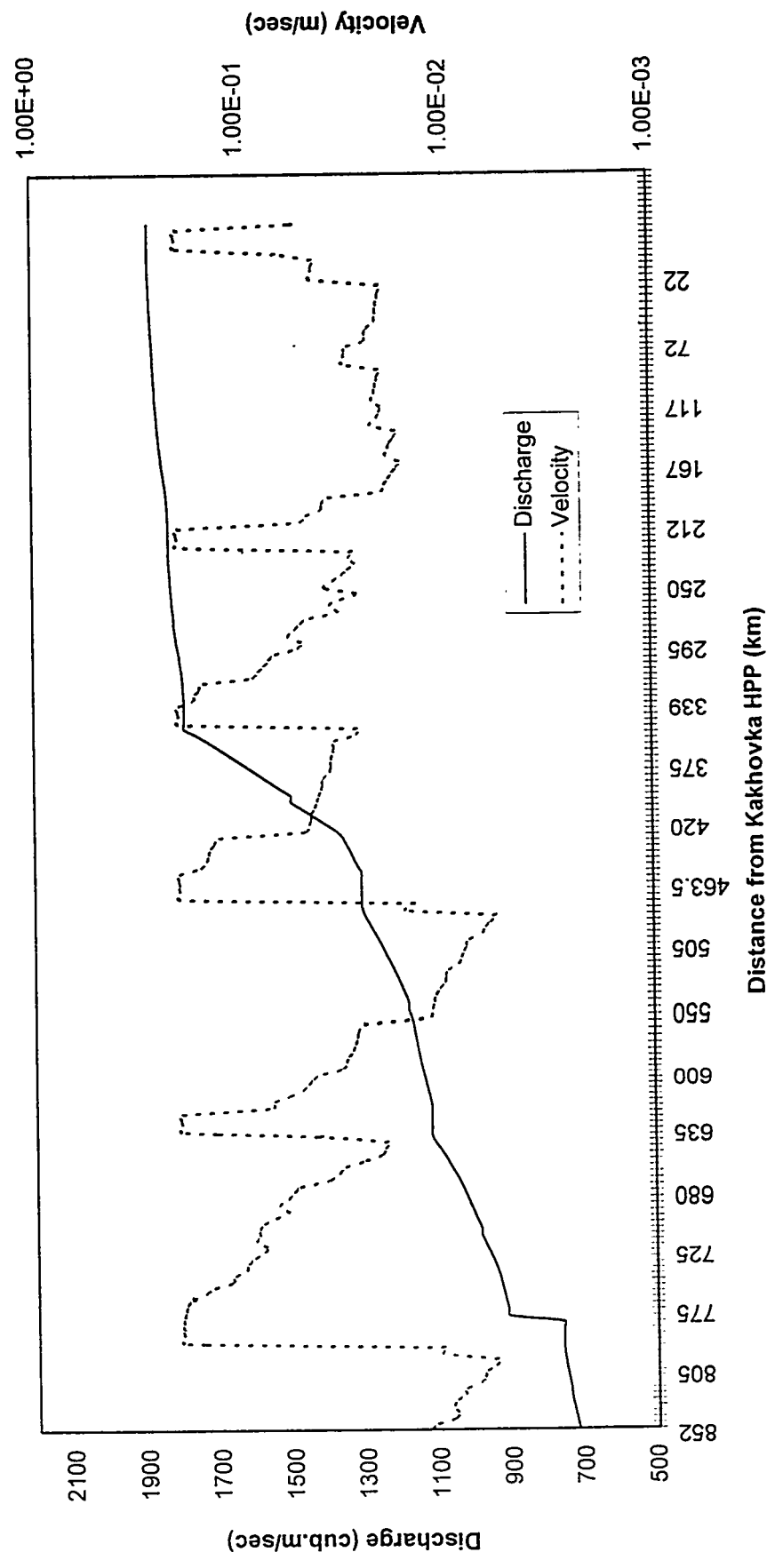


Fig. 10

Chart1

### Hydrodynamics (January 1991)



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**Chernobyl Nuclear Accident  
Hydrologic Analysis and Emergency  
Evaluation of Radionuclide  
Distributions in the Dnieper River,  
Ukraine, During the 1993 Summer  
Flood**

O. V. Voitsekhovitch  
M. J. Zheleznyak  
Y. Onishi

---

June 1994

Prepared for the U.S. Department of Energy  
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory  
Operated for the U.S. Department of Energy  
by Battelle Memorial Institute



# **Chernobyl Nuclear Accident Hydrologic Analysis and Emergency Evaluation of Radionuclide Distributions in the Dnieper River, Ukraine, During the 1993 Summer Flood**

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June 1994

Prepared for  
the U.S. Department of Energy  
under Contract DE-AC06-76RLO 1830

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Richland, Washington 99352

---

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(b) Cybernetics Center of the Ukrainian Academy of Sciences (Kiev, Ukraine).



## Summary

This report describes joint activities of Program 7.1.F, "Radionuclide Transport in Water and Soil Systems," of the USA/Commonwealth of Independent States (CIS) Joint Coordinating Committee of Civilian Nuclear Reactor Safety to study the hydrogeochemical behavior of radionuclides released to the Pripyat and Dnieper rivers from the Chernobyl Nuclear Power Plant in Ukraine. These joint activities included rapid evaluation of radionuclide distributions in the Pripyat and Dnieper river system and field data evaluation and modeling for the 1993 summer flood to assist the Ukrainian government in their emergency response during the flood.

About 19 million people in Ukraine consume water from the Dnieper River between Kiev and the Black Sea and thus are exposed to the impacts of the radionuclides in the river through drinking water, irrigation, and fishing; 8 million consume Dnieper River water as their drinking water. With the most current water use information available, a collective effective equivalent dose (EED) of internal exposure to the population and expected risks due to different water usage was calculated. We estimated that during 1986-1992, the collective dose (EED) for 19 million people resulting from 8 million people drinking the Dnieper River water and 19 million people consuming fish or irrigated food products are 216, 100, and 513 menSv, respectively, for a total of 829 menSv. The irrigation pathway is clearly the dominant pathway among these aquatic pathways. The total aquatic pathway contribution constitutes about 7.0% of the total collective EED of 11,832 menSv from all pathways. The equivalent radiation risks from the aquatic pathway for the 19 million people are  $3.2 \times 10^{-6}$ , as compared to  $4.5 \times 10^{-5}$  for all pathways. The expected human cancer effects from drinking the Dnieper River water and consuming radioactively contaminated fish and irrigated food products are estimated as 16, 7, and 38 people with cancers, for a total of 61 people in the total population of 19 million. The total number of people who will get cancers due to all pathways is expected to be 864.

Even though the aquatic pathway contributes only 7% of the total dose from all the pathways, radionuclide migration into and within the rivers is important for determining potential dose to people through aquatic pathways. This is mainly because most of the practical current and future remediation will be confined to within a 30-km zone around Chernobyl to control and reduce potential radionuclide

migration in the aquatic (surface and groundwater) pathways. The field data evaluation and modeling revealed that flooding is a critical factor that increases radionuclide concentrations in the rivers. The Pripyat River floodplain directly across from the Chernobyl Nuclear Power Plant is especially important because it received a significant amount of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  deposition, with  $^{90}\text{Sr}$  concentrations reaching  $1000\ \mu\text{Ci}/\text{m}^2$ , accounting for approximately half of all  $^{90}\text{Sr}$  entering the Pripyat River. During a January 1991 flood caused by an ice jam, the  $^{90}\text{Sr}$  concentrations reached 250-300 pCi/L at Yanov Bridge (at the downstream end of the floodplain, exceeding the local drinking water limit of 100 pCi/L). The search for effective countermeasures led to the construction of an earthen dike in 1991. The construction of a 10-km dike in the floodplain across from the Chernobyl Nuclear Plant has proved to be effective for reducing  $^{90}\text{Sr}$  concentrations in the Pripyat River. However, despite construction of the dike, radionuclide migration and interaction between the floodplain and the Pripyat River are a long-term problem. Surface and groundwater interaction must be assessed in the future.

Despite these remediation measures, the problem of increasing of  $^{90}\text{Sr}$  concentrations in the Pripyat and Dnieper rivers during high floods still remains. In July-August 1993, heavy rainfall over the Pripyat River catchment in Belarus and Ukraine caused severe flooding, significantly raising  $^{90}\text{Sr}$  concentrations in the river. Because of heightened public concern about radionuclide levels in the river and the need of the Ukrainian government to make an emergency response, we conducted an emergency evaluation of radionuclide distributions in the Dnieper River, while the flooding was occurring. Near the Chernobyl area, the maximum  $^{90}\text{Sr}$  concentration in the Pripyat River reached 20-25 pCi/L in early August; near the Pripyat River mouth, the concentration rose to 35 pCi/L. The peak  $^{90}\text{Sr}$  concentration in the Kiev Reservoir (a major source of drinking water for Kiev) was 12 pCi/L. The evaluations showed that if the 10-km dike had not been constructed,  $^{90}\text{Sr}$  concentrations in the Pripyat River, and thus also in the Dnieper River, would have been much higher. Based on these measured radionuclide levels, additional modeling results and the assumption of water purification in a water treatment station,  $^{90}\text{Sr}$  concentrations in Kiev's drinking water were estimated to be less than 8 pCi/L. Unlike  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  concentrations in the Pripyat River during the flood did not rise significantly from the pre-flood levels. Estimated  $^{137}\text{Cs}$  concentrations for the Kiev drinking water were two orders of magnitude lower than the drinking water standard of 500 pCi/L for  $^{137}\text{Cs}$ . Thus the water was determined to be safe for Kiev's citizens to drink during the 1993 summer flood.

## **Acknowledgments**

This study has been founded by U.S. Department of Energy, Office of Environment, Safety and Health under Contract DE-AC06-76RLO 1830 as a part of the USA/CIS Joint Coordinating Committee on Civilian Nuclear Reactor Safety. Partial financial and logistical supports for CIS scientists to work at PNL were also provided by the U.S. Department of Commerce's Special American Business Internship Training Program.

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JULY 1994

# EH-40 Monthly Report

July 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi  
**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

---

*Address each item, if applicable.*

- I. Project Objective**
- II. Current Project Status / Monthly Progress**
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns**
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff**
  - Identify EH-40 staff member(s) with each requests.

## **I. Project Objective**

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

We continued to work on the following three related, but separate, modeling activities in July.

(i) Radionuclide migration in the Pripyat and Dnieper Rivers over the river reaches of approximately 1000 km from the Pripyat River at the town of Chernobyl to the Dnieper River at the end of Kakhovka Reservoir with one-dimensional codes (PNL-developed TODAM and CHARIMA).

(ii) Radionuclide migration in the Pripyat River and its floodplain across from the Chernobyl Nuclear Power Plant for a flood condition with two-dimensional codes (PNL-developed FETRA and RMA-2).

(iii) Radionuclide migration in the same Pripyat River floodplain with PNL-developed subsurface code (MSTS).

### (1) The Dnieper River Modeling

We are now simulating  $^{90}\text{Sr}$  transport in the Dnieper River by applying the one-dimensional, sediment-contaminant transport code, TODAM to the 1000 km river reaches, as shown in Fig. 1. The simulation covers from 1986-1992. Predicted time-varying  $^{90}\text{Sr}$  concentrations starting from January 1986 to mid 1991 near the Kiev, Kremenchug and Zaporozhie Reservoirs are shown in Figs. 2, 3 and 4 along with measured values. These figures show good agreements with data. We are planning to simulate  $^{137}\text{Cs}$  after the  $^{90}\text{Sr}$  modeling. We plan to submit our TODAM modeling results to IAEA for the VAMP program to compare our model results with other model results generated by European countries, including the former Soviet Union. We are also combining the TODAM code with the hydrodynamic code, CHERIMA, so that there will be feedback between hydrodynamic and sediment-contaminant transport modeling to improve the model accuracy for the future applications.

### (2) Pripyat River and Floodplain Modeling

We completed steady-state hydrodynamic modeling for the Pripyat River and its floodplain with two-dimensional RMA-II for the four-year-flood event, which is considered one of the worst cases to have increased  $^{90}\text{Sr}$  concentrations in the Pripyat River, thus also in the Dnieper River. Model results appear reasonable. We then initiated  $^{90}\text{Sr}$  modeling in this area by applying two-dimensional sediment-contaminant code, FETRA. The code simulated the  $^{90}\text{Sr}$  transport in the study area. However, it could only cover a short duration because of the slowness of the computation. We identified why it was taking so much computer time. We now plan to replace the FETRA's current matrix solver with a faster solver to make the computation faster.

### (3) The Floodplain Subsurface Modeling

We completed the application of the subsurface code, MSTS, to the Pripjat River floodplain to simulate two-dimensional (vertical and longitudinal)  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  concentrations in both vadose and saturated groundwater zones which interact with the Pripjat River. We plan to apply the MSTS code to the same floodplain to predict three-dimensional distributions of  $^{90}\text{Sr}$  and/or  $^{137}\text{Cs}$  in the next month. However, there is a large uncertainty on the speed of computation time to be able to conduct three-dimensional modeling by using our computer facilities.

### (4) Enhancement of Pripjat River Photographs

We are currently enhancing several photographs that the Ukrainian Hydro-meteorological Institute sent to us through our computer. These were the Pripjat River and its floodplain photographs taken during the last spring flood.

## III. Significant Problems/Issues/Concerns

Dr. Onishi received the following two invitations from IAEA.

(i) Advisory Group Meeting on Dose Assessment Methods for the Purposes of Limiting Radioactive Releases to be held at IAEA in Vienna, Austria during October 17-21, 1994, in order to revise IAEA Safety Series Report 57 "Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases - Exposures of Critical Groups."

(ii) Final Meeting of the River/Reservoir Group of IAEA Validation of Environmental Model Predictions (VAMP) Program to be held at IAEA in Vienna, Austria during October 31–November 4, 1994, in order to complete a IAEA river/reservoir model validation document based on the Dnieper River in Ukraine (the Chernobyl Accident case) and the Clinch/Tennessee River case.

Dr. Onishi has been involved in both of these activities over the years in order to prepare these documents. These two upcoming meetings are one week apart; so if he attends both meetings, he will be in Europe without charging any cost to DOE. IAEA will cover Dr. Onishi's travel expenses (an airplane ticket between the U.S. and Vienna, and his per diem) for the first trip (October 17-21), but will not cover the expenses associated with the VAMP meeting. IAEA will not cover Dr. Onishi's labor cost to attend these meetings.

Dr. Onishi plans to ask PNL to cover the labor cost to attend the Nuclear Safety meeting (on October 17-21) with PNL internal funding. These meetings were not budgeted for in our 7.1F subprogram funding. In order for him to also attend the VAMP meeting (on October 31–November 4) to work on the IAEA Chernobyl river model comparison document, he needs additional funding assistance of \$6.2K from

DOE-EH for subprogram 7.1F to cover his 6-day stay in Vienna (\$1.5K) and 40 hours of his time (\$4.7K) during October 31–November 4.

#### IV. Assistance Required of EH-40 Staff

Additional \$6.2K as indicated above.

AUGUST 1994

# EH-40 Monthly Report

August 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi  
**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

We continued to work on the following modeling in August;

(i) Radionuclide migration in the Pripyat and Dnieper rivers over the river reaches of approximately 1000 km from the Pripyat River at the town of Chernobyl to the Dnieper River at the end of Kakhovka Reservoir with one-dimensional codes (PNL-developed TODAM and CHARIMA).

(ii) Radionuclide migration in the Pripyat River and its floodplain across from the Chernobyl Nuclear Power Plant for a flood condition with two-dimensional codes (PNL-developed FETRA and RMA-II).

(iii) Radionuclide migration in the same Pripyat River floodplain with the PNL-developed subsurface code, MSTs.

### (1) The Dnieper River Modeling

We have simulated  $^{90}\text{Sr}$  transport in the Dnieper River by applying the one-dimensional, sediment-contaminant transport code, TODAM to the 1000 km river reaches over 1986-1992. We are currently simulating  $^{137}\text{Cs}$  transport and deposition in the river system. We plan to submit our TODAM modeling results to IAEA for the VAMP program to compare our model results with other model results IAEA received. As reported in the July Monthly Report, Dr. Onishi was invited to attend an IAEA Advisory Final meeting of the River/Reservoir Group of IAEA Validation of Environmental Model Predictions (VAMP) Program to be held at IAEA in Vienna, Austria during October 31-November 4, 1994. The main objective of the meeting is to complete an IAEA river/reservoir model validation document based on the Dnieper River in Ukraine (the Chernobyl Accident case) and the Clinch/Tennessee River case. Since there is no funding to cover the expenses for him to attend this IAEA meeting without additional funding from DOE-EH, he is currently not planning to attend it. In August, we also combined the TODAM code with the hydrodynamic CHARIMA code to incorporate feedback between river hydrodynamics and sediment-contaminant transport.

### (2) Pripyat River and Floodplain Modeling

Initial simulation of  $^{90}\text{Sr}$  transport in the Pripyat River with FETRA indicated that the computer simulation was too slow to predict the transport and accumulation of  $^{90}\text{Sr}$  in the study area. This requires either to significantly reduce a number of computational points or modify FETRA to improve computational efficiency. Because the needed reduction of computational points is too great to produce meaningful distribution of  $^{90}\text{Sr}$  in the study area, we opted to improve the code itself. Since most of the computer simulation time was spent on manipulating matrices (i.e., assigning boundary concentrations in a matrix and then solving the matrix), we decided to improve these two aspects. We replaced an original FETRA

matrix solver with a faster solver. This new solver was tested to be approximately two orders faster than the old solver for the Pripyat River floodplain application. We currently are working on better boundary value assignment in the code.

### (3) The Floodplain Subsurface Modeling

After completing simulations of two-dimensional (vertical and longitudinal)  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  concentrations in both vadose and saturated groundwater zones in the Pripyat River floodplain which interacts with the Pripyat River, we initiated the applications of the MSTS code to predict three-dimensional radionuclide distributions. However, we found that the speed of computational time was too slow to conduct three-dimensional modeling by using our computer facilities. Attached is the description of two-dimensional modeling for the Pripyat River floodplain. It contains the model site description, model formulation, two-dimensional (both lateral-longitudinal, and vertical-longitudinal) model prediction of water table heights (note that lateral-longitudinal modeling results were used as parts of initial and boundary conditions for the vertical-longitudinal modeling), and two-dimensional (vertical-longitudinal) distributions of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ .

### (4) Ukrainian Participation under SABIT

Under the framework of the U.S. Department of Commerce's Special American Internship Training (SABIT) Program, Drs. Pavel Tkalich and Sergei Kivva, (both from the Cybernetic Centers in Kiev, Ukraine) and Dr. Igor Bilyi (from the Ukrainian Hydrometeorological Institute in Kiev, Ukraine) have been working with us at PNL for several months to participate in the Program 7.1.F modeling activities discussed above. At the end of August, Drs. Tkalich and Kivva went back to Kiev. Dr. Bilyi plans to leave here in mid-October.

## III. Significant Problems/Issues/Concerns

No new issue.

## IV. Assistance Required of EH-40 Staff

No new request.

## Simulation of $^{90}\text{Sr}$ and $^{137}\text{Cs}$ Migration in Ground Water at Pripyat River Floodplain Site

The purpose of this work was to simulate the migration of by radionuclides  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in a critical section of the floodplain of the Pripyat River. These simulations dynamically estimate concentrations and water level elevations throughout the floodplain. Simulation results will be used to determine the main sources and migration paths contamination. The efficacy of remediation actions can be assessed using these results.

### Description of Modeling Region

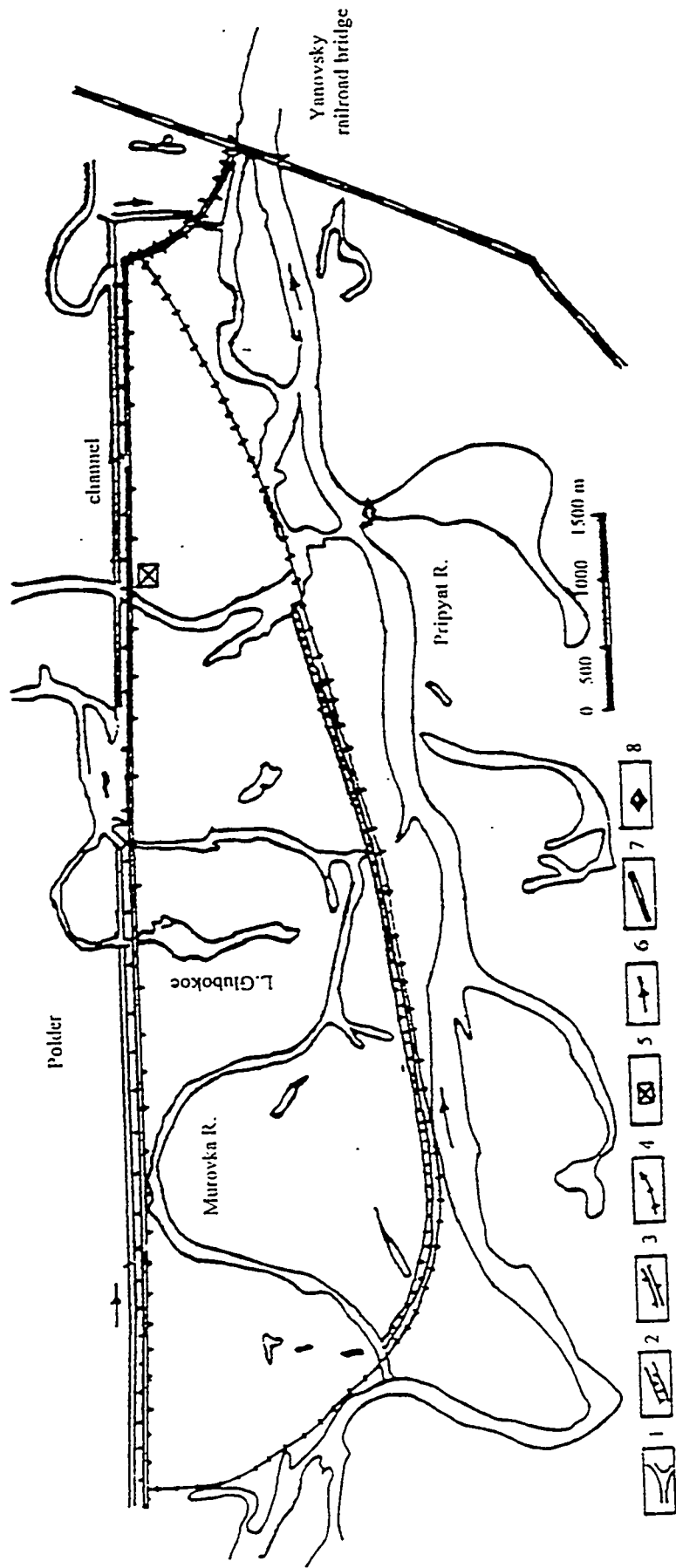
Left bank floodplain of the Pripyat River is bounded on the the north by the Yanovsky railroad bridge, on the west by Pripyat River and on the east by polder dam and channel (Figure 1.). After the Chernobyl accident this area was highly contaminated by  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ . This floodplain area is 2 km by 10 km in size and contains more than 8000 Ci of  $^{90}\text{Sr}$  and 11000 Ci of  $^{137}\text{Cs}$  (Figures 2 and 3.). It is potentially the greatest source of  $^{90}\text{Sr}$  contamination to the Dnieper reservoir system. In 1991 a special dam around the contaminated area was constructed as a countermeasure to prevent radionuclide washout into the Pripyat River during spring floods and heavy rains.

There is wide distribution of alluvial sands in the upper part of geologic section in this region. Aquifers of this site are composed of fine, medium and sometimes by coarse sands. Medium sands prevail. Hydraulic conductivity at saturation for the alluvial water-bearing sand is estimated between 6 and 15 m/day. Porosity estimates range from 0.31 to 0.66. Thickness of the floodplain alluvial sands in average varies from 10 to 20m.

These alluvial sands lie above 20 to 25 m of flat relatively impermeable marls of Kiev Eocene suite. Hydraulic conductivity at saturation of these deposits ranges from 0.0001 to 0.005 m/day. The alluvial sands constitute an unconfined aquifer. Water table levels in the floodplain varies within 1 to 5m of the surface.

The water-bearing complex is supplied by recharge from polder, precipitation infiltration and partially by upward flow from lower water-bearing horizon of Eocene deposits. Natural discharge of groundwater is mainly into the river, floodplain water intake and also partially downward flow to low-lying water-bearing horizon of Eocene deposits.

The overall annual average sum of precipitation for this site is 550-600 mm, with extreme values of 762 mm in wet years and 301 mm in dry years. Average annual total evapotranspiration is equals 300-400 mm.



1. reservoir system and polder channel; 2. floodplain channel; 3. polder dam;
4. floodplain dam; 5. pumping station; 6. flow direction; 7. railroad; 8. dam with pour off.

Fig. 1. Scheme of Left Bank Floodplain of the Prip'yat River.

SEPTEMBER 1994

## EH-40 Monthly Report

September 1994

**Project Title:** Chernobyl Studies  
7.1F Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** N/A

**Principal Investigator:** Yasuo Onishi

**M&O Contractor:** Pacific Northwest Laboratory (direct funding)

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*Address each item, if applicable.*

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- II. Current Project Status / Monthly Progress**
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  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff**
  - Identify EH-40 staff member(s) with each requests.

### I. Project Objective

The project objective is to assess radionuclide migration in the water and soil environment with mathematical modeling in order to provide information on potential health impacts and remediation requirements associated with the Chernobyl accident. Specifically, radionuclide distributions in the Pripyat-Dnieper River system from the Chernobyl Nuclear Power Plant to the Black Sea will be predicted under major flooding of the Pripyat River, because flooding can significantly increase radionuclide concentrations in these rivers. For the Iput River Basin in Russia, we will combine Landsat data and available Chernobyl data to characterize the area. These results will then be fed to a watershed/groundwater model to predict potential runoff and soil scouring areas from where  $^{137}\text{Cs}$  can migrate overland to receiving surface water. Identification of major radionuclide source locations could be used for potential remedial activities. We will also initiate examination of radionuclide contaminations in the groundwater near the Chernobyl Nuclear Power Plant to study interactions with the Pripyat River, especially during flooding periods.

These studies test/improve predictive methodologies for aquatic environmental assessment. The study results will also be used by CIS countries for identifying necessary remediation activities and their effectiveness.

## II. Current Project Status/Monthly Progress

In the month of September, we conducted two-dimensional Pripyat River/floodplain modeling with FETRA and RMA II codes. We completed the FETRA modification to improve computational efficiency to be able to cover a flooding event of the Pripyat River. The code modification made the sediment-contaminate code, FETRA about one order of magnitude faster for overall simulation time and was also made more stable to be able to use a larger time step. With this modified FETRA, we predicted  $^{90}\text{Sr}$  distributions for four-year flood event with one-minute time step. As discussed previously, the four-year flooding is considered to be one of the worst conditions for the  $^{90}\text{Sr}$  concentration rise in the river. After completing the simulation, we conducted a case with an earthen dike built along the river in the floodplain to block off the flooding water penetrating into the floodplain. Predicted  $^{90}\text{Sr}$  concentrations are very close to measured levels during 1991 winter flood event. With the dike installed, concentrations at the downstream end of the Pripyat River were predicted to be about 50% less than the level without the dike. This predicted reduction was supported by measured data in the area. The attached 15 figures show our model prediction results.

Figure. 1 shows the computational grid distribution for the case before the earthen dike was built in 1992. Predicted water surface elevations (ft) and water depth (m) for the four-year flood are shown in Figs. 2 and 3, which are in good agreement with the measured data. A predicted velocity distribution is shown in Fig. 4, depicting fast river flow with very slow velocities in the floodplain, as expected. Measured  $^{90}\text{Sr}$  concentrations in Ci/km<sup>2</sup> in the river bed and on the floodplain bottom sediment are shown in Fig. 5. This contaminated bed is a main source of the  $^{90}\text{Sr}$  coming out from the floodplain during the flood event. With this bottom  $^{90}\text{Sr}$  level as input, FETRA predicted  $^{90}\text{Sr}$  concentrations (pCi/L) in the river and floodplain, as shown in Figs. 6 and 7 at 12 and 36 hours after flooding, respectively. These figures show high concentrations near the downstream end of the floodplain and at the Yanev Bridge located near the downstream end of the river. This clearly reflects the description and diffusion of the  $^{90}\text{Sr}$  from the floodplain bed to the overlying floodwater, which is coming back to the river near the downstream end of the study area.  $^{90}\text{Sr}$  levels at 36 hours reached their steady state concentrations, as will be shown in later figures. The concentration level predicted is very close to those measured during the 1991 winter flooding, showing  $^{90}\text{Sr}$  concentration reaching over 250 pCi/L in river water near the Yanev Bridge. This confirms the adequacy of the modeling.

Since the winter flooding exceeded the new local drinking water standard of  $^{90}\text{Sr}$  (which is set to be 100 pCi/L), the Ukrainian government built an earthen dike along the river in the floodplain as a remediation measure. We simulated this case by installing the earthen dike in our Pripyat River/floodplain model. The new grid is shown in Fig. 8. Corresponding hydrodynamic results for this case are shown in Figs. 9-11 for predicted water surface elevation (ft), water depth (m), and velocity

distribution, clearly depicting restricted river flow mostly in the river portion. With the  $^{90}\text{Sr}$  bed distributions shown in Fig. 12, FETRA then predicted  $^{90}\text{Sr}$  concentrations with the dike installed. These results are shown in Figs. 13 and 14 at 12 and 36 hours after the flooding. The benefit of the dike to reduce the  $^{90}\text{Sr}$  concentrations are clearly shown in Fig. 15, depicting predicted  $^{90}\text{Sr}$  concentrations in the Pripyat River at Yanev Bridge. This figure also shows that the steady state  $^{90}\text{Sr}$  concentrations were reached within 36 hours of the flooding. The model predicted that without the dike, expected  $^{90}\text{Sr}$  concentration there would be about 280 pCi/L. This level matched very well with the measured level of 270-300 pCi/L. With the dike, this concentration is almost reduced to half, having been recently measured. With the dike installed, however, the model predicts that the drinking water limit would still be exceeded under the four-year flood event.

We will submit these FETRA results to IAEA for BIOMOVs (an International Study to Test Models Designed to Predict the Environmental Transfer and Bioaccumulation of Radionuclides and Other Trace Substances) Program for model comparisons with data as well as among various models. The BIOMOVs meeting will be held at IAEA in Vienna on October 24-28, 1994.

### III. Significant Problems/Issues/Concerns

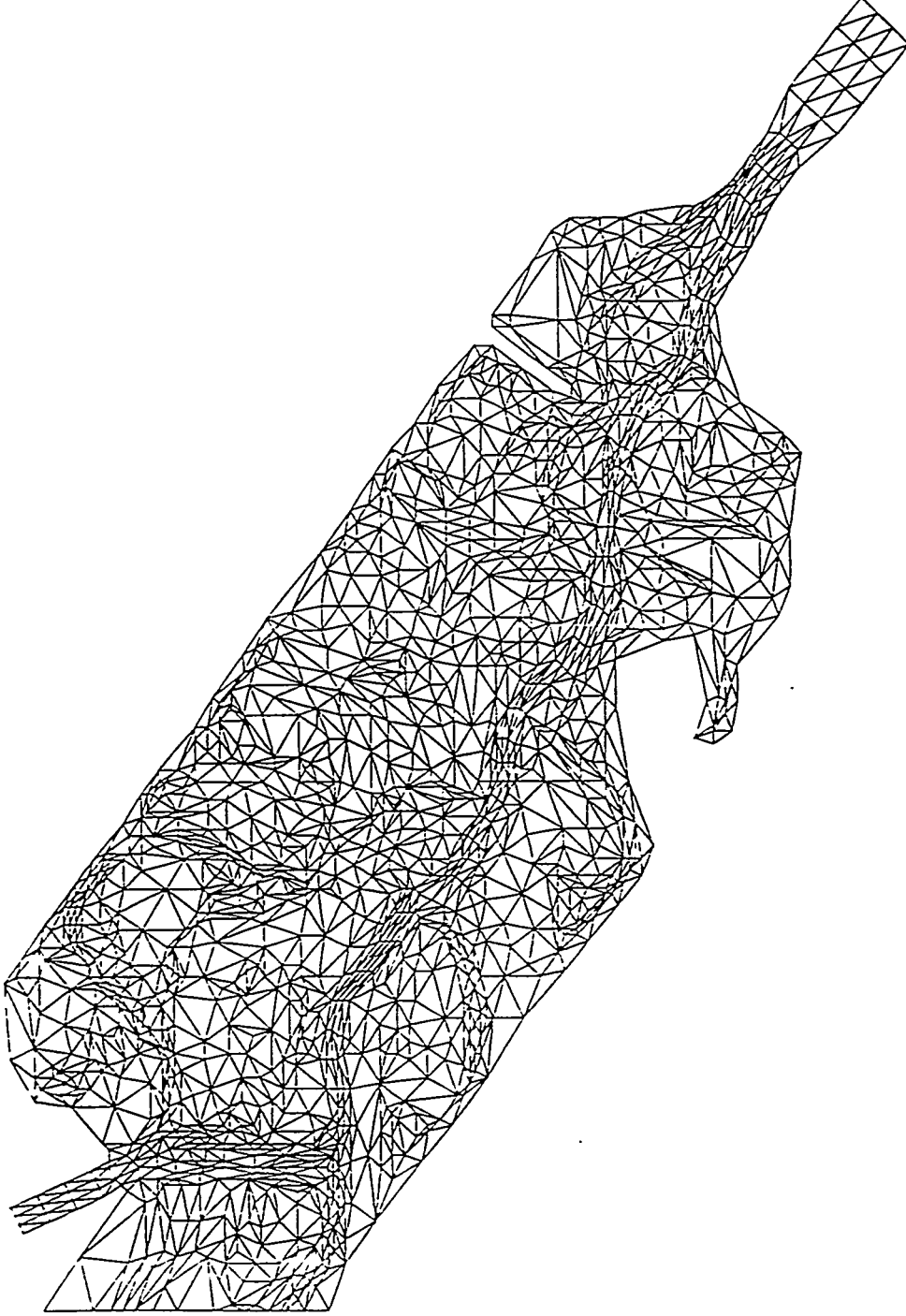
No new issue.

### IV. Assistance Required of EH-40 Staff

No new request.

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MAY 31 1994  
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ELEMENTS  
TYPE NUM

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XF =18077  
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ZF =341.225



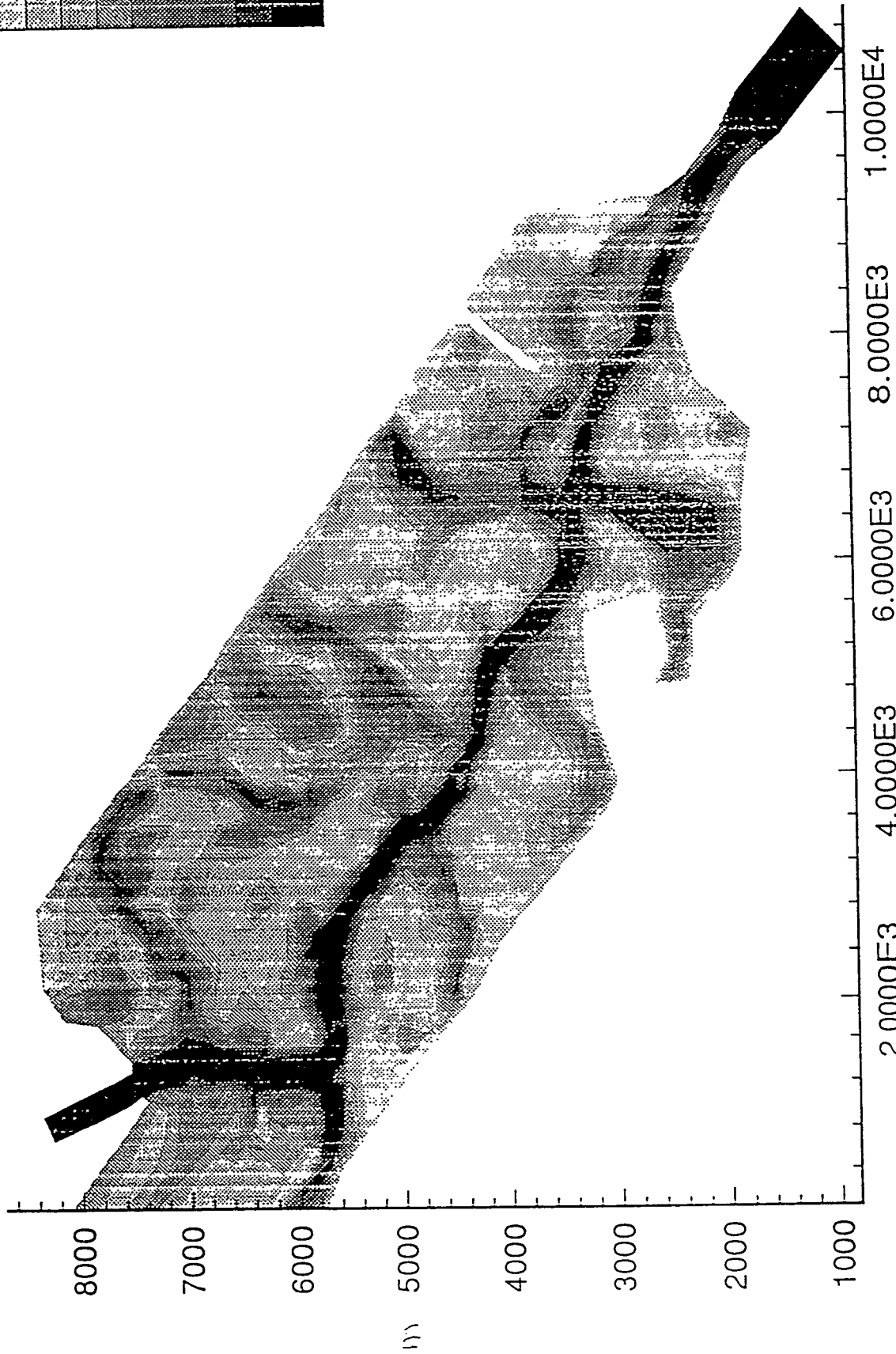
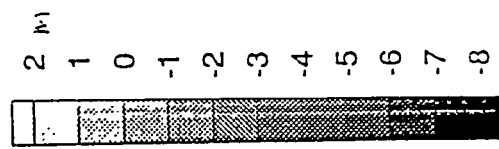
Y  
X

Fig 1. Computational  
mesh without  
on Eirhorn  
Dike along the  
River



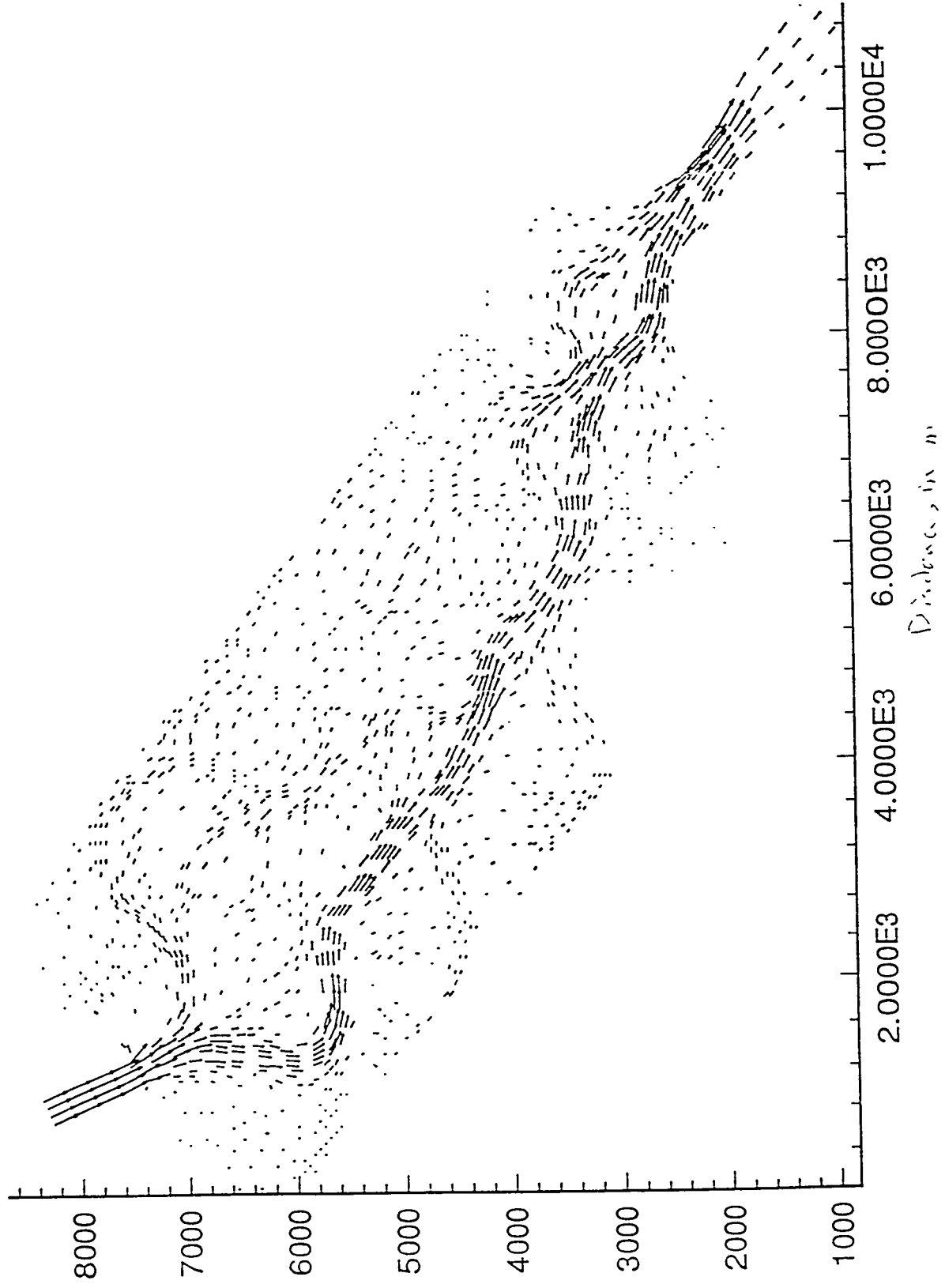
Distance, ft

Plot of water elevation (ft) vs. distance (ft)

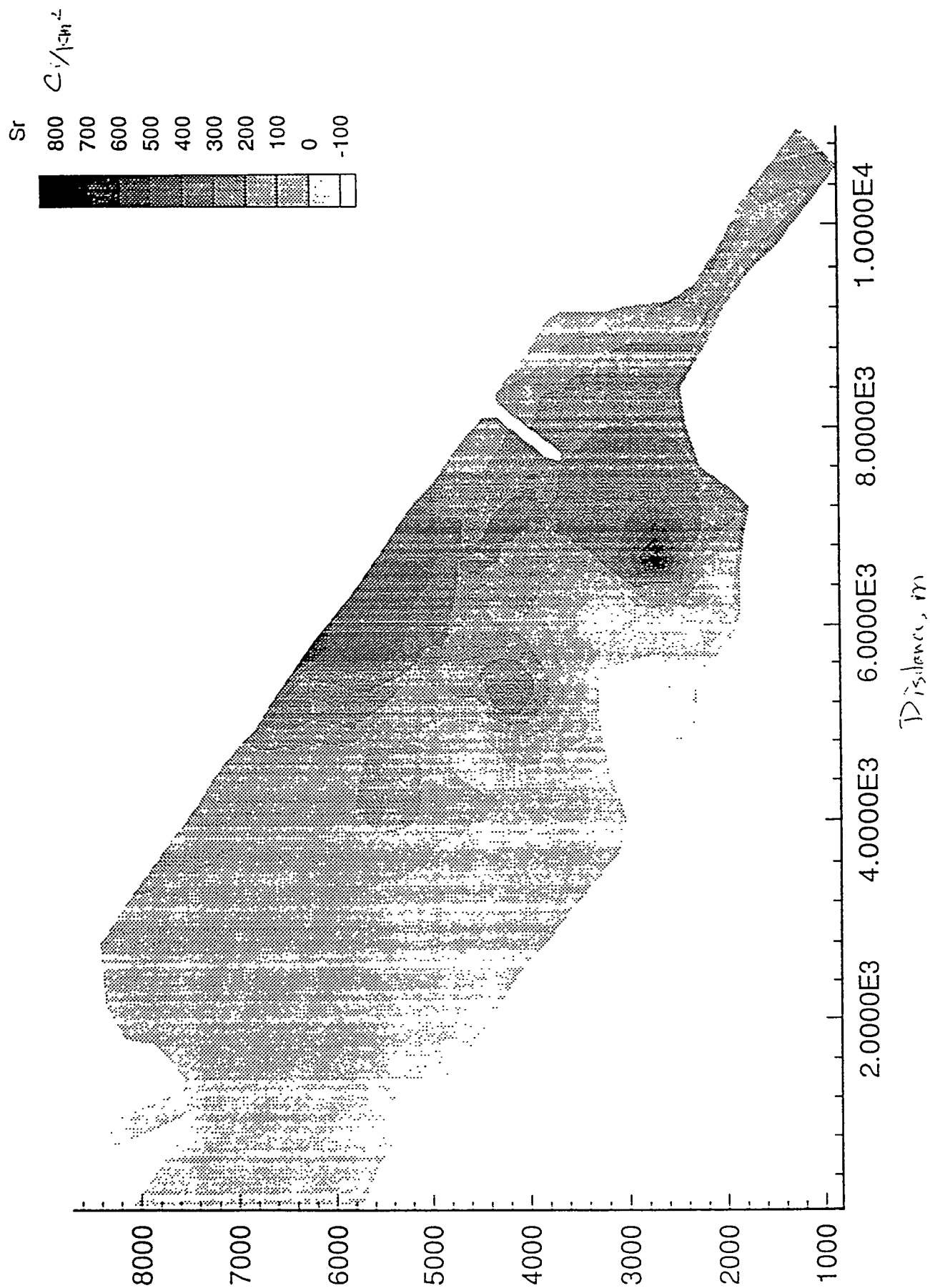


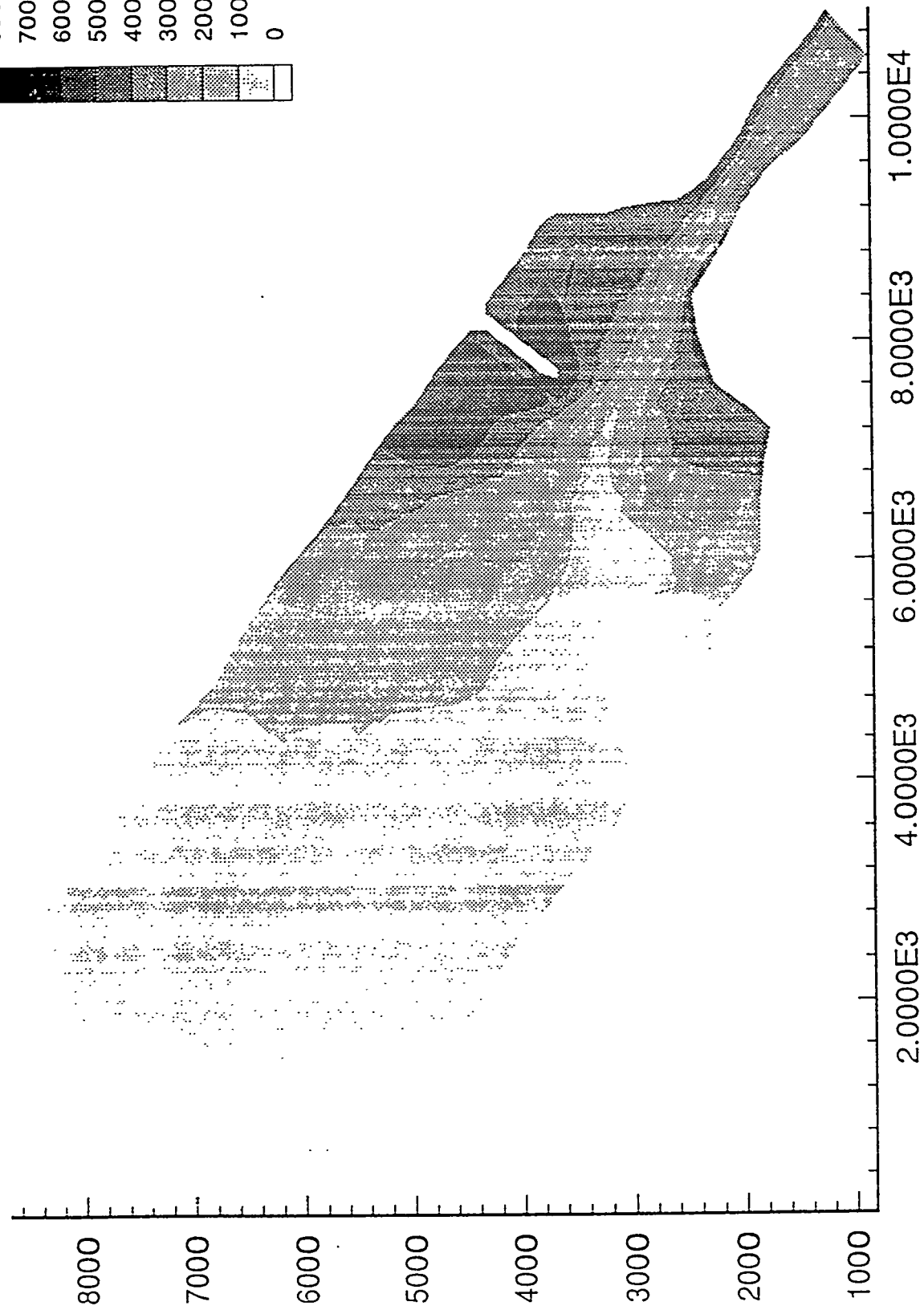
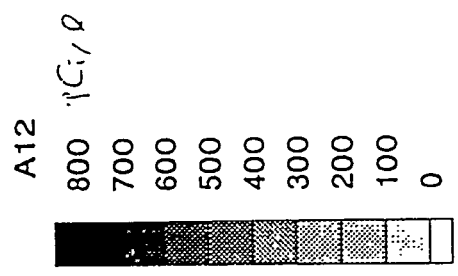
Distance, m

For 7000000

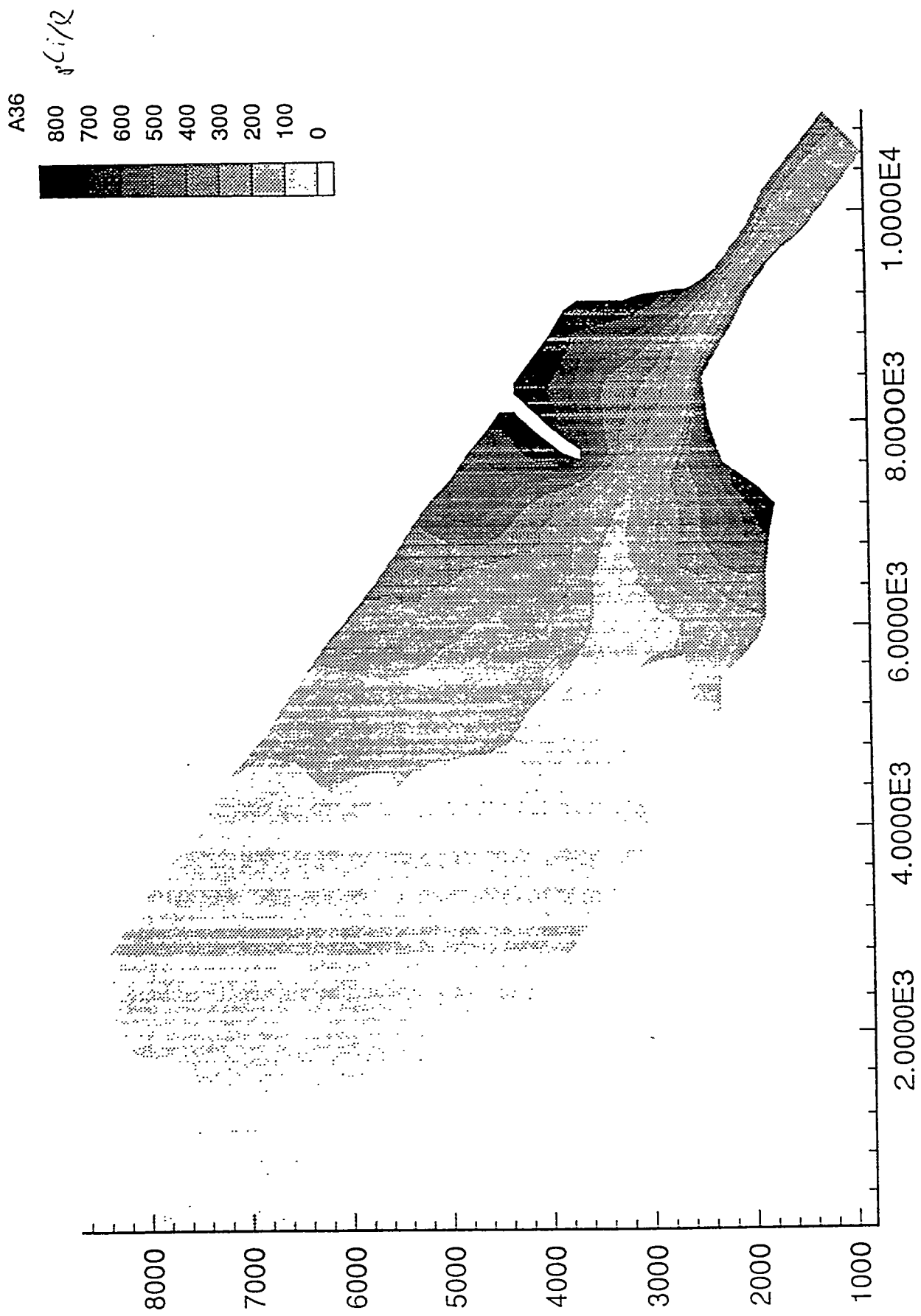


For a Belarus River Velocity in Distribution

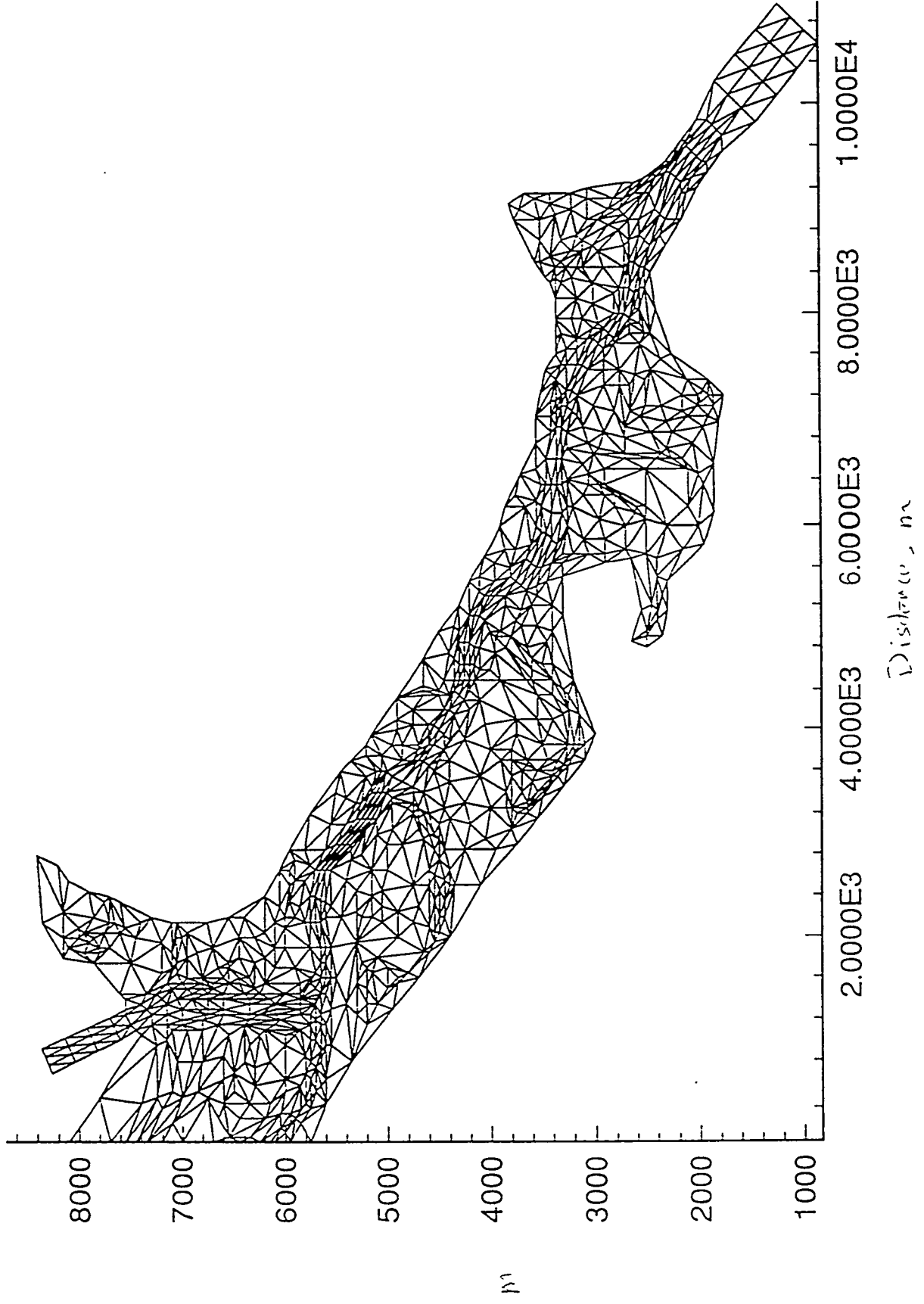




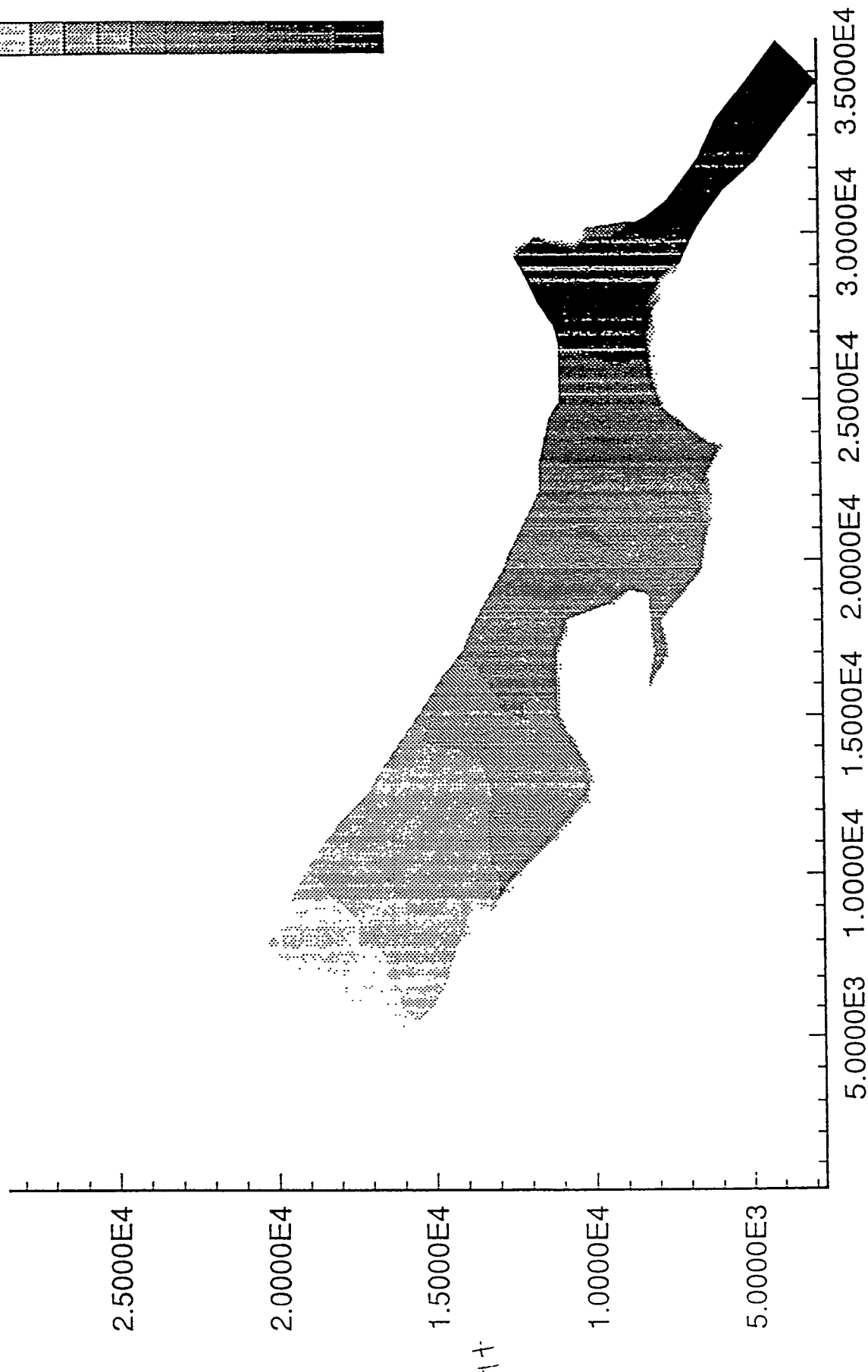
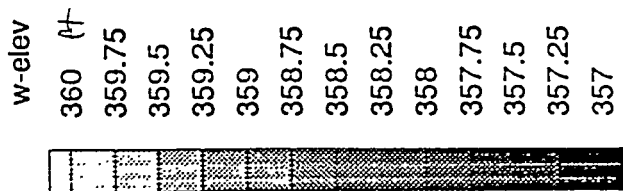
Printed on 10 Oct 1994 at 12:12



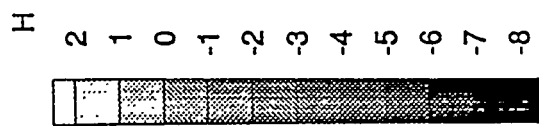
Distributed  $\mu\text{Ci}/\text{Q}$  Concentration in Water After 36 hours



4 - Computational Mesh with the Eastern Pike

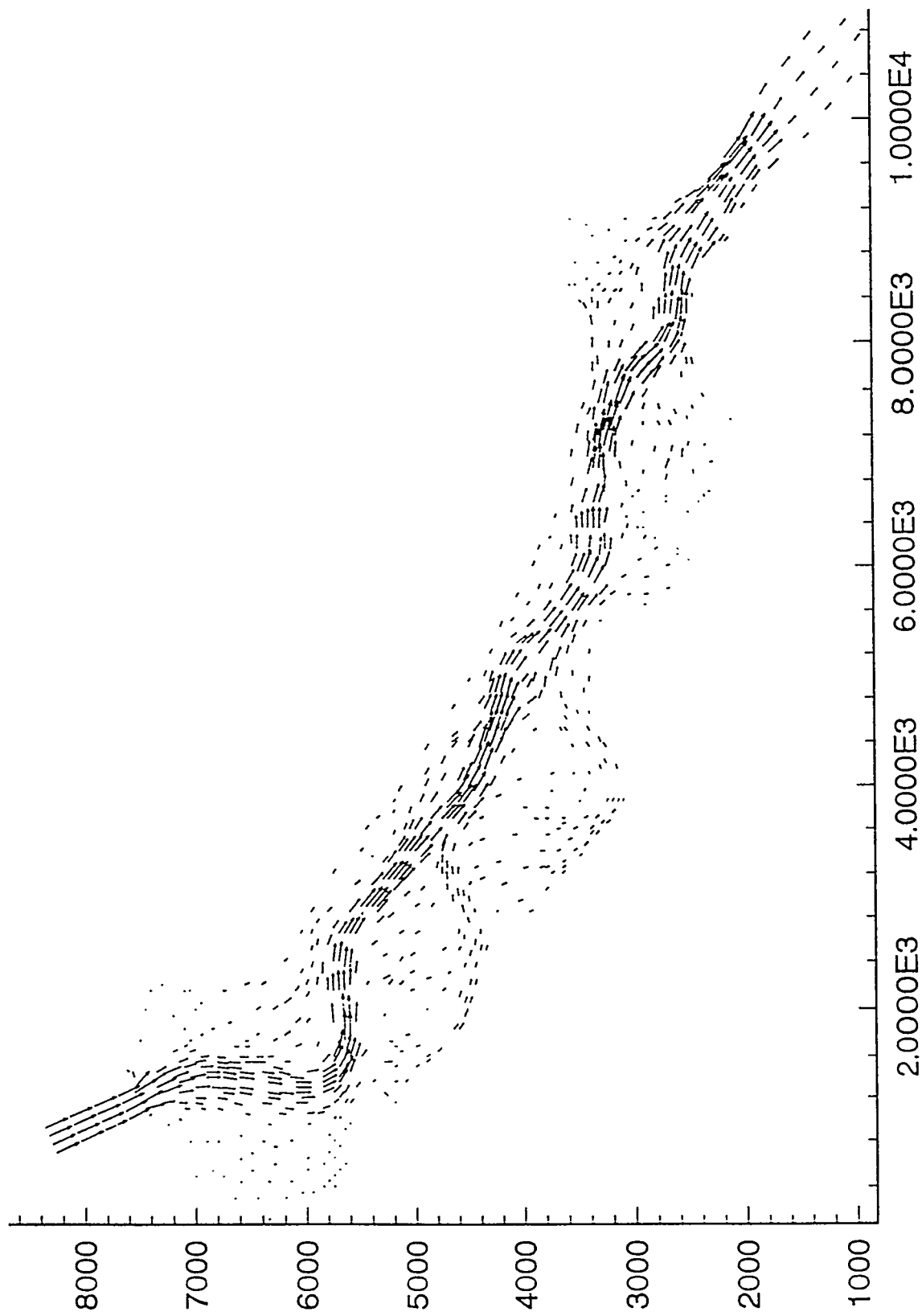


fp509.plt

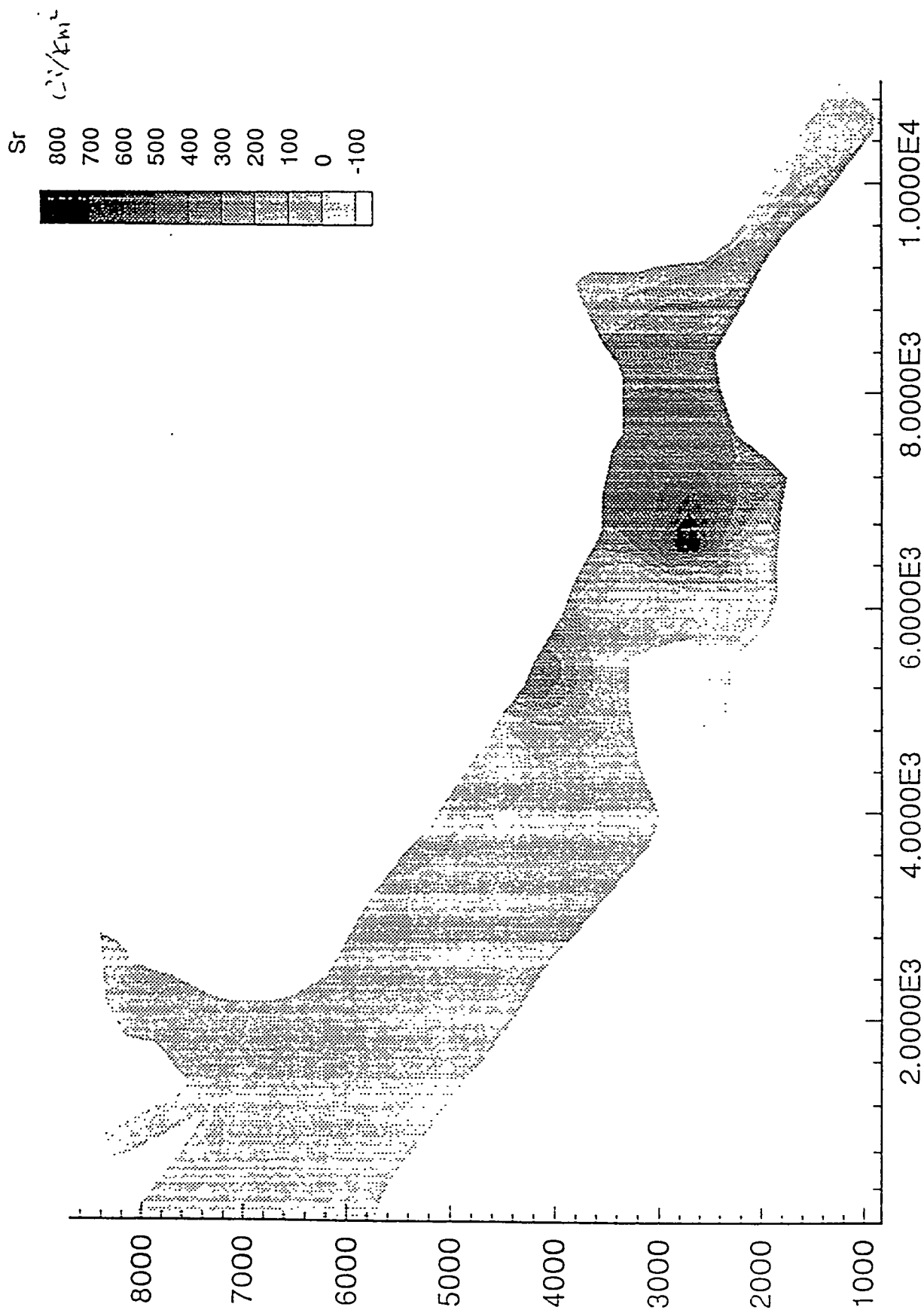


Distance, m

in "Predictor" = correlation with the Carbon Dioxide



File # 11-1649 Filed 11/14/16 Page 1 of 1



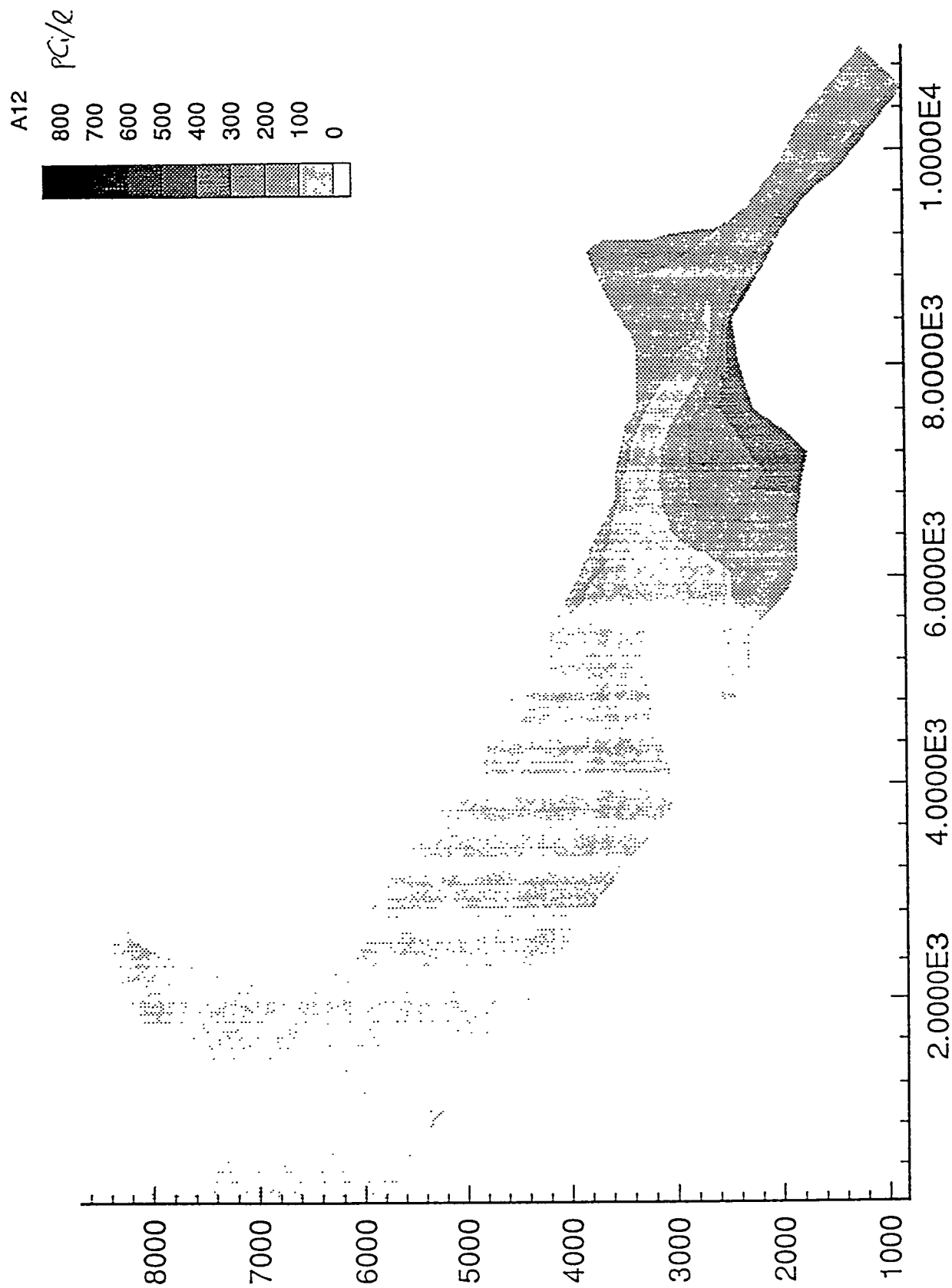


FIG 17 Predicted  $^{90}\text{Sr}$  Concentration in Water After 12 Years

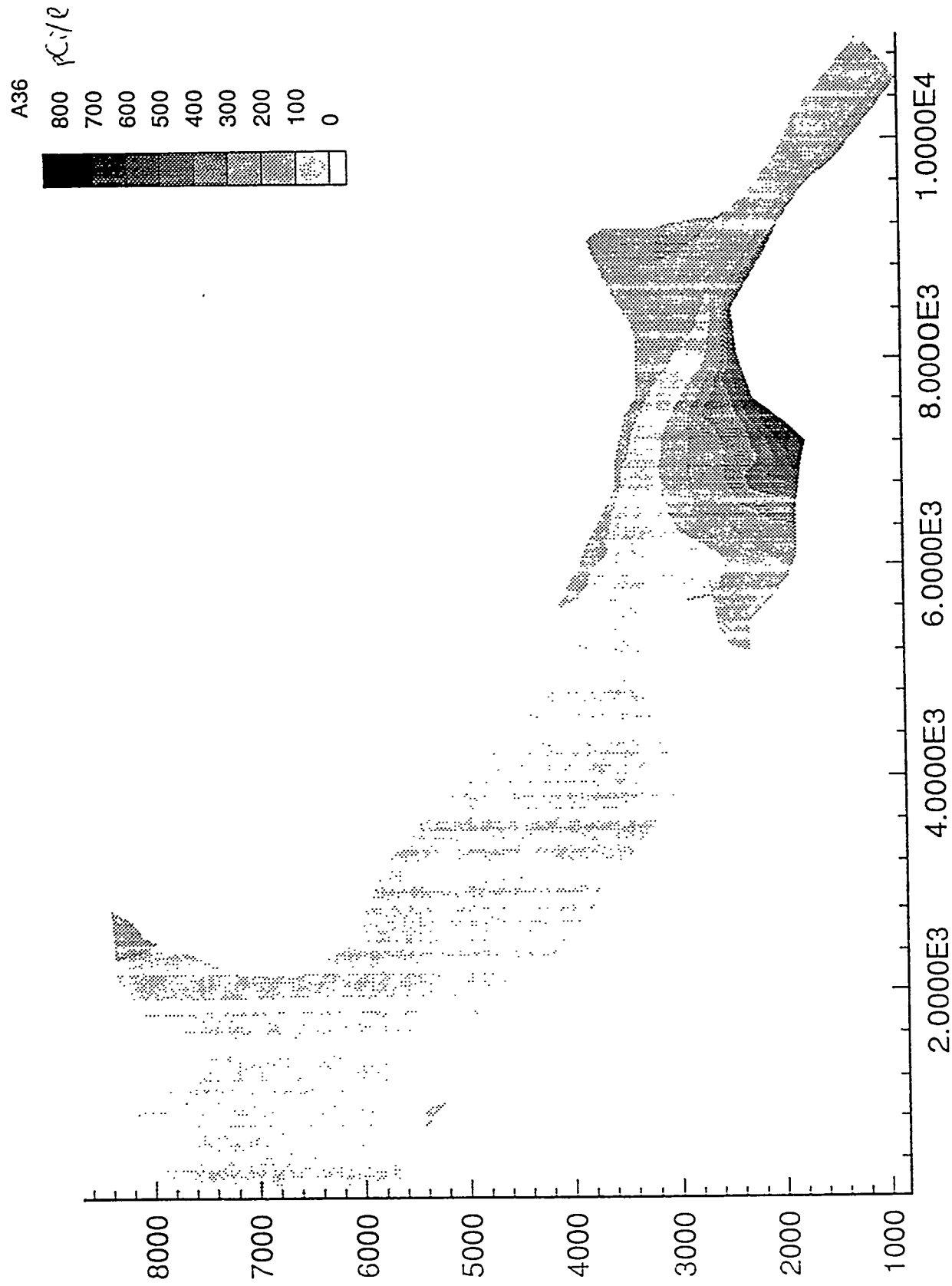
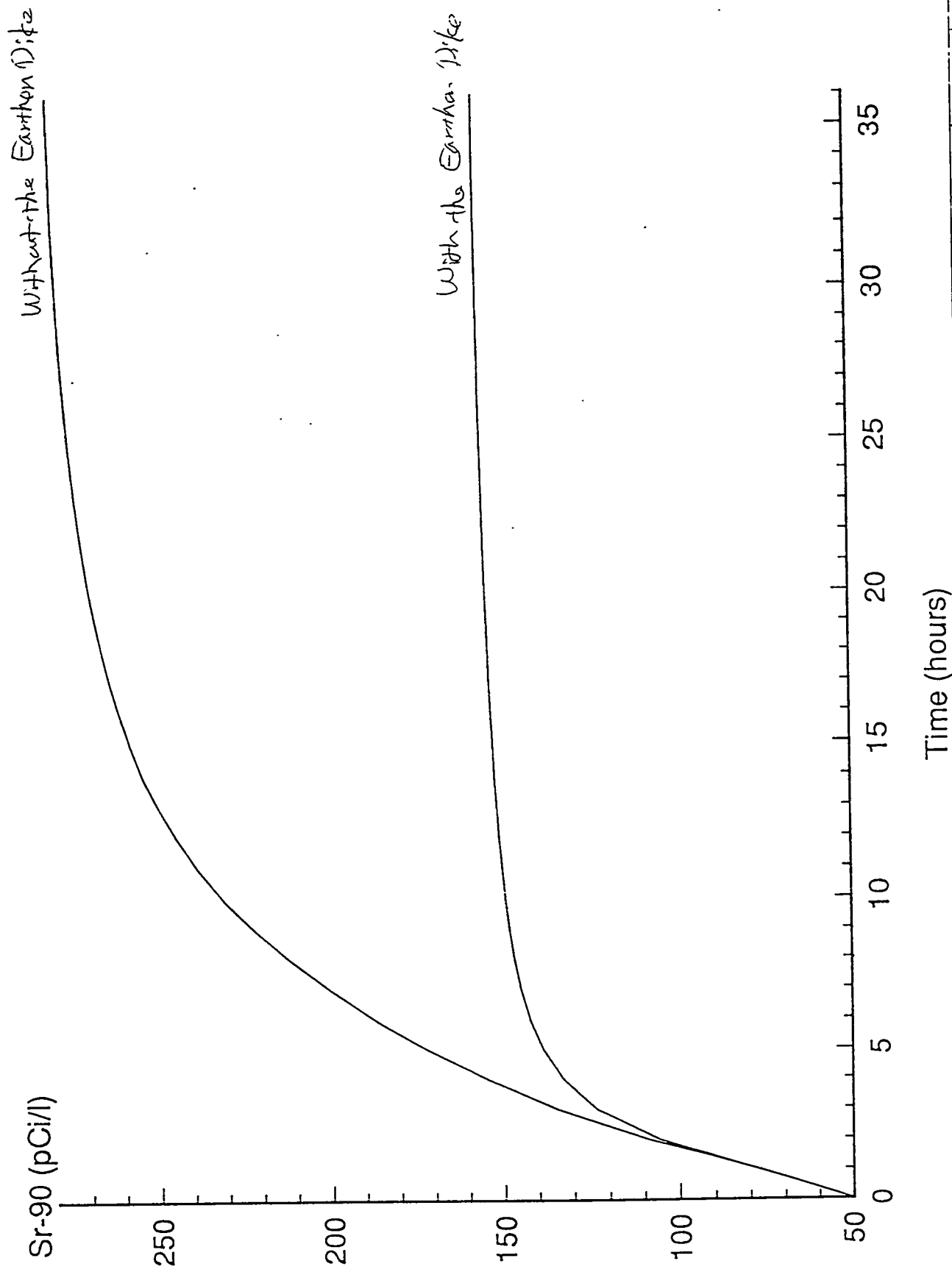


FIG 10 Dosed, del 987, Cernobyl, Kevlar in Water After 10 Hr



	<u>Time (hours)</u>
t = 0, 15'	Prodicarbazine abs Concentration Building up in water at the " " " " " " " " " "

## 7.2A4 – CHROMOSOME PAINTING DOSIMETRY

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
(1,000 Dollars)

**Project:** 7.2A4 Chromosome Painting Dosimetry (Tore Straume / Joe Lucas) LLNL No: 6288-09  
DOE No: 94-ES-1031

Cost Item	Months												Year-to-Date
	1993			1994									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits					4.8	1.2	2.8	5.7	11.0	13.4	4.7	3.4	47.0
Travel					0.6	0.5	0.3	3.0	10.5	-2.6	-1.2	0.8	11.9
Procurement and Expenses*					0.0	0.3	0.1	0.0	0.7	2.2	1.1	0.9	5.3
Technical Information Department					0.0	0.2	0.5	0.0	0.2	0.0	0.2	0.0	1.1
Facility/Service/Distributed Charges					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LLNL Overhead+ /Taxes**					2.7	0.7	5.6	3.6	7.0	23.8	0.7	2.3	46.4
TOTAL					8.1	2.9	9.3	12.3	29.4	36.8	5.5	7.4	111.7
Liens/Preliens													
Budget					100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Funds Available					91.9	89.0	79.7	67.4	38.0	1.2	-4.3	-11.7	
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts													
** General & Administrative (G&A)													
+ LDRD; Division and Directorate Burdens, etc.													

## EH-40 Monthly Report

March 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031      **LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

### I. Project Objective

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

### II. Current Project Status/Monthly Progress

Funding received in January 1994 Financial Plan and released for spending in late February 1994.

During March we continued to score translocations in blood lymphocytes from a Ukrainian who was exposed to a known dose in connection with the Chernobyl accident. By the end of March, we had scored 5049 metaphases with 27 translocations. This reduces the uncertainties in the counting statistics so that the SD is less than 20% of the mean. Next month we will begin the analysis of these results, which includes comparing them to the physical dose actually measured for this individual.

### III. Significant Problems/Issues/Concerns

N/A.

### IV. Assistance Required of EH-40 Staff

N/A.

# EH-40 Monthly Report

April 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

---

*Address each item, if applicable.*

**I. Project Objective**

**II. Current Project Status / Monthly Progress**

Administrative (meetings organized).

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

Travel. Include copy of foreign trip report.

**III. Significant Problems/Issues/Concerns**

Substantial changes in project expectations, protocol, funding.

Problems occurring or anticipated (corrective actions).

**IV. Assistance Required of EH-40 Staff**

Identify EH-40 staff member(s) with each requests.

**I. Project Objective**

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

**II. Current Project Status / Monthly Progress**

During April, we completed biodosimetric measurements on the first individual to be evaluated from the Ukraine using chromosome painting in our laboratory. This individual was evaluated previously by others using electron paramagnetic resonance (EPR) in tooth enamel which resulted in a dose-estimate of  $0.3 \pm 0.1$  Gy. Our biodosimetry, which used chromosome painting of blood lymphocytes, resulted in  $0.33 \pm 0.12$  Gy. The agreement between the two independent biodosimeters is excellent. Additional Chernobyl cases that can be used to validate dosimetry models and other biodosimetry methods will be identified and evaluated.

Also during April, Dr. Straume and Dr. Lucas attended the Workshop on the Development and Applications of Biomarkers in Santa Fe, New Mexico. This was a workshop organized and sponsored by DOE/EH under the direction of Dr. Tara O'Toole, Assistant Secretary of Energy. The presentation by Straume and Lucas was entitled Validation Studies Using Molecular Cytogenetics for Monitoring of Workers. An extended abstract was published in a DOE report (DOE-EH-0377T, April 1994). Also in connection with the Santa Fe meeting, a full paper on biodosimetry was prepared for publication as a chapter in a book to be published in October 1994 by the National Academy Press. Copies of the extended abstract and the full paper are enclosed.

**III. Significant Problems/Issues/Concerns**

N/A.

**IV. Assistance Required of EH-40 Staff**

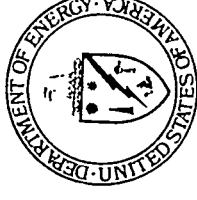
N/A.

**THE DEVELOPMENT AND APPLICATIONS OF  
BIOMARKERS**

SELECTED ABSTRACTS

EDITED BY

Janet Normandy, Ph.D. and John Peeters, Ph.D.



APRIL 15, 1994

U.S. DEPARTMENT OF ENERGY

OFFICE OF ENVIRONMENT, SAFETY AND HEALTH  
OFFICE OF OCCUPATIONAL MEDICINE

WASHINGTON, D.C. 20585

# VALIDATION STUDIES USING MOLECULAR CYTOGENETICS FOR MONITORING OF WORKERS

Tore Straume and Joe N. Lucas  
Lawrence Livermore National Laboratory  
Livermore, California 94550

## ABSTRACT

The Health & Ecological Assessment Division of the Lawrence Livermore National Laboratory (LLNL) has a biological dosimetry program that focuses on the transition between basic research in biotechnology and useful applications to exposure and risk assessment. An example is our validation and calibration of the "chromosome painting" technology developed at LLNL for use in the assessment of radiation- and chemically-exposed individuals. Chromosome painting employs fluorescence *in situ* hybridization (FISH) to rapidly and accurately detect chromosome abnormalities such as reciprocal translocations in human cells. Our studies include measurement of several key parameters that define the utility of chromosome painting, e.g., the stability of translocations with time after exposure, dose-response relationships, interindividual differences, and background frequencies. The following is a partial list of accomplishments using FISH:

- o Demonstration that full genomic translocation frequencies can be accurately obtained after painting only a small fraction of the genome (1). This finding was of critical importance as it permitted scaling to full genome from only a few painted chromosomes.
- o Dose reconstruction for a DOE radiation worker exposed occupationally during the 1950's, 1960's, and early 1970's. His exposure was always within the dose limits of 0.05 Sv per year. The best-estimate dose obtained biologically was 0.7 Sv, in agreement with the total integrated value of 0.6 Sv recorded in his official dosimetry records (2). That study also helped to prioritize key uncertainties.
- o Dose reconstruction for a worker in Switzerland who accidentally inhaled tritium oxide in 1986. Biodosimetry results in 1992 (six years after exposure) were identical to the dosimetry results obtained immediately after the accident from urinalysis and dicentric (3).
- o Dose reconstruction in 1993 for five monkeys exposed to 2.3 GeV protons by NASA in the early 1960's. The biodosimetric doses were in good agreement with the doses actually delivered in 1963. Because 30 years in the life of these primates is equivalent to about 90 years in humans, these measurements indicate lifetime persistence of the reciprocal translocation

- o Dose reconstruction for a Ukrainian scientist exposed to  $^{137}\text{Cs}$  in connection with the Chernobyl accident in 1986. Our biodosimetry in 1993 resulted in a dose of 0.33 Sv, which is essentially identical to his dose estimate of 0.32 Sv from physical measurements.
  - o Development of standard dose-response curves for reciprocal translocations using radiations, doses, and dose rates most relevant for dose reconstruction and monitoring of radiation workers. Such curves are obtained using human lymphocytes exposed *in vitro* and are required to translate the translocation frequency measured in an individual into dose and risk. A key aim is to quantify and reduce uncertainties.
  - o Evaluation of benzene workers using chromosome painting. This work is in support of an epidemiology study conducted by NCI. Although only preliminary results are currently available, damage involving certain chromosomes appears to be over-represented and will be further explored as possible markers of exposure to benzene.
  - o Measurement of translocation frequencies in unexposed individuals. The limited results thus far suggest a background frequency in adults of about  $0.006 \pm 0.002$  reciprocal translocations per lymphocyte. Also, we have developed a method that appears to facilitate pre-cancer biodosimetry in patients with diagnosed leukemia - this method prevents the common problem of contamination of the study sample by cancer-induced aberrations.
  - o These and related studies should provide the information and tools necessary to translate a measured translocation frequency into a meaningful estimate of exposure, dose, and risk. It is noteworthy that similar studies would be required before any biomarker can in fact be used reliably in exposure assessment.
- ## References:
- 1 Lucas, J.N., Awa, A., Straume, T., Poggensee, M., Kodama, Y., Nakano, M., Ohtaki, K., Weier, U., Pinkel, D., Gray, J., and Littlefield, G., 1992. Rapid translocation frequency analysis in humans decades after exposure to ionizing radiation. *Int. J. Radiat. Biol.* 62:53-63.
  - 2 Straume, T., Lucas, J.N., Tucker, J.D., Bigbee, W.L., and Langlois, R.G. 1992. Biodosimetry for a radiation worker using multiple assays. *Health Phys.* 62:122-130.
  - 3 Lucas, J.N., Poggensee, M., Straume, T. 1992. The persistence of chromosome translocations in a radiation worker accidentally exposed to tritium. *Cytogenet. Cell Genet.* 60:255-256.
- "Work performed under the auspices of the  
U.S. Department of Energy by the Lawrence  
Livermore Laboratory under contract number  
W-7405-ENG-48."

## Validation Studies for Monitoring of Workers Using Molecular Cytogenetics

Tore Straume  
Joe Lucas

This paper was prepared for submittal to  
*National Academy Press*

August 1994

Lawrence  
Livermore  
National  
Laboratory

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

## **Validation Studies for Monitoring of Workers Using Molecular Cytogenetics**

Tore Straume and Joe N. Lucas, Health & Ecological Assessment Division,  
Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550.

### **Abstract**

Recent developments in molecular cytogenetics provide an opportunity for individual monitoring and dose reconstruction using the frequency of stable reciprocal translocations in human cells. Prior to the development of "chromosome painting" (a molecular cytogenetics approach based on fluorescence *in situ* hybridization), the detection of reciprocal translocations was much too labor intensive for applications in biological dosimetry. Here, we present results from our validation and calibration studies demonstrating that chromosome painting can be used to reconstruct radiation dose for workers exposed within the DOE dose limits, for individuals exposed a long time ago, and even for those who have been diagnosed with leukemia. Efforts to further reduce uncertainties in biodosimetric estimates are underway. In addition to radiation biodosimetry, molecular cytogenetics may also have promise for chemical clastogens.

### **Introduction**

There is a need for reliable methods to assess past clastogenic exposures. This is particularly the case for a large number of workers who may have received upper-level exposures, but for whom the real-time monitoring data are unreliable or not available. For example, a substantial number of DOE radiation workers were exposed to neutrons during the 1940's, 50's, and 60's when neutron dosimetry was in its infancy. Also, a large number of individuals have received substantial radiation exposures in connection with accidents, nuclear weapons testing, human experimentation, the atom bombs dropped on Hiroshima and Nagasaki, and various medical radiological procedures. In addition to radiation, reliable methods are also needed to help assess exposures to hazardous chemicals and other agents.

Several biological markers developed to evaluate persons with known or suspected exposures to hazardous agents are listed in Table 1. These include a variety of cytogenetic effects (Lucas et al. 1992a; Littlefield et al. 1990, 1992; Krepinsky and Heddle 1983), somatic mutations (Langlois et al. 1987; Akiyama et al. 1992), and adducts (Turteltaub et al. 1993). It is noted that useful attributes, such as the

## Validation Studies for Monitoring of Workers Using Molecular Cytogenetics

Tore Straume and Joe N. Lucas

Methods to assess past clastogenic exposures are needed particularly to monitor workers who may have received substantial exposures, but for whom real-time monitoring data are either unreliable or not available. For example, many Department of Energy (DOE) radiation workers were exposed to neutrons during the 1940's through the 1960's when neutron dosimetry was in its infancy. Also, many individuals have received substantial radiation exposures in connection with accidents, nuclear weapons testing, human experimentation, the atom bombs dropped on Hiroshima and Nagasaki, and various medical radiological procedures. Reliable methods are also needed to help assess exposures to hazardous chemicals and other agents.

A number of biological markers developed to evaluate persons with known or suspected exposures to hazardous agents are available and listed in Table 1. These include markers of cytogenetic effects (Lucas et al., 1992a; Littlefield et al., 1990, 1992; Krepinsky and Heddle, 1983), somatic mutations (Albertini et al., 1982; Langlois et al., 1987; Mendelsohn, 1990; Straume et al., 1991; Akiyama et al., 1992), and adducts (Rothman et al., 1990; Turteltaub et al., 1993). It is noted that useful attributes, such as the applicability of the marker to all individuals in a population, availability of *in vitro* and experimental animal model systems, variability between individuals, stability with time post-exposure, and availability of supporting data, vary considerably among the assays. For example, GPA and HLA are applicable to only 50% of the population, and several other assays have not been sufficiently characterized to provide a reasonable estimate of their inter-individual variability.

A particularly important parameter for monitoring of workers and for use in dose reconstruction is the stability of the assay with time post-exposure. Two of the biomarkers (translocations and GPA) appear to exhibit lifetime persistence and, thus, could potentially be used to help reconstruct exposures that may have occurred many years or even decades previously. However, of these two biomarkers, only for translo-

cations are there *in vitro* and animal models for use in dose-response characterization.

TABLE 1. A COMPARISON OF USEFUL ATTRIBUTES OF  
SELECTED BIOMARKERS

Biomarker	Human <i>in vivo</i>	Human <i>in vitro</i>	Animal model	Inter-person variation <sup>a</sup>	Applicable time post-exposure <sup>a</sup>
Translocations <sup>b</sup>	yes	yes	yes	low	0-lifetime
Dicentrics	yes	yes	yes	low	0-6 mo
Micronuclei	yes	yes	yes	high	0-6 mo
HPRT <sup>c</sup>	yes	yes	yes	medium	1 mo-1 yr
GPA <sup>d</sup>	50%	no	no	high	6 mo-lifetime?
TCR <sup>e</sup>	yes	no	no	high	1 mo-2 yr
HLA <sup>f</sup>	50%	yes	no	?	1 mo-1 yr
SCEs	yes	yes	yes	?	0-6 mo
DNA adducts	yes	yes	yes	?	0-6 mo
Protein adducts	yes	yes	yes	?	0-6 mo

<sup>a</sup> Estimates based on studies cited in the text and evaluation by the authors.

<sup>b</sup> Reciprocal chromosome translocations.

<sup>c</sup> Hypoxanthine phosphoribosyltransferase assay.

<sup>d</sup> Glycophorin-A somatic mutation assay.

<sup>e</sup> T-cell antigen receptor mutation assay.

<sup>f</sup> Human leukocyte antigen mutation assay.

As recently as three years ago, it was doubtful whether any biomarker would be useful in the determination of radiation doses for workers exposed a long time ago or for those who received protracted low-level

# EH-40 Monthly Report

May 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

## II. Current Project Status / Monthly Progress

During May, Dr. Liktarov and colleagues in Kiev identified 10 liquidators for whom chromosome painting biodosimetry would be particularly helpful. These individuals were selected because their doses had been measured previously using electron spin resonance methods. Blood samples were obtained some time ago from the ten liquidators in Kiev and metaphase spreads made on glass slides. The glass slides were stored in Kiev until they were transported to Livermore during the last part of May for chromosome painting analysis. Because the slides were prepared sometime ago, a new FISH protocol had to be developed to achieve proper hybridization. After chemically pretreating the slides with proteolytic enzyme we were able to achieve good hybridization staining.

## III. Significant Problems/Issues/Concerns

N/A.

## IV. Assistance Required of EH-40 Staff

N/A.

# EH-40 Monthly Report

June 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

---

*Address each item, if applicable.*

**I. Project Objective**

**II. Current Project Status / Monthly Progress**

Administrative (meetings organized).

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

Travel. Include copy of foreign trip report.

**III. Significant Problems/Issues/Concerns**

Substantial changes in project expectations, protocol, funding.

Problems occurring or anticipated (corrective actions).

**IV. Assistance Required of EH-40 Staff**

Identify EH-40 staff member(s) with each requests.

**I. Project Objective**

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

**II. Current Project Status / Monthly Progress**

During June, we began scoring the slides from 10 Chernobyl liquidators using the protocol that we developed in May. We completed scoring one of the ten liquidators. Because the slides are coded, we do not yet know how our biodosimetry result compares with other Dosimetry information for this individual. A letter was sent to Dr. M. Pilinskaya informing her that we were able to hybridize the slides using our new protocol developed for hybridization of old slides.

Also during June, Dr. Straume attended the Workshop on Dose Reconstruction in Bad Honnef, Germany. This was a workshop organized to update and evaluate world-wide dosimetry efforts in connection with Chernobyl. Dr. Straume presented and discussed the biodosimetry efforts that are underway using chromosome painting. Immediately following the Bad Honnef meeting, Dr. Straume visited GSF in Munich where he discussed possible chromosome painting intercomparison measurements with Dr. Bauchinger. These discussions included (1) intercalibration of chromosome painting labs and (2) development of chromosome painting biodosimetry capability for thyroid cells. The agenda for the Workshop on Dose Reconstruction and Dr. Straume's foreign trip report are enclosed.

**III. Significant Problems/Issues/Concerns**

N/A.

**IV. Assistance Required of EH-40 Staff**

N/A.

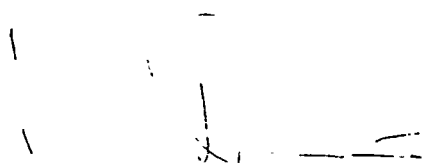
## FOREIGN TRIP REPORT

Tore Straume, Ph.D.  
Leader, Dosimetry & Dose-Response Group  
Health and Ecological Assessment Division  
Environmental Programs Directorate  
Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94551-9900  
(510) 422-5138

Contract No. W-7405-Eng-48

July 5, 1994

Approved by:

  
-----  
Jay C. Davis  
Acting Associate Director  
Environmental Programs Directorate

## Summary

### Destinations:

Bad Honnef and Munich, Germany, and Washington, DC.

### Purpose of Trip:

To participate and present three scientific papers at a multinational workshop on dose reconstruction in Bad Honnef, Germany; to discuss current and develop new scientific collaborations with GSF scientists in Munich, Germany; and to attend a meeting in Washington DC as an expert on the assessment of worker exposure to toxic agents at the invitation of the Director of the National Institute of Occupational Safety and Health (NIOSH) and the Assistant Secretary of Energy for Environment, Safety, and Health.

### Abstract:

The three scientific papers that I presented at the Workshop on Dose Reconstruction in Bad Honnef, Germany, were: Status Report on  $^{129}\text{I}$  Measurements; Dose Reconstruction from Reciprocal Translocation Frequencies Measured by FISH; and Neutron Dose Reconstruction for Hiroshima/Nagasaki: Implications for Risk Assessment for Low-LET Radiation (program enclosed).

In GSF (Munich), new collaborations were established with scientists that will include a doctoral student from GSF spending 3 months later this summer/fall at LLNL to learn our procedure on iodine measurement.

The meeting in Washington D.C. was in response to an invitation from the Director of the National Institute of Occupational Safety and Health (NIOSH) and the Assistant Secretary of Energy for Environment, Safety, and Health. It involved a small group of experts assembled to discuss how DOE can improve health and safety surveillance of workers, particularly in future clean-up activities of contaminated DOE sites. A report will be prepared by the attendees.

## Detailed Trip Report

### *Workshop on Dose Reconstruction, Bad Honnef, Germany.*

The Bad Honnef workshop focused on measurements and modeling efforts that may be used to help reconstruct doses to individuals and populations exposed to radiation released during the 1986 Chernobyl nuclear reactor accident. I made three presentations at the workshop describing dosimetry research efforts underway at LLNL.

Status Report on I-129 Measurements: Our current iodine efforts involve a feasibility study to determine if  $^{129}\text{I}$  (half life,  $1.6 \times 10^7$  y) can be used today, some eight years after the Chernobyl accident, to help reconstruct deposition patterns and thyroid doses from the short-lived  $^{131}\text{I}$  (half life, 8.05 d). Due to the very large areas contaminated by the Chernobyl accident, it was not possible to complete radiological assessments before the disappearance of  $^{131}\text{I}$ . The lack of basic data for  $^{131}\text{I}$  has presented a serious limitation to dose reconstruction for thyroid because this isotope produced more than 90% of the thyroid dose. The DOE mission includes support for post-Chernobyl evaluations, including dosimetry and epidemiology—per agreement between FSU states and the US.

This is a particularly important project as Belarus health authorities report dramatic increases in childhood-thyroid cancer in regions where cesium contamination levels are low. Similar reports are coming from the Ukraine and underscore the need for iodine deposition measurements.

The following information was presented at Bad Honnef:

- We have completed a soil sampling expedition to Belarus and obtained 220 cores from selected settlements. The soil samples were initially processed in Minsk and are now being transported to LLNL for analysis of total iodine and  $^{129}\text{I}$ .
- We have obtained archived soil samples from both Belarus and the Ukraine that were collected shortly after the Chernobyl accident in May-July, 1986. Measurements were made of  $^{131}\text{I}$  at the time of sampling. These and other archived samples are now providing  $^{131}\text{I}/^{129}\text{I}$  ratios in the deposited material. These ratios must be approximately constant for this approach to be useful.

- We have developed a simple and reliable method to determine total iodine in soil samples. This method (which involves new technology) has been disclosed to our patent office and a manuscript has been drafted for publication. We are also working with NIST to use this method to develop soil standards for iodine (note that NIST standards for iodine in soil do not exist because of the inadequacy of available analytical methods).

#### Dose Reconstruction from Reciprocal Translocation Frequencies Measured by FISH:

The development of a new method (chromosome painting) at LLNL to detect genetic damage in human cells have substantially reduced the uncertainties of several key parameters used in biological dosimetry. Of particular significance are the measurements made of the persistence of the reciprocal translocation frequency with time after exposure, the dose-response curve for reciprocal translocations at low doses, and the background frequency for reciprocal translocations in "unexposed" individuals. The following is a summary of our chromosome painting results presented at Bad Honnef:

- We evaluated a worker in Switzerland who accidentally inhaled tritium oxide in 1986 (Lucas, Poggensee, and Straume 1992). The accident victim was a healthy 33-year-old woman who incorporated about 35 GBq of tritiated water. Dose was determined within a few weeks after the accident using both urinalysis and biodosimetry (Lloyd et al., 1986). Biodosimetry involved measurement of the dicentric frequency in blood lymphocytes. Dosimetry results indicated that the woman had received about 0.4 Gy of absorbed radiation dose to the soft tissues of the body (Lloyd et al., 1986). Our biodosimetry results in 1992 (six years after exposure) were identical to the dosimetry results obtained immediately after the accident from urinalysis and dicentrics. These results show that the net frequency of reciprocal translocations measured 6 years after exposure was the same as the net frequency of dicentrics measured immediately after the accident. Because dicentrics and translocations are induced with the same frequency, these results demonstrate that the translocation frequency for this individual has remained unchanged since exposure six years previously. This result was the first clear demonstration that the translocation frequency measured in human blood T-lymphocytes remained identical to its induction frequency for many years after exposure, even though about 70% of the blood T-lymphocytes had been repopulated from stem cells.

- A DOE radiation worker exposed occupationally during the 1950's, 1960's, and early 1970s was evaluated. His whole-body penetrating exposure was always within the dose limits of 0.05 Sv per year. In 1989, the best-estimate dose obtained biodosimetrically was  $0.5 \pm 0.2$  Sv, in good agreement with the total integrated dose recorded in his official dosimetry record from badge readings of  $0.56 \pm 0.20$  Sv. In addition to translocations, we also used three other biomarkers to evaluate this individual—GPA, dicentrics, and micronuclei (Straume et al. 1992). GPA mutation frequencies, which have been shown to be persistent (Langlois et al. 1987), were also significantly elevated. However, dicentrics and micronuclei were not elevated above background levels as expected from their instability and the exposure pattern of this DOE worker (Straume et al. 1992). Although this is only one individual, these results suggested that stable biomarkers could be detected in workers exposed within the DOE dose limits.

- In 1993 we evaluated five monkeys exposed to 2.3 GeV protons by NASA in the early 1960's (Lucas et al. 1994). The biodosimetric doses were in good agreement with the doses actually delivered in 1963. Because 30 years in these primates is equivalent to about 90 years in humans, these measurements indicate lifetime persistence of the reciprocal translocation frequency in stem cells of blood lymphocytes. Also, these results show very little, if any, inter-individual variation in both response and stability.

- Dose was also reconstructed for a Ukrainian scientist exposed to  $^{137}\text{Cs}$  in connection with the Chernobyl accident in 1986. Our biodosimetry in 1993 resulted in  $0.33 \pm 0.12$  Sv, a dose that was essentially identical to his dose estimate of 0.3 Sv from independent physical measurements.

Neutron Dose Reconstruction for Hiroshima/Nagasaki: Implications for Risk Assessment for Low-LET Radiation: We have demonstrated large discrepancies in the neutron dosimetry for survivors of the Hiroshima atomic bombings. This neutron discrepancy is so large (factors of 10 at relevant distances) that if left unresolved will render highly unreliable the data used as the basis for radiation risk assessment. My presentation at Bad Honnef focused on the implications that these uncertainties may have on radiation risk assessment for those exposed at Chernobyl. My presentation included the following information:

- Large discrepancies are now observed between neutron activation measurements and calculations based on the currently accepted dosimetry system (DS86) for Hiroshima. In contrast, neutron activation in Nagasaki and

results from a neutron air-transport experiment performed at the Army Pulsed Radiation Facility (APRF) in Aberdeen, MD, do not show discrepancies like those seen in Hiroshima (Figs. 1 and 2). This suggests that the discrepancy in Hiroshima is the result of uncertainties associated with the modeling of the early exploding bomb rather than a problem with the air transport calculations.

Figure 1. Measured/calculated activation in Nagasaki (dashed curve is the best fit to Hiroshima data).

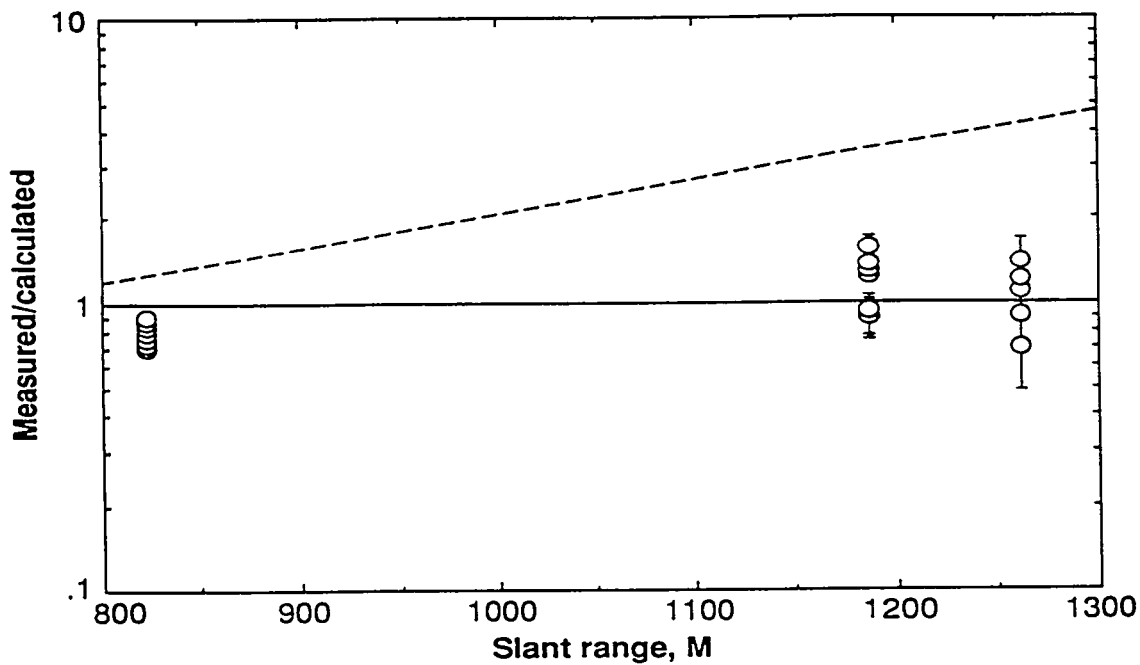
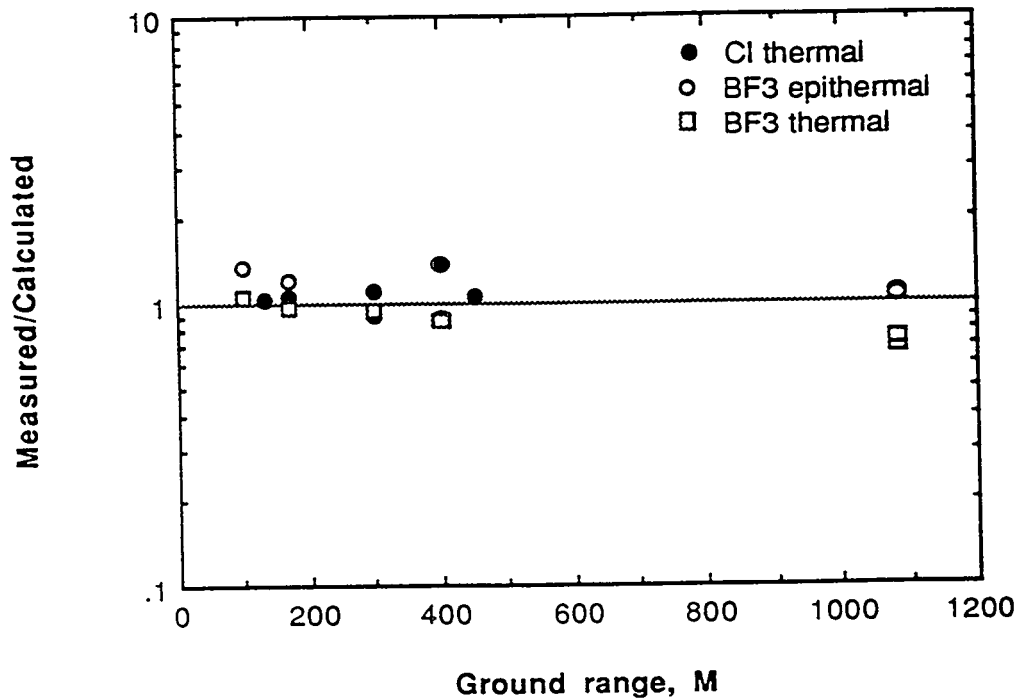


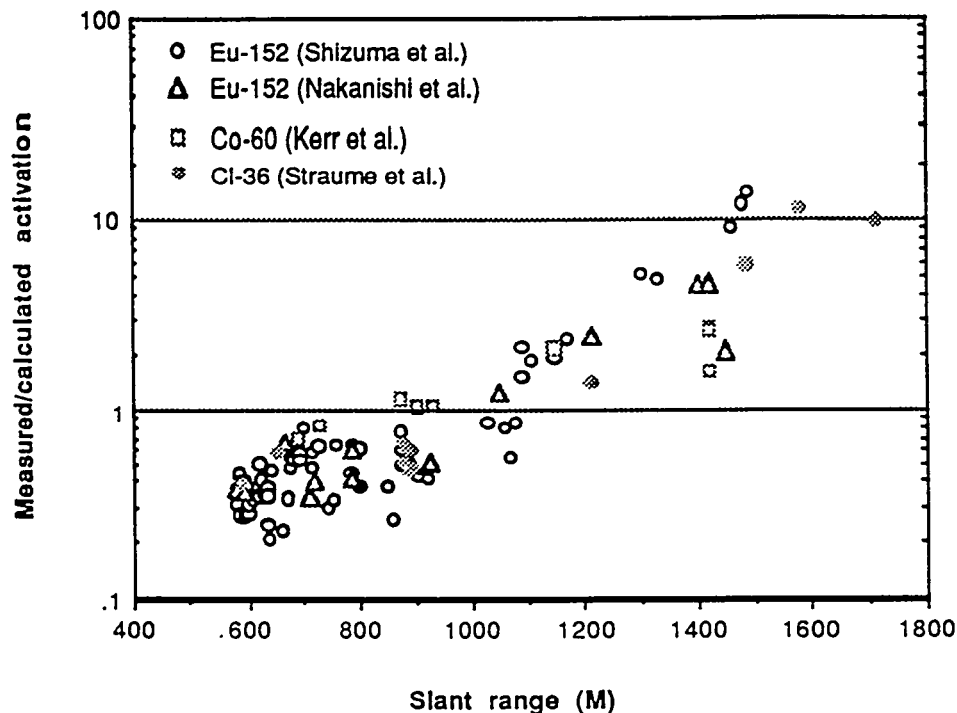
Figure 2. Measured/calculated activation at APRF.



- The Hiroshima University group has a new paper in Health Physics (in press) that demonstrates good agreement between both fast and thermal neutron activation measurements and MCNP calculations for fission neutron transport in 10 cm iron + nylon or lucite moderators to attenuation levels corresponding to about 1500 m in Hiroshima. Although 10 cm of Fe is less than used in Little Boy, the excellent agreement observed between measurements and MCNP calculations appears to make it even less likely that the unique neutron leakage spectrum emitted from the Hiroshima bomb could have resulted in a large discrepancy in the DS86 air transport calculations.

- Although it is clear that we have a systematic discrepancy in Hiroshima thermal neutrons, the actual magnitude of this discrepancy is not at all clear—at ~1500 m the measured/calculated ratios range from less than 2 to more than 10 (Fig. 3). Therefore, before we spend a lot of time on "what if" calculations, we should define the neutron discrepancy more accurately.

Figure 3. Current results for Hiroshima.



- Also of importance in solving the neutron dosimetry problem would be fast neutron information for Hiroshima that is sufficiently quantitative to permit validation of sulfur. At present, the sulfur data severely limit the number of neutrons that can be added above ~3 MeV. This restriction forces the selection of a rather incredible fission source to fit the current thermal neutron data.

#### *Munich*

At GSF (Munich) I met with Dr. Voigt to discuss collaborations involving the iodine project. We agreed to perform joint intercalibration measurements and for a student from Dr. Voigt's lab to spend about 3 months at LLNL to learn our

iodine extraction and measurement methods. Also while at GSF, I met with Dr. Bauchinger and discussed intercomparison studies involving chromosome painting. We agreed that LLNL and GSF should perform a joint experiment to compare chromosome painting results. This is important because the chromosome painting technology is new and the several laboratories now using the method have never intercompared their results using standardized scoring criteria and conditions.

#### *Washington DC*

The purpose of the Washington DC meeting on May 16th and 17th was to assist NIOSH and DOE in developing a program of surveillance for the identification and ongoing medical evaluation of current and former employees at DOE Defense Nuclear Facilities. The development of these programs by DOE with NIOSH consultation is mandated in the 1993 Defense Authorization Act. Copies of the invitation letter from the Director of NIOSH and the Assistant Secretary of Energy, the names of the attendees, and the agenda are attached.

#### **Appendix**

##### **Itinerary:**

6/3-4/94	Traveled from San Francisco to Frankfurt, Cologne, and Bad Honnef, Germany.
6/6-9/94	Workshop in Bad Honnef
6/10/94	Traveled from Bad Honnef to Munich, Germany
6/15/94	Traveled from Germany to Washington DC
6/16-17/94	Meeting in Washington DC
6/17/94	Traveled from Washington DC to San Francisco.

Persons Contacted: The persons with which I had discussions in Germany are listed in the attached list of participants of the Bad Honnef workshop. The persons that I had discussions with at GSF were also at the Bad Honnef workshop.

Literature Acquired: None

GSF/CEC/IAEA/GAST

## Workshop on Dose Reconstruction

Bad Honnef June 6 to 9, 1994

### Programme

#### Monday, June 6

- 10:00 -12:00      Registration
- 13:00              Lunch
- 14:00              Welcome (*P. Jacob, H. Menzel*)  
Presentation of the first draft of a 'recommendation paper for reliable dose reconstruction' (*H. Menzel*)  
Establishment of a drafting committee
- 14:30              Session I  
Experimental physical methods for dose assessments: I-129 measurements  
Chairman: *M. Crick*  
*T. Straume* (USA): Status report on I-129 measurements  
*K. Heinemann* (FRG): A method of retrospective reconstruction of children's thyroid gland dose using I-129 soil contamination
- 15:30              Coffee break
- 16:00              Session II:  
Experimental physical methods for dose assessments: Thyroid measurements  
Chairman: *Chr. Reinert*  
*G. Gulko* (Ukraine): Retrospective thyroid dose reconstruction  
*I. Zvonova* (Russia): Methods of thyroid dose estimation for the population of Russia following the accident at Chernobyl NPP  
*A. Ulanovsky* (Belarus): Influence of measurement geometry to the estimate of I-131 concentration in the thyroid  
*V. Krouch* (Russia): Key problems of individual thyroid dose reconstruction due to the Chernobyl accident

Tuesday, June 7

9:00

**Session III:**

Experimental physical methods for dose assessments: Thermoluminescence

Chairman: *E. Haskell*

*I. Bailiff* (UK): The use of luminescence with ceramic materials

*Y. Göksu* (FRG): The limits of luminescence techniques with domestic materials for retrospective dosimetry

*L. Brodski* (Estonia): Vitreous materials: prospects in retrospective dosimetry

*L. Heide* (FRG): Retrospective dosimetry by chemoluminescence measurements on sorbite

10:30

Coffee break

11:00

*T. Maruyama* (JPN): Dose assessment by means of TL techniques using ceramic materials

*V. Polyakov* (Estonia): Absorbed dose depth profiles for the radionuclide composition in Pripyat

12:00

**Session IV:**

Experimental physical methods for dose assessments: Electron Paramagnetic Resonance

Chairman: *I. Bailiff*

*A. Wieser* (FRG): Potential and limitations of retrospective EPR dosimetry

*G. Liidja* (Estonia): Temperature and frequency effects in tooth enamel by electron spin resonance dosimetry

13:00

Lunch

14:00

*P. Fattibene* (I): Dose reconstruction in bones using Electron Paramagnetic Resonance

*E. Haskell* (USA): Combined ESR dosimetry using dentine and enamel of teeth

*A. Brik* (Ukraine): About new approaches to EPR and luminescent retrospective dosimetry of objects from Chernobyl accident zone

15:30

Coffee break

16:00

**Session V:**

Experimental biological methods for dose assessments

Chairman: *Chr. Streffer*

*T. Straume* (USA): Dose reconstruction from reciprocal translocation frequencies measured by FISH

*M. Bauchinger* (FRG):

*Chr. Streffer* (FRG): Micronuclei - a method for biological dosimetry

20:00

Meeting of the drafting committee

Wednesday, June 8

- 9:00            Distribution of the second draft of the 'Recommendation Paper'  
                 **Session VI:**  
                 Sourceterm, atmospheric dispersion and deposition  
                 Chairman: *L. Anspaugh*  
                 *Dr. Pietsch* (FRG):  
                 *T. Mikkelsen* (DEN): Backfitting and data assimilation of measured  
                 exposures on the different atmospheric scales  
                 *I. Kryshev* (Russia): A model of dose reconstruction with consideration of  
                 multiple pathways of contamination of the natural environment for the  
                 regions of Russia impacted by the Chernobyl accident  
                 *G. Pröhl* (FRG): Deposition, interception and post-deposition retention of  
                 radionuclides by vegetation
- 10:30            **Coffee break**
- 11:00            **Session VII:**  
                 Models for prediction of external exposure  
                 Chairman: *M. Balonov*  
                 *P. Jacob* (FRG): External exposure due to deposited radionuclides  
                 *K. Andersson* (DEN): URGENT - a model for prediction of exposure from  
                 radiocaesium deposited in urban aereas  
                 *V. Chumak* (Ukraine)/*R. Meckbach* (FRG): Present state of retrospective  
                 dosimetry of external exposure to evacuees and liquidators
- 13:00            **Lunch**
- 14:00            **Session VIII:**  
                 Food chain models: short-term exposure  
                 Chairman: *I. Likhtarev*  
                 *V. Minenko* (Belarus): Grounds for the necessity of clarification the the  
                 methodical approaches to the reconstruction of thyroid doses  
                 *I. Kairo* (Ukraine): Individual thyroid dose recostruction  
                 *Y. Gavrilin* (Russia): The problem of internal thyroid dose reconstruction  
                 from the mathematical statistics point of view
- 15:30            **Coffee break**
- 16:00            Discussion of the second draft of the 'Recommendation Paper'  
                 Meeting of the drafting committee

Thursday, June 9

- 9:00            Distribution of the third draft of the Recommendation Paper'  
*Chr. Reiners* (FRG): Results of I-131 treatment in children from Belarus  
with advanced thyroid cancer  
*T. Straume* (USA): Neutron dose reconstruction for Hiroshima/Nagasaki:  
Implications for Risk Assessment for low-LET Radiation  
*M. Crick* (IAEA): Experiences from reconstructing thyroid doses due to the  
Windscale Reactor Fire - October 1957
- 10:30            **Coffee break**
- 11:00            **Session IX:**  
Food chain models: long-term exposure  
Chairman: *L. Anspaugh*  
*I. Likhtarev* (Ukraine): Models for reconstruction and prediction internal  
doses  
*Y. Kenigsberg* (Belarus): The role of ration structure peculiarities in  
estimation of radiocaesium concentration in the body  
*M. Balonov* (Russia): Overview of the problem of dose reconstruction for  
Russia and prognosis of population internal exposure after the Chernobyl  
accident  
*H. Müller* (FRG): Application of radioecological models for reconstruction  
of ingestion doses
- 13:00            **Lunch**
- 14:00            *A. Bouville* (USA): Methods of dose reconstruction being used in the US  
*V. Stepanenko* (Russia): The methodology of retrospective individual  
dosimetrical examination for residents of contaminated territories:  
approaches and problems  
*M. Hoshi* (JPN): Cs-137 concentration among children in Mogilev and  
Belarus
- 15:30            **Coffee break**
- 16:00            Summary of the workshop (*H. G. Paretzke*)  
Discussion and Adoption of the Recommendation Paper:  
Chairman: *H. G. Paretzke*
- 20.00            **Workshop Dinner**

Short contributions are welcome during discussion period at the end of each session



National Institute for  
Occupational Safety and Health  
Centers for Disease Control  
and Prevention (CDC)  
Washington, DC 20201

June 7, 1994

Tore Straume, Ph.D.  
Head, Dosimetry and Dose Response Group  
Health and Ecological Assessment Division  
Lawrence Livermore National Laboratory  
Livermore, California 94550

Dear Dr. Staume:

The National Institute for Occupational Safety and Health (NIOSH) has been requested by the Department of Energy (DOE), Office of Environment, Safety and Health, to provide assistance to DOE in developing a program of surveillance for identification and ongoing medical evaluation of current and former employees at DOE Defense Nuclear Facilities. The development of these programs by DOE with NIOSH consultation is mandated in the 1993 Defense Authorization Act. This is an enormous and historic endeavor to which DOE is committed.

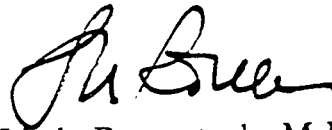
We would like to invite you to attend a NIOSH/DOE-sponsored planning meeting on June 16, 1994. The purposes of this meeting will be to bring together a small group of NIOSH and DOE staff and experts in technical fields related to surveillance at DOE; to hear about the goals of this program from DOE; and to develop recommendations about possible future activities. These recommendations should particularly be related to exposure assessment, hazard surveillance, and medical surveillance as well as mechanisms to accomplish these activities. The recommendations should identify activities that could be pursued immediately as well as activities that require further development and discussion at a larger meeting involving all interested parties. The goal of DOE is to establish a pragmatic, sequential, prevention-oriented program that will help ensure and protect the health and safety of DOE employees. A list of invitees is enclosed. A half-day working staff meeting will be held on June 17, 1994, for the purpose of reviewing and compiling all the recommendations from the previous day. All invitees to the June 16 meeting are invited and welcome to attend this session. The agenda for these meetings is enclosed.

Page 2 -- Tore Straume, Ph.D.

These meetings will be held at the Washington Renaissance, 999 9th Street, N.W., Washington, D.C., 202/898-9000. A block of 20 rooms has been reserved for people staying overnight on June 15 and 16.

We hope you are able to join us at this meeting. A flip chart, overhead projector, and slide projector will be provided. If additional audiovisual aids are needed, please inform us. Primary contacts for this or other issues related to this meeting are Dr. Ted Meinhardt at 513/841-4366, Dr. Richard Hornung at 513/841-4400, and Dr. Steven Galson at 202/586-6151.

Sincerely yours,

A handwritten signature in black ink, appearing to read "L. Rosenstock".

Linda Rosenstock, M.D., M.P.H.  
Director, NIOSH

A handwritten signature in black ink, appearing to read "Tara O'Toole".

Tara O'Toole, M.D., M.P.H.  
Assistant Secretary for Environment,  
Safety and Health, DOE

2 Enclosures

## **Proposed Format for a NIOSH-Sponsored Working Meeting\***

### **An Initial Plan in Assisting DOE in Developing a Prevention-Oriented Surveillance Plan June 16, 1994**

**NIOSH and DOE Co-Chairs: Ted Meinhardt and Steven Galson**  
**Rapporteur: Phil Bierbaum**

<u>Time</u>	<u>Activity</u>
8:30 a.m.	Welcome and Introduction -- <b>Linda Rosenstock, NIOSH</b>
8:45	Overall DOE Goal and Mission in Developing Surveillance -- <b>Tara O'Toole, DOE</b>
9:00	Discussion of Major Components of an Effective Prevention- oriented Surveillance Program -- <b>Steven Galson, DOE</b>
	Clarification -- Questions and Answers
9:30	Targeted, Structured Discussion
	Hazard Surveillance
	<ul style="list-style-type: none"><li>• What hazard surveillance can accomplish at DOE facilities to help protect workers (10 minutes) -- <b>Alice Greife, NIOSH</b></li><li>• Status of hazard surveillance and exposure assessment across DOE complex and review of relevant data (10 minutes) -- <b>Rick Jones, DOE</b></li><li>• General Discussion</li></ul>
10:15	Break

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\*This meeting was initially designed to be a one-day meeting from 8:30 a.m. to 3:45 p.m. To maximize progress and the availability of people, a one-half day working session on June 17 has been scheduled for the purposes of reviewing and compiling all recommendations from the previous day. All invitees to the June 16 meeting are invited and welcome to attend this working session.

<u>Time</u>	<u>Activity</u>
10:30 a.m.	<p>Targeted, Structured Discussion</p> <p>General and Specific Medical Screening</p> <ul style="list-style-type: none"><li>• What can be accomplished by general and specific medical screening at DOE sites and issues that must be weighed to determine efficiency (10 minutes) -- <b>Bill Halperin, NIOSH</b></li><li>• Status of medical screening across the DOE complex and review of relevant data (10 minutes) -- <b>George Gebus, DOE</b></li><li>• General Discussion</li></ul>
11:15	<p>Targeted, Structured Discussion</p> <p>Prevention/Intervention Activities</p> <ul style="list-style-type: none"><li>• What are the ranges of prevention and intervention activities that can be pursued at DOE facilities and what are real world expectations (10 minutes) -- <b>Larry Fine, NIOSH</b></li><li>• Status of prevention/intervention activities at DOE facilities and review of relevant data (10 minutes) -- <b>Tara O'Toole, DOE, or Steven Galson, DOE</b></li><li>• General Discussion</li></ul>
12:00 N	Lunch

TimeActivity

3

12:45 p.m. Three Targeted Topic Panels to Develop Issues and Recommendations

- Approach would be to supply each panel with a moderate number of questions specific to topic and about integration with other panels to start discussion. Each panel would produce recommendations associated with supplied questions, discussion of other topics that need to be developed and suggestions concerning an initial action plan that would include immediate activities and activities to be discussed at public meetings after which an overall long-term action plan will be developed. Three possible topics are "Hazard Surveillance," "Medical Screening," and "Prevention/Intervention Activities."

2:45 Break  
Panel and Meeting Chairs in Executive Session

3:15 Summary and Wrap Up

- Discussion of follow-up activities and future plans.  
**Tara O'Toole, DOE, and Linda Rosenstock, NIOSH**

3:45 Adjourn

**Working Staff Session  
June 17, 1994**

9:00 a.m. - 12:00 Noon All recommendations from the panels of June 16, 1994, and an initial compilation will be made.

**Invitees to the  
NIOSH-sponsored Planning Meeting on DOE Surveillance  
Washington Renaissance Hotel, 999 9th Street, N.W., Washington, D.C.  
June 16, 1994**

Edward Baker  
Public Health Practice Program Office  
CDC

Scott Barnhart  
University of Washington

Charles Barrett  
Oil, Chemical and Atomic Workers  
Union

Phillip Bierbaum  
NIOSH Extramural Consultant

Michael Wright  
United Steelworkers of America

Joseph Cocalis  
NIOSH

Mark Cullen  
Yale University

John Dement  
Duke University

Lawrence Fine  
NIOSH

Marilyn Fingerhut  
NIOSH

Melvin First  
Harvard University

Joseph Fitzgerald  
Office of Environment, Safety and  
Health, DOE

Jack Fix  
Battelle Northwest

Steven Galson  
Office of Environment, Safety and  
Health, DOE

George Gebus  
Office of Environment, Safety and  
Health, DOE

Alice Greife  
NIOSH

William Halperin  
NIOSH

Richard Hornung  
NIOSH

Barbara Hargas  
Los Alamos National Laboratories

Richard Jones  
Office of Environment, Safety and  
Health, DOE

Virginia Lee  
ATSDR

Theodore Meinhardt  
NIOSH

L. Christine Oliver  
Massachusetts General Hospital

Tara O'Toole  
Office of Environment, Safety and  
Health, DOE

John Moran  
Laborers International Union of North  
America

Knut Ringen  
Center to Protect Workers' Rights

Linda Rosenstock  
NIOSH

Paul Seligman  
NIOSH

Heather Stockwell  
Office of Environment, Safety and  
Health, DOE

Tore Straume  
Lawrence Livermore National  
Laboratories

Jerry Williams  
Los Alamos National Laboratories

Carol Henry  
Office of Environmental Management  
DOE

# EH-40 Monthly Report

July 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

---

*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

## II. Current Project Status / Monthly Progress

During July, we continued scoring slides from the ten liquidators as well as from two controls. By the end of July we had scored about half of the slides received, i.e., a total of about 5000 cells from five liquidators.

Also during July, in conjunction with a related project (Biodosimetry Tools) we began the measurement of a standard *in vitro* calibration curve for  $^{137}\text{Cs}$  gamma rays. This calibration curve is required in order to convert measured frequency into dose for individuals that have received  $^{137}\text{Cs}$  gamma-rays exposures. The calibration curve is for the low dose-rate exposures most relevant to Chernobyl conditions.

## III. Significant Problems/Issues/Concerns

N/A.

## IV. Assistance Required of EH-40 Staff

N/A.

# EH-40 Monthly Report

August & September 1994

**Project Title:** Chernobyl Studies  
7.2A4 Chromosome-Painting Dosimetry

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-09

**Principal Investigators:** Tore Straume and Joe Lucas  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

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*Address each item, if applicable.*

- I. **Project Objective**
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  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
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- III. **Significant Problems/Issues/Concerns**
  - Substantial changes in project expectations, protocol, funding.
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- IV. **Assistance Required of EH-40 Staff**
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

The project objective is to use chromosome painting to provide dose estimates for selected individuals as needed for post-Chernobyl-accident surveillance and epidemiology studies.

## II. Current Project Status / Monthly Progress

In August and September, we completed our evaluation of the ten slides that we received from Kiev in late May. These were microscope slides with chromosome preparations from selected individuals apparently exposed during the Chernobyl accident. The identities or exposure histories of the individuals were not given to us. Our principal objectives for these slides were three fold: (1) to determine if the Kiev group preparing the slides can provide adequate quality metaphase preparations for FISH analysis, (2) to determine if archived slides prepared some time ago (as is sometimes the case) can be refreshed for hybridization, and (3) to demonstrate adequate interlaboratory coordination for a successful study.

During the report period, we determined that the slide preparation methods used by the Kiev laboratory are adequate for chromosome translocation analysis. Also, we determined that the archived slides required a modification in our hybridization method. This was successfully accomplished. However, the overall coordination in terms of selection of individuals for study, lines of communication, who will do what, etc. needs some additional work. We are currently working with the Kiev retrospective dosimetry group (Dr. Chumak) to develop a joint protocol that we believe will assure that only the

most important cases are evaluated and that will closely coordinate our FISH biodosimetry measurements with other dosimetry methods that may be used to evaluate the same individual.

During August, Dr. Lucas traveled to Rio de Janeiro, Brazil, to participate in a workshop on radioactive contamination in the urban environment. Because biological dosimetry was an important part of the workshop, one of the organizers of the workshop (Dr. Paretzke of GSF) invited us to present a paper on our DOE/EH funded biodosimetry work. Many key scientists that are involved in our joint studies with the Former Soviet Union were present at the workshop and the presentation was well received. A trip report is enclosed along with the workshop program.

Also during August-September, in conjunction with a related DOE/EH project (Biodosimetry Tools) we completed the measurement of a standard *in vitro* calibration curve for  $^{137}\text{Cs}$  gamma rays. This calibration curve is required to convert measured frequency into dose for individuals that have received  $^{137}\text{Cs}$  gamma-ray exposures. The calibration curve was specifically tailored for the low dose-rate exposures most relevant to Chernobyl conditions and will be used in our future Chernobyl dose reconstruction efforts.

III and IV. NA

# FOREIGN TRIP REPORT

Joe Nathan Lucas

Biology and Biotechnology Program  
Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

September 21, 1994

## SECTION A: SUMMARY

### a. Traveler

Joe Nathan Lucas  
(Senior Scientist)  
(510) 422-6283  
Biology and Biotechnology Program  
Lawrence Livermore National Laboratory  
Livermore, CA 94551  
Contract No. W-7405-Eng-48  
9/21/94

INTERNATIONAL WORKSHOP ON SCIENTIFIC BASES FOR DECISION MAKING AFTER A RADIOACTIVE CONTAMINATION OF AN URBAN ENVIRONMENT. August 27 to August 31, Rio de Janeiro, Brazil

### Purpose of the Trip

To attend and present an invited paper at the International Workshop on Scientific Bases for Decision Making After a Radioactive Contamination of an Urban Environment.

### Abstract

Several talks relating to biological dosimetry were presented at this meeting by various scientists and are described in this report. Although the report focused mainly on the  $^{137}\text{Cs}$  accident in Goiania, Brazil, several discussions took place while attending the workshop. Also, included is a short discussion on measuring dose from translocation frequencies. Finally, the itinerary and persons contacted are listed in the Appendix.

## SECTION B: TRIP REPORT

A. To attend and present an invited paper at the International Workshop on Scientific Bases for Decision Making After a Radioactive Contamination of an Urban Environment. To discuss with scientists the use of chromosome painting (developed at LLNL) in reconstruction of dose to radiation victims, including Chernobyl. The meeting represented important DOE interests, e.g., Chernobyl and radiation workers in DOE facilities.

B. I attended all workshop lectures and functions during August 28-31. During that time, I had many discussions on dose reconstruction for radiation accident victims. Many of the Goiania accident victims did have significant internal radionuclide contamination and thus could provide a source of data

for us to validate the stability of reciprocal translocations measured using our FISH technology.

C. This workshop was designed to discuss the important aspects of and scientific bases needed for decision making after a significant radioactive contamination in an urban environment. The Workshop had several talks, including: early and planned environmental measurements, individual monitoring and dosimetry, and prospective dose and risk assessment. The workshop provided a forum for critical, direct comparison of our research results with other international scientists who are experts in the field of low dose ionizing radiation. Since our initial work on biodosimetry for Goiania accident victims was published in 1992, we have made considerable advances in biological dosimetry. In addition to very important discussions and data inter-comparisons, the workshop provided an opportunity for us to explore additional collaborations with Brazilian scientists, and the possibility to re-sample a few selected Goiania accident victims to obtain additional validation data on the stability of translocations with time post exposure. The information gained at this workshop will help projects currently supported by DOE/EH.

I participated in active discussions of all relevant papers either during the questioning period or other informal discussion throughout the course of the workshop. Examples of papers important to our research presented at this meeting included:

Dr. M. Crick presented an overview of the pathways by which people living in contaminated urban environments can be exposed to radiation. He reviewed approaches to model these exposure pathways and the subsequent assessment of doses to individuals and populations.

Dr. I. Likhtarev described a method to measure dose from the enamel of people's teeth. This method employs electron spin resonance (ESR) and appears to be reasonably reliable, but it requires the extraction of a tooth and may reflect dental X-ray exposures. We are using FISH to independently validate ESR and other dosimetry methods employed at Chernobyl in collaboration with Dr. Likhtarev's group. At the meeting, we had a chance to compare initial results, and they are very encouraging.

Dr. Ramalho gave a talk on the follow-up measurement of dicentrics in the Goiania accident victims. The results showed a rapid decline in the frequency of dicentrics in these victims with time after exposure. The half-time was on the order of 4 – 6 months for most.

Dr. Natarajan presented results of translocations measured on some of these same individuals using chromosome painting. His results showed that the

translocation frequencies (as he measured them), were not equal to the initial dicentric frequency as measured by Dr. Ramalho. Many at the workshop saw this as a point of controversy. However, I pointed out that in our lab, we compare only reciprocal translocations with dicentrics. The differences that Dr. Natarajan reported between dicentrics and translocations appear to be due to his improper comparisons, i.e., lumping all translocations together for comparison to dicentrics.

D. I recommend that Dr. Bill Robison (Division Leader of Health, and Ecological Assessment) contact Dr. Eliana Amaral (director of Instituto de Radioprotecao e Dosimetria, IRD) to discuss the possibility of establishing a collaboration between LLNL and IRD scientists to reconstruct doses to those people exposed.

## SECTION C: APPENDIX

### a. Itinerary

8/27/94: Flew from San Francisco to Rio de Janeiro, Brazil.

8/28-31/94: Attended workshop, conducted discussions, and presented paper.

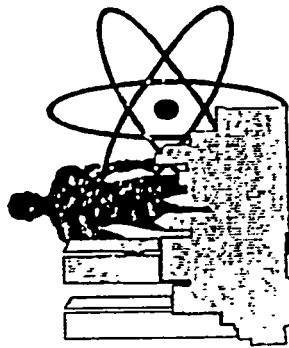
8/31/94: Flew from Rio de Janeiro, Brazil to San Francisco, CA.

### b. List of Persons contacted

Discussions of measuring chromosome aberrations using chromosome painting for Chernobyl dose reconstruction: Dr. I. Likhtarev. Other discussions of measuring chromosome aberrations using chromosome painting for dose reconstruction for Goiania accident victims and other: Dr. A. Ramalho (IRD), M. Crick (IAEA), A. Oliveria (UERJ), E. Haskell (Univ. of Utah), Dr. I. Likhtarev (Ukraine), G. Voigt (GSF), H. Paretzke (GSF).

### c. Future Funding Prospects

In discussions with Dr. Crick, he offered to have the IAEA work with us in obtaining support to develop better methods for measuring chromosome aberrations.



# INTERNATIONAL WORKSHOP ON SCIENTIFIC BASES FOR DECISION MAKING AFTER A RADIOACTIVE CONTAMINATION OF AN URBAN ENVIRONMENT

Rio de Janeiro and Goiânia, Brazil

August 29 - September 2, 1994

Final Circular

and

Programme



## PROGRAMME

LOCATION: IRD, Rio de Janeiro

Sunday, Aug. 28

9:00-11:00 Registration at the hotel  
13:30 City Tour (Workshop Excursion)  
18:00 Cocktail Reception by GSF at Calçanes Club, Lagoa Rodrigo de Freitas

Monday, Aug. 29

Opening Session Chairman: A. Caubi de Silva (CENEN, Rio de Janeiro)  
9:00 Opening

Dr. J. Mauro Esteves dos Santos, President of CENEN  
Prof. J. Klein, Director of GSF

9:20 Rex N. Alves (CENEN, Rio de Janeiro)  
"Challenges to decision makers after urban contaminations: the Goiânia experience"

9:50 L.A. Ilyin (Inst. of Biophysics, Moscow)  
"Challenges to decision makers after urban contaminations: the Chernobyl experience"

10:30 Coffee Break

Session 1

Chairman: J. Sinnavee (CEC, Brussels)

11:00 A. Gonzalez (IAEA, Vienna)  
"Advice given to decision makers by the Basic Safety Standards of the IAEA"

11:30 P.H. Jensen and M. Crick (RISO National Lab., Roskilde)  
"Intervention principles - theory and practice"

11:45 M. J. Crick (IAEA, Vienna)  
"Exposure pathways in the urban environment: theory"

12:00 P. Jacob and R. Meckbach (GSF, Neutherberg)  
"Measurements after the Chernobyl accident regarding the exposure of an urban population"

12:15 Yu.L. Dobrynin and P.B. Khrantsov (Russian Research Centre, Moscow)  
"The Chernobyl Experience for Decision Support System Development"

12:30 Visit 1 to IRD laboratories

13:00 Lunch

Session 2

Chairman: W.L. Robison (LLNL, Livermore)

14:00 J.M. Godoy *et al.* (CENEN, Rio de Janeiro)  
"Early measurements after the Goiânia accident"

14:30 E.C.S. Amaral *et al.* (CENEN, Rio de Janeiro)  
"Dose assessment for decontamination in Goiânia"

14:45 I. Likhartsev *et al.* (Scientific Center for Rad. Med., Kiev)  
"Early measurements in urban areas after the Chernobyl accident"

15:05 R. Alexakin *et al.* (Inst. of Agricultural Radiology, Obninsk)  
"Early measurements of food supply for urban areas after the Chernobyl accident"

15:25 M.A. Balonov *et al.* (Inst. of Rad. Hygiene, St. Petersburg)  
"Distributions of external exposures after the Chernobyl accident"

15:45 J. Rod and K. Anderson (RISO National Laboratory, Roskilde)  
"Early measurements in Scandinavia following the Chernobyl accident"

## 16:00 Coffee Break

## Last Minute Papers" Chairman: A. Gonzalez (AEA, Vienna)

- 16:30 G. Voigt (GSF, Neuherberg)  
"Intercomparison of iodine thyroid doses estimated for people living in an urban and rural environments"
- 16:40 M. A. Novitsky, O. I. Vozzhennikov and A. C. Gerasimenko (SPA Typhoon, Obninsk)  
"Prediction of the radionuclide contamination of the surface waters due to the Chernobyl accident, lessons learned"
- 16:50 M. Al-Soliman, A. M. Al-Arfaj and M. A. Farouk (Inst. of Atomic Energy Research, Riyadh)  
"Emergency response plan for accidents involving radioactive materials used in the Kingdom of Saudi Arabi"
- 17:00 A. Paschua and A. Tranjan (Catholic Univ., Rio de Janeiro)  
"Pre-Planned versus unplanned decision making in the case of environmental decontamination"

## 17:10 Departure for hotel

## Tuesday, Aug. 30

## Session 3

- 9:00 K. Eckerman *et al.* (ORNL, Oak Ridge)  
Chairman: H. Mäthler (IPSN, Fontenay-aux-Roses)  
"Internal Dosimetry and excreta analysis"
- 9:30 J. Lipzstein, D.R. Melo, C.A.N. Oliveira (CNEN, Rio de Janeiro)  
"Individual monitoring and dosimetry: the Goiânia experience"
- 10:00 D.R. Melo, J. L. Lipzstein, C. A. N. Oliveira and L. Bertelli (CNEN, Rio de Janeiro)  
"<sup>137</sup>Cs metabolism in pregnant women"
- 10:15 G. Launer *et al.* (NYU, New York)  
"The calibration of whole body counters for accident in vivo monitoring"
- 10:35 L. Malkova, I. Bucina, D. Drabová, I. Čepirová (Centre of Radiation Hygiene, Prague)  
"Simplified calibration and evaluation procedures for improvised whole body gamma spectrometry in emergency situations"

## 10:55 Coffee Break

- 11:15 C. A. N. Oliveira *et al.* (CNEN, Rio de Janeiro)  
"Whole body counter measurements of contaminated people in Goiânia"
- 11:45 H. Doerfel (KKK, Karlsruhe)  
"Whole body measurements for in vivo monitoring in emergency situations"

## Session 4

- 12:00 J. N. Lucas (LLNL, Livermore)  
Chairman: J. L. Lipzstein (CNEN, Rio de Janeiro)  
"Dose reconstruction from reciprocal translocation frequencies"
- 12:20 A. T. Natarajan *et al.* (Univ. Leiden, Leiden)  
"Goiânia Radiation Accident: Results of follow-up"
- 12:40 A. Ramalho and A.T. Natarajan (CNEN, Rio de Janeiro)  
"Six years cytogenetic follow up of unstable chromosomal aberrations in Goiânia patients"

## 13:00 Lunch

## Session 5

- Chairman: A.R. Oliveira (INB, Rio de Janeiro)  
14:00 N.J. Valverde and A. R. Oliveira (Lab. of Rad. Sciences/UERJ, Rio de Janeiro)  
"The early medical response during the Goiânia accident"
- 14:30 D. Denzow, H. Kindler and T. M. Fliedner (Ulm University, Ulm)  
"Medical experience: Chernobyl and other accidents"
- 15:00 A. B. Carvalho (CNEN, Rio de Janeiro)  
"Post-traumatic stress disorders: after effects of the Goiânia radiological accident"

## 15:20 Coffee Break

## Session 6

- Chairman: P. Jacob (GSF, Neuherberg)  
15:50 A. Rossi *et al.* (Brazilian Center for Phy. Res., Rio de Janeiro)  
"Retrospective EPR dosimetry with teeth of victims of the Goiânia accident"
- 16:05 A. Wieser and A. Romanyukha (GSF, Neuherberg)  
"Retrospective EPR dosimetry with teeth of persons exposed in Cheljabinsk"
- 16:20 I. Baillif *et al.* (University of Durham, Durham)  
"Retrospective TL dosimetry in urban areas after the Chernobyl accident"
- 16:35 L. B. Jensen (RISO National Laboratory, Roskilde)  
"Retrospective dose reconstruction using optically stimulated luminescence on natural materials collected in areas of accidental radioactive contamination"
- 16:50 Ed Haskell (University of Utah, Utah)  
"Retrospective TL Dosimetry of inhabited regions downwind of the Nevada test site"

## 17:05 Departure for hotel

## Wednesday, Aug 31

## Session 7

- Chairman: C. E. V. Almeida (UERJ, Rio de Janeiro)  
9:00 R.G. Smetsers, J. F. Van Sonderen and M. J. Pruppers (RIVM, Bilthoven)  
"Nuclear emergency planning and response in the Netherlands: experiences obtained from large scale exercises"
- 9:25 P. G. Mueller (DOE, Nevada)  
"The United States Federal Radiological Monitoring and Assessment Center (FRMAC), Las Vegas"
- 9:35 D. Thomé (EG&G, Las Vegas)  
"Emergency radiological monitoring and analysis of the United States Federal Radiological Monitoring and Assessment Center"
- 9:45 J. M. Smith, R. L. Blanchard, Z. G. Burson and K. Kerns (EG&G, Las Vegas)  
"Methodology manual for FRMAC evaluation and assessment for a radiological emergency"
- 9:55 R.L.L. Baskett, J. S. Ellis and T. J. Sullivan (LLNL, Livermore)  
"Real time modeling of complex atmospheric releases in urban areas"

## 10:15 Visit 2 to IRD laboratories

- Session 8**  
**Chairman:** M.J. Crick (IAEA, Vienna)  
 11:00 K. Sinkko and T. K. Ikhelmonen (Centre for Radiation and Nuclear Safety, Helsinki)  
 "Decision analysis of cleanup strategies in urban environment"  
 11:15 U. Tveten (I. for Energiteknikk, Kjeller)  
 "Radioactive contamination of an urban environment under winter conditions"  
 11:30 A. Simpson (Scottish Nuclear, Scotland)  
 "Developments in emergency planning within Scottish Nuclear"  
 11:45 J. Gulleraz and C. Vasquez (CIEMAT, Madrid)  
 "Intervention strategies for the recovery of radioactivity contaminated environments"  
 12:00 S. Hög, S. Thykier-Nielsen and L. B. Steffensen (Emerg. Manag. Agency, Birkeroed)  
 "ARGOS-NT: A computer based emergency management system"  
 12:20 S. French and D. Ranyard (Univ. Leeds, Leeds)  
 "Development of applications for response to nuclear accidents"  
 12:40 E. Rochedo, H.G. Paretzke, L.F. Conit (CNEN, Rio de Janeiro)  
 "PARATI - A program for radiological assessments after radioactive contamination of urban areas"

#### 13:00 Lunch

- 14:00 General discussion: "Scientific bases for decision making after an urban contamination - solved and open problems" (Moderator: H.G. Paretzke, GSF, Neuherberg)

#### 16:00 Visit 3 to IRD laboratories

#### 16:45 Departure for hotel

#### Thursday, Sep. 1

morning - Transfer to Goiânia

- 5:45 Workshop busses will take the participants to the airport  
 10:40 Workshop busses will leave the Goiânia airport to the Kananxué Hotel

#### 13:00 Lunch

- 14:00-18:00 Visit to the contamination sites in Goiânia, the temporary waste deposit and new repository.  
 19:00 Cocktail Reception by IRD at Kananxué Hotel

#### LOCATION : KANANXUÉ HOTEL, GOIÂNIA

#### Friday, Sep. 2

- Session 9**  
**Chairman:** A. Paschoa (Catholic Univ., Rio de Janeiro)  
 9:00 W. M. Ferreira (CNEN, Goiânia)  
 "Discovery of the Goiânia Accident"  
 9:20 W. M. Ferreira *et al.* (CNEN, Goiânia)  
 "Large scale public monitoring at the Olympic stadium"  
 9:40 C. A. N. Oliveira *et al.* (CNEN, Rio de Janeiro)  
 "Measurement of contaminated people: follow up"  
 10:05 C.E. Brandão *et al.* (CNEN, Rio de Janeiro)  
 "The medical follow up of the Goiânia victims"  
 10:35 P. Curado (CNEN, Rio de Janeiro)  
 "Psychological and social problems of the Goiânia victims"

#### 11:05 Coffee Break

- Session 10**  
**Chairman:** E. Penna Franca (IBUFRJ, Rio de Janeiro)  
 11:35 M. Pites do Rio, E. C. S. Amaral, H.G. Paretzke (CNEN, Rio de Janeiro)  
 "The spreading of  $^{137}\text{Cs}$  by resuspension of contaminated soil at the urban area of Goiânia"  
 11:50 J.M. Godoy, M.E. de Luca (CNEN, Rio de Janeiro)  
 "The behaviour of  $^{137}\text{Cs}$  in the aquatic environment"  
 12:05 S. T. W. Maw *et al.* (CNEN, Belo Horizonte)  
 "Experiences in waste management from the Goiânia accident"  
 12:20 A. Tranjan (FURNAS, Rio de Janeiro)  
 "Technical aspects of the design of the repository"  
 12:35 A. Paschoa *et al.* (Catholic University, Rio de Janeiro)  
 "Social and economic aspects of the site selection in Goiânia"

#### 13:00 Lunch

- Session 11**  
**Round Table** Moderator: A. Tranjan (FURNAS, Rio de Janeiro)  
 14:00 The Governor of the State of Goiás (Goiânia)  
 "The city response to the accident"  
 14:30 R. Azeredo (Média, Goiânia)  
 "The role of the press in an urban accident: the Goiânia experience"  
 14:50 Q.C. Santos (Funileide, Goiânia)  
 "The role of FUNLEIDE on the follow up or assistance of the victims after the Goiânia accident"  
 15:10 Closing remarks:  
 Organizing Committee  
 Government Representatives  
 17:00 Workshop busses will take the participants to the Goiânia airport

## FOREIGN TRIP REPORT

Garrett Keating

Health and Ecological Assessment Division  
Environmental Programs Directorate  
Lawrence Livermore National Laboratory  
Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

October 5, 1994

## SECTION A: Summary

a. Date of Trip Report: October 5, 1994

b. Traveler: Garrett Keating  
Post-doctoral Researcher  
(510) 422-0921  
Dosimetry and Dose Response Group  
Health and Ecological Assessment Division  
Lawrence Livermore National Laboratory

c. Dates and Destination:

9/14/1994 Istituto Superiore di Sanita, Rome, Italy

9/27/94 to 10/3/94 Institut für Strahlenbiologie, GSF - Forschungszentrum  
für Umwelt und Gesundheit, Munich, Germany

d. Purpose of Trip:

The purpose of the trip to Rome was to present a paper at the symposium, "Assessing and Managing Health Risks from Drinking Water Contamination: Approaches and Applications", sponsored by the International Association of Hydrological Sciences. The purpose of the trip to Munich was to observe laboratory methods for processing thyroid tumors for cytogenetic analysis.

e. Abstract

The paper, titled "Assessment of dermal exposure to contaminants in drinking water - new measurements and models", was presented in a session on Multipathway Exposure Assessment at the symposium. The paper resulted from a collaboration between LLNL and Dr. Richard Guy, Department of Pharmacy and Pharmaceutical Chemistry, University of California, San Francisco (UCSF), CA. Results from dermal exposure of human subjects to radiolabeled compounds conducted at UCSF and analyzed with accelerator mass spectrometry at LLNL were compared with predictions from newly developed skin absorption models proposed for risk analysis. The proceedings of the symposium will be published. The laboratory visited in Munich was that of Dr. Manfred Bauchinger in the Institut für Strahlenbiologie at GSF. This laboratory is involved in several projects on cytogenetic analysis of tumors and assessment of cytogenetic damage from exposure to radiation and chemicals. Of interest to our group at LLNL is the cytogenetic analysis of thyroid tumors in Chernobyl accident victims conducted by this laboratory. The visit entailed discussions with various laboratory personnel involved in the project, observation of thyroid tissue preparation and culture techniques, observation of cytogenetic analysis, and review of bibliographic material prepared and collected by the laboratory. A meeting with Dr. Johannes Doehmer of the Institut für Toxikologie und Umwelthygiene, GSF, was also held.

## SECTION B: Trip Report

### a. Summary of Activities

The Rome meeting was organized by the International Commission on Groundwater of the International Association of Hydrological Sciences (IAHS) and the Istituto Superiore di Sanita (ISS). The attendance of LLNL personnel was solicited by Organizing Committee member Dr. Eric Reichard of the U.S. Geological Survey, who was familiar with the multipathway exposure modeling developed at LLNL. The abstract I submitted was co-authored by Drs. Aarti Naik and Richard Guy of UCSF and Drs. John Vogel (Center for Accelerator Mass Spectrometry) and Thomas McKone (Exposure Assessment Group, HEA). We were subsequently asked to submit an article for inclusion in the published proceedings. The session at which I spoke was attended by approximately 100 people. The talk briefly outlined skin physiology and standard methods for measuring skin absorption, two newly proposed dermal uptake models and new methods for measuring skin uptake being developed at UCSF and LLNL. I concluded the talk with a discussion of our results and a comparison of the model predictions with our results. My assessment of the attendees at the session was that most were hydrologists and engineers by training. Questions pertained to the assumptions about exposure to water contaminants typically used in risk assessment.

The visit to the GSF cytogenetic laboratory was initiated through discussions between Dr. Tore Straume, head of the Dosimetry and Dose Response Group, HEA, and Dr. Bauchinger. Dr. Bauchinger was attending a scientific conference during the visit and I was unable to meet with him, however the laboratory staff was aware of my visit and were prepared to accommodate me. My activity entailed observing different individuals in the laboratory involved in the preparation of cell cultures from thyroid tumors and the cytogenetic analysis of these cultures with fluorescent-in-situ- hybridization (FISH). My principal contact was with Mr. Lars Lehmann, a Ph.D. candidate in the laboratory and the primary laboratory individual involved in the thyroid tumor project. The first day of my visit entailed review of his master's thesis work on developing the cell culture methods and histochemical techniques for establishing the thyroid-origin of the tissue cultures. I also reviewed publications of other members of the group. On days 2 and 3 I observed procedures for cell culture and FISH staining of thyroid cells from cultures initiated before my visit. Cell cultures are established directly on glass slides for FISH staining, a procedure Mr. Lehmann indicated was more successful for obtaining metaphase spreads than the dropping of cells onto the slides. Three-color probes (chromosomes 1, 4, and 12) were used for the FISH staining of the thyroid cells. The final day of my visit was spent with Mr. Lehmann reviewing the culture and staining procedures and making detailed notes. He showed me FISH slides of thyroid cells previously prepared by the laboratory. That day, the laboratory was notified that thyroid tumors obtained from children in Byelorussia would be arriving in Munich that afternoon. I hoped to observe the procedures for establishing cell cultures from whole tumor tissue, however upon arrival of the tissue samples it was learned that the tumors were adenomas and not carcinomas.

and therefore not suitable for analysis. Mr. Lehmann noted that communication with investigators in Minsk from whom the tumors are obtained was problematic.

I also met with Dr. Johannes Doehmer at GSF. Dr. Doehmer's laboratory has established cell lines of V79 Chinese hamster cells that express individual isozymes of human cytochrome P450. Given the specificity of these cell lines, they are useful tools in studying the metabolic pathways of many xenobiotics, which is typically complicated by the expression of multiple forms of cytochrome P450 in other cells and animals. Dr. Doehmer is very willing to share the cells with other investigators and provided me with a list of the available cell lines.

#### b. Traveler's Role

For the Rome trip, my role was to present the paper at the IAHS meeting. For the Munich trip, my role was to observe and take notes on the laboratory procedures used for thyroid cell culture.

#### c. Recommendations

Future participation in IAHS symposia is recommended. The groundwater contamination issues of interest to this international organization are ones that LLNL has unique expertise in addressing. Unfortunately, the effectiveness of our presentation to this group was constrained by several factors. Other commitments made it impossible for the co-authors to attend the IAHS meeting, although their backgrounds were better suited for the meeting. My participation at the meeting was limited (I only attended the session at which I spoke) because I was on vacation in Europe at the time and wanted to continue my travel as quickly as possible. While this reduced expenses, our participation at the symposium would have benefited from more interaction with the attendees. Publication of the symposium proceedings will assist circulation of our results among hydrological scientists.

Dr. Bauchinger's laboratory is one of the leading groups on the cytogenetic analysis of Chernobyl accident victims. Continued contact and exchange of information with his group is highly recommended. The group also conducts other research using FISH analysis that will be of interest to the Dosimetry and Dose Response research program. Further contact with Dr. Doehmer is also recommended. The cell lines developed in his laboratory will be very useful tools in our research on chemical dosimetry.

### SECTION C. Appendix

#### a. Itinerary

9/13/94	Left Paris by train; arrived at meeting next morning.
9/14/94	Left Rome by train; arrived in Paris next morning.
9/25/94	Left Geneva by train.
9/27/94	Began visit to laboratory at GSF
9/30/94	Ended visit to laboratory.
10/3/94	Left Frankfurt for Oakland.

b. List of Persons contacted

Dr. Eric Reichard, U.S. Geological Survey

Mr. Lars Lehmann, Institut für Strahlenbiologie, GSF

Dr. Johannes Doehmer, Institut für Toxikologie und Umwelthygiene, GSF

c. Literature Acquired

Published references from laboratories of Drs. Bauchinger and Doehmer

Unpublished articles:

Schmalix, W.A., et al. (1994), "Stable expression of human cytochrome P450 2E1 in V79 Chinese Hamster Cells and metabolic activation of p-nitrophenol, chlozoxazone and n-nitrosodimethylamine".

Salassidis, K., et al. (1994), "Dicentric and translocation analysis for retrospective dose estimation in humans exposed to ionizing radiation during the Chernobyl nuclear power plant accident".

## 7.2D – STOCHASTIC EFFECTS

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
(1,000 Dollars)

**Project:** 7.2D Stochastic Effects [Marvin Goldman—UCD] (Lynn Anspaugh / Sheilah Hendrickson) LLNL No: 6288-11  
DOE No: 94-ES-1031

Cost Item	Months												Year-to-Date
	1993			1994									
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits				0.5	0.3	0.6	0.9	0.6	1.0	0.9	0.9	0.9	6.6
Travel				0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.0	0.7	1.8
Procurement and Expenses*				1.3	0.6	0.5	0.1	0.2	0.3	3.7	0.9	1.0	8.6
Technical Information Department				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Facility/Service/Distributed Charges				0.0	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.1
LLNL Overhead+ /Taxes**				0.2	0.0	0.7	0.9	0.5	0.0	0.9	0.0	0.0	3.2
TOTAL				2.0	1.3	1.8	1.9	2.0	1.6	6.3	1.8	2.6	21.3
Actual to-date UCD+LLNL Total				1.5	0.0	0.0	2.6	0.6	0.0	4.6	0.0	0.0	9.3
Liens/Preliens IUT \$24 K			24.0	24.0	22.3	22.3	22.3	22.3	22.3	18.7	18.7	18.7	
Budget			38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	
Funds Available			38.0	36.5	36.5	36.5	33.9	33.3	33.3	28.7	28.7	28.7	
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts													
** General & Administrative (G&A)													
+ LDRD; Division and Directorate Burdens, etc.													

Total = Combination of actual LLNL charges and "estimate" monthly costs from UCD  
Actual to-date UCD+LLNL Total = Actual invoices paid to UCD + LLNL costs  
Liens/Preliens = IUT award minus actual invoices billed to LLNL

# EH-40 Monthly Report

March, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (UT): UC, Davis

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*Address each item, if applicable.*

## **I. Project Objective**

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

## **II. Current Project Status / Monthly Progress** Administrative (meetings organized).

None

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

In March, we received a travel grant from Soros Foundation to bring the Russian scientists to the US to attend the Health Physics meeting in June and to stay on to complete the editing of the Stochastics report. This will eliminate the need to expend previously requested foreign travel funds.

Travel. Include copy of foreign trip report.

None

## **III. Significant Problems/Issues/Concerns** Substantial changes in project expectations, protocol, funding. Problems occurring or anticipated (corrective actions).

In view of the presence of our Russian colleagues in the United States in June and July, we shall reallocate the cost centers for this grant to better utilize our resources.

## **IV. Assistance Required of EH-40 Staff** Identify EH-40 staff member(s) with each requests.


EH-40 (Dr. H. Pettingill & Ed Washburn) will be requested to permit rearrangement of available funds to take advantage of the fortuitous events described above.

**EH-40 Monthly Report**  
April, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman   
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (UT): UC, Davis

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*Address each item, if applicable.*

**I. Project Objective**

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

**II. Current Project Status / Monthly Progress**  
Administrative (meetings organized).

We plan to meet with the Russians coming to the Health Physics Society Meeting in San Francisco. Some will meet with us in Davis prior to the meeting, and the rest will meet with us the week after.

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

None.

Travel. Include copy of foreign trip report.

None

**III. Significant Problems/Issues/Concerns**  
Substantial changes in project expectations, protocol, funding.  
Problems occurring or anticipated (corrective actions).

None.

**IV. Assistance Required of EH-40 Staff**  
Identify EH-40 staff member(s) with each requests.

EH-40 (Dr. H. Pettingill & Ed Washburn) have agreed to permit rearrangement of available funds as described in the March report.

# EH-40 Monthly Report

May, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (IUT): UC, Davis

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*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15–19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

## II. Current Project Status / Monthly Progress

Travel arrangements have been completed for six Russians from Chelyabinsk to come to California under Soros International Science Foundation funding. They will also participate in the June meeting of the Health Physics Society in San Francisco. Arrangements have been made for secretarial and administrative support in Davis to aid in completion of the workshop report.

## III. Significant Problems/Issues/Concerns

None

## IV. Assistance Required of EH-40 Staff

None

## EH-40 Monthly Report

June, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (IUT): UC, Davis

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*Address each item, if applicable.*

**I. Project Objective**

**II. Current Project Status / Monthly Progress**

Administrative (meetings organized).

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

Travel. Include copy of foreign trip report.

**III. Significant Problems/Issues/Concerns**

Substantial changes in project expectations, protocol, funding.

Problems occurring or anticipated (corrective actions).

**IV. Assistance Required of EH-40 Staff**

Identify EH-40 staff member(s) with each requests.

**I. Project Objective**

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

**II. Current Project Status / Monthly Progress**

Six Russian experts from Chelyabinsk and Moscow arrived in Davis June 20 to work on editing their presentations and to have discussions of the June, 1992 Workshop. In addition there was input from Dr. S.S. Yaniv of the USNRC, who assisted during the week. The work would continue in the first week after the Health Physics Society meeting in San Francisco. Work also progressed on an executive summary of the meeting.

**III. Significant Problems/Issues/Concerns**

None

**IV. Assistance Required of EH-40 Staff**

None

# EH-40 Monthly Report

July 1994

**Project Title:** Chernobyl Studies  
7.2D Hydrological Transport

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman

**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (IUT): UC, Davis

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*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

## II. Current Project Status/Monthly Progress

From July 1 through July 8, Dr. Igor Filyushkin, Dr. Mira Kossenko, Academician Lev Buldakov, and Katherine Zhidkova, from the former Soviet Union, and Lynn Anspaugh and Sheilah Hendrickson from LLNL, joined us in Davis to work on the editing of the Stochastics Report and the revision of the Executive Summary. Six foreign manuscripts were edited for content by the visitors, including the manuscripts of Dr. Nina Koshurnikova and Dr. Marina Degteva. Upon the departure of the visitors, the editing of the reports for English grammar and scientific content was begun by Dr. Goldman and his assistant, Lisa Croll Di Dio. Dr. Goldman made plans to meet with Igor Filyushkin in Moscow for further discussion of the Executive Summary en route to a conference in Siberia.

III. Significant Problems/Issues/Concerns  
None

IV. Assistance Required of EH-40 Staff  
None

## EH-40 Monthly Report

August, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman  
**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**  
IntraUniversity Transaction (IUT): UC, Davis

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*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

### I. Project Objective

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

### II. Current Project Status / Monthly Progress

Editing and revision of the stochastic workshop report for English grammar and scientific content by Dr. Goldman and his assistant, Lisa Croll Di Dio, continues. Dr. Goldman met with Igor Filyushkin in Moscow on 1 and 2 September for further discussion and revision of the Executive Summary, en route to a conference in Siberia.

### III. Significant Problems/Issues/Concerns

None

### IV. Assistance Required of EH-40 Staff

None

## EH-40 Monthly Report

September, 1994

**Project Title:** Chernobyl Studies  
7.2D Stochastic Effects

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-11

**Principal Investigator:** Marvin Goldman

**M&O Contractor:** Lawrence Livermore National Laboratory  
(Lynn Anspaugh / Sheilah Hendrickson)

**Contract to:**

IntraUniversity Transaction (IUT): UC, Davis

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*Address each item, if applicable.*

**I. Project Objective**

**II. Current Project Status / Monthly Progress**

Administrative (meetings organized).

Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).

Travel. Include copy of foreign trip report.

**III. Significant Problems/Issues/Concerns**

Substantial changes in project expectations, protocol, funding.

Problems occurring or anticipated (corrective actions).

**IV. Assistance Required of EH-40 Staff**

Identify EH-40 staff member(s) with each requests.

**I. Project Objective**

Complete and print proceedings for the bilateral stochastic workshop held at the University of California, Davis, June 15-19, 1992. Participants used the most recent estimates of stochastic risk to understand somatic effects of low-level radiation. The proceedings will also include reviewed data compiled on the exposed populations from the South Urals regions of Russia.

**II. Current Project Status / Monthly Progress**

Editing and revision of the stochastic workshop report for English grammar was continued by Lisa Croll Di Dio. Scientific review of the individual papers was continued by Marvin Goldman, who also completed changes on the Executive report.

**III. Significant Problems/Issues/Concerns**

None

**IV. Assistance Required of EH-40 Staff**

None

## 7.2F – THYROID STUDIES

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
**(1,000 Dollars)**

**Project:**

**7.2F Thyroid Studies (Lynn Anspaugh)**

**LLNL No: 6288-16**

**DOE No: 94-ES-1031**

Cost Item	Months												Year-to-Date
	1993		1994										
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Salary/Benefits	16.2	7.3	14.0	5.8	7.0	5.8	10.5	15.3	11.4	13.4	12.6	46.0	165.3
Travel	-1.6	0.0	0.6	2.5	-2.0	0.0	3.9	0.0	3.4	2.8	1.2	8.8	19.6
Procurement and Expenses*	2.7	0.1	0.0	1.0	4.6	0.8	0.9	0.1	0.0	0.0	9.1	15.8	35.1
Technical Information Department	0.3	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.1	2.9	4.2
Facility/Service/Distributed Charges	0.0	0.2	1.1	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.5	0.1	2.4
LLNL Overhead+ /Taxes**	11.7	5.3	10.1	4.1	5.4	5.0	46.7	14.9	9.6	36.8	8.8	29.7	188.1
TOTAL	29.3	12.9	25.8	14.0	15.4	11.6	62.0	30.3	24.4	53.4	32.3	103.3	414.7
Liens/Preliens												1.4	416.1
Budget	510.0	510.0	510.0	510.0	510.0	510.0	510.0	510.0	510.0	510.0	434.3	434.3	
Funds Available	480.7	467.8	442.0	428.0	412.6	401.0	339.0	308.7	284.3	230.9	122.9	18.2	
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts													
** General & Administrative (G&A)													
+ LDRD; Division and Directorate Burdens, etc.													

# EH-40 Monthly Report

March—September 1994

**Project Title:** Chernobyl Studies  
7.2F Thyroid Studies

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-16

**Principal Investigator:** Lynn Anspaugh

**M&O Contractor:** Lawrence Livermore National Laboratory

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*Address each item, if applicable.*

- I. **Project Objective**
- II. **Current Project Status / Monthly Progress**
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. **Significant Problems/Issues/Concerns**
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. **Assistance Required of EH-40 Staff**
  - Identify EH-40 staff member(s) with each requests.

## I. Project Objective

To develop and implement a long term epidemiology study to detect thyroid disease among persons, especially children, who were exposed to the iodine radionuclides during and/or following the Chernobyl accident. (1) Develop a clinical surveillance program for a large fixed cohort of known tissue dose, particularly in children, (2) and agree on procedures for detecting thyroid dysfunction, methods to define and reconstruct exposure levels and doses, and ways in which standardization of procedures and quality control might be assured, and (3) identify and facilitate needs for training, equipment and supplies to conduct the study.

The primary goals at this time are to conduct case-control and cohort studies of childhood-thyroid cancer in Belarus and Ukraine.

The epidemiological aspects of these projects are being undertaken by scientists at the National Cancer Institute, who are assisted with funding from the Department of Energy, Office of Health. The goal of the work described here is twofold: (1) to provide radiation doses to the thyroid for the Ukrainian and Belarussian individuals to be studied (this work is being performed by Ukrainian, Belarussian, and Russian scientists with the advice and assistance of Lynn Anspaugh and André Bouville of the National Cancer Institute) and (2) to provide

material and equipment to the Ukrainian, Belarussian, and Russian scientists to aid in the overall aspects (including clinical) of the studies.

## II. Current Project Status / Monthly Progress

Lynn Anspaugh and Sheilah Hendrickson participated in several equipment and programmatic meetings and discussions regarding the "Scientific Protocol for the Study of Thyroid Cancer and Other Thyroid Disease in Belarus Following the Chernobyl Accident" with DOE, NCI, and other member of the US team participating in this study. Also included was a meeting with the United Nations recognized Children of Chernobyl Relief Fund to determine if there were any working areas of overlap where we could possibly assist each other.

Lynn Anspaugh with a delegation of US dosimetrists and epidemiologists met with Ukrainian and Russian scientists working on the case-control and cohort studies of childhood-thyroid cancer among children exposed to fallout from the Chernobyl accident. With the Ukrainians, we continued to develop the dosimetry support needed for studies of childhood-thyroid cancer and for the studies of leukemia and cataracts in liquidators. With the Russians, we continued our efforts to supply radiation doses for the children in the case-control study of thyroid cancer in Belarus. See attached foreign trip report.

## III. Significant Problems/Issues/Concerns

Sheilah Hendrickson continues to work through the multiple administrative issues with LLNL, EH-40 staff, Office of the Assistant Secretary for Environment, Safety and Health, and DOE Oakland Office, that are associated with the purchase and delivery of equipment and supplies to Belarus. This is for the equipment and supplies for the Belarussian Minister of Health as called out in the "Scientific Protocol for the Study of Thyroid Cancer and Other Thyroid Disease in Belarus Following the Chernobyl Accident" for the Belarussian cohort study. Until this process is complete, we are unable to purchase and provide equipment and supplies to Belarus.

## IV. Assistance Required of EH-40 Staff

See Section III above.

## FOREIGN TRIP REPORT

Lynn R. Anspaugh

Risk Sciences Center  
Health and Ecological Assessment Division  
Environmental Sciences Directorate  
Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

June 2, 1994

## SECTION A: SUMMARY

a. Traveler

Lynn R. Anspaugh, Director, Risk Sciences Center  
(510) 424-6409  
Health and Ecological Assessment Division  
Environmental Sciences Directorate  
Lawrence Livermore National Laboratory  
University of California  
Livermore, CA 94551-9900

June 2, 1994

b. Dates and Destinations

4/10/94-4/15/94      Scientific Centre for Radiation Medicine and  
other Institutes, Kiev, Ukraine

4/16/94-4/19/94 Institute of Biophysics, Moscow, Russia

c. Purpose of the Trip

The purpose of the trip to Ukraine was to continue work on developing dosimetry support needed for case-control and cohort studies of childhood-thyroid cancer and of studies of leukemia and cataracts in liquidators. The purpose of the visit to Russia was to continue joint efforts to supply radiation doses for the children in the case-control study of thyroid cancer in Belarus.

d. Abstract

Most of the time in Ukraine was spent with Prof. Likhtarev of the Department of Dosimetry and Radiation Hygiene. Dr. André Bouville, National Cancer Institute, and I discussed our future work with Ukrainian scientists in dosimetry research; this work will form the basis for doses for four planned epidemiological studies. In this regard, we discussed and planned for the further modification of our joint Protocol on Dosimetry Research; this protocol is being developed following the agreement between DOE and the Ukrainian Minister of Health. We also developed modified outlines for papers that we are jointly preparing. We visited the National Registry to learn more about their possible role in epidemiological studies. In Moscow we continued our discussions with the Russian scientists who are supporting the joint efforts to supply doses for the Belarussian childhood-thyroid-cancer study. These initial dose estimates have now been completed and forwarded to the epidemiological scientists for their further analysis.

## SECTION B: TRIP REPORT

### a. Purpose of the Trip

The purpose of the trip to Ukraine was to continue work on developing dosimetry support needed for case-control and cohort studies of childhood-thyroid cancer and of studies of leukemia and cataracts in liquidators. The purpose of the visit to Russia was to continue joint efforts to supply radiation doses for the children in the case-control study of thyroid cancer in Belarus.

### b. Summary of Activities

#### MEETINGS IN UKRAINE

Dr. André Bouville, U.S. National Cancer Institute, and I spent most of our time at the Department of Dosimetry and Radiation Hygiene at the Ukrainian Scientific Centre for Radiation Medicine where we discussed dosimetric matters with Prof. Ilya Likhtarev and Dr. Leonilla Kovgan. We also spent a few hours at the National Registry with Dr. Shuljenko (Director of the Registry), had a short meeting with Dr. Romanenko (Director of the SCRM), and a business lunch with Dr. Olga Bobylova (Ukrainian Ministry of Health, Head of Department, Chernobyl Problems).

During the same week, Dr. Roy Shore and Alexander Forowicz worked at the Institute of Endocrinology and Metabolism, headed by Acad. Nikolai Tronko, on the epidemiological aspects of the thyroid-case-control study. The U.S. delegation was therefore divided into two groups with almost completely separate schedules. We were only together, for business reasons, at the National Registry and for a discussion on the selection of controls for the thyroid-case-control study with Ilya Likhtarev and Boris Sobolev.

There was a good atmosphere of cooperation between the U.S. and Ukrainian scientists. We also spent most of our evenings with our Ukrainian counterparts. Although Olga Tsvetkova (Ukrainian employee of the U.S. National Cancer Institute) kept a low profile, she was very effective in finding solutions to our operational problems.

#### DISCUSSIONS AT THE DEPARTMENT OF DOSIMETRY AND RADIATION HYGIENE.

The main topics of discussion at the Department of Dosimetry and Radiation Hygiene were:

- the thyroid case-control study,

- the dosimetry project,
- the cataract study,
- the leukemia study,
- the joint publication on internal irradiation,
- the joint publication on external irradiation.

### Thyroid Case-Control Study

There are now about 400 cases of thyroid cancer among Ukrainian children (280 girls and 120 boys). In the three Ukrainian Oblasts that were most exposed to Chernobyl fallout, there were 136 cases of thyroid cancer among children (19 in Chernigov Oblast, 11 in Gitomir Oblast, and 106 in Kiev Oblast). It would therefore seem that the study could be limited to those three Oblasts. The list of cases was to be established by Dr. Tatiana Bogdanova with Roy and Alexander. Only eleven cases had direct thyroid measurements immediately following the accident.

Irina Kairo and Boris Sobolev told us that they have estimated thyroid doses for all settlements in those three Oblasts. Those doses, based on the information derived from thyroid measurements, are determined from the  $^{137}\text{Cs}$  deposition, the polar coordinates of the settlement relative to the Chernobyl reactor, and the age class of the individual considered; the doses are the equivalent of the passport doses established for settlements in Belarus. More refined doses (individualized doses) could be obtained from personal information derived from interviews. Responses from questionnaires have been collected for 40,000 people, out of which 35,000 have been computerized. The information provided, however, is of poor quality.

For the purpose of the case-control study, thyroid doses could be obtained very quickly. The validity of those doses is a matter that has not been explored.

With regard to the selection of controls and the organization of the study, there were differences of opinion between the Ukrainian dosimetrists and the U.S. epidemiologists. The Ukrainian dosimetrists would like to select the controls from the thyroid-dosimetry database, whereas Roy Shore would like to use the Belarussian study as a model. Ilya Likhtarev would like to be in charge of the organization of the study, whereas Roy Shore is more inclined toward Prof. Tereschenko (Tronko's deputy). Who would handle the questionnaires was not clear either. It seems clear that a protocol or operations manual should be established quickly and approved by all interested parties in order to avoid chaos or future confrontations.

It is anticipated that Dan Hryorschuk will go to Kiev in July to continue the work undertaken by Dr. Shore. In order to assure continuity, he will be accompanied by Alexander Forowicz and by one or two dosimetrists (Anspaugh and/or Bouville). The exact dates of that trip need to be established soon as many Ukrainians intend to be on vacation during part of July.

Among other news, Gulko (former Head of Thyroid Dosimetry in Likhtarev's Department) left for Germany at the beginning of April. He obtained enough funds (from the EU?) to work for five months at GSF in Paretzke's Institute on thyroid-dose reconstruction. Irina Kairo is now the senior thyroid dosimetrist; she is interested in using  $^{129}\text{I}$  to reconstruct doses from  $^{131}\text{I}$  and asked Lynn whether the Ukrainian soil samples that were taken to Livermore had been analyzed for  $^{129}\text{I}$ . She provided for the first time a list of the locations from which the soil samples had been taken.

#### Dosimetry Project

Prof. Likhtarev understands very clearly that dosimetry is an essential component of the epidemiological studies planned or undertaken in Ukraine. He gives priority to the development of a dosimetry project that would be under his responsibility. This agreement was also negotiated by the Ukrainian Ministry of Health during his recent visit to DOE Headquarters.

The dosimetry project would include all research necessary to evaluate doses from the Chernobyl accident to clean-up workers and members of the public in a better way than is currently available and would focus on the estimation of individual doses required in the epidemiological studies that are planned or have been undertaken. The dosimetry project would cover biological as well as physical dosimetry. A draft protocol had been prepared by Anspaugh in December 1993. This protocol needs to be completed with data on organization, management, personnel, equipment, and supplies. Some information, notably on equipment and supplies, was provided during this visit. Current plans are to prepare a complete draft protocol before July and to discuss it with the Ukrainians during our planned visit in July.

The future visit of Prof. Likhtarev to LLNL was discussed and the invitation reaffirmed. While in Livermore, Prof. Likhtarev would work on the dosimetry project and in continuing the preparation of papers for publication. Tentative plans are for Prof. Likhtarev to go to Livermore in mid-September 1994.

We also learned that the EU is becoming more and more active in the area of dosimetry. For example, the purpose of project ECP10 is a comparison of physical and biological methods for dose reconstruction, while the project

JSP5 covers models of environmental transfer of radionuclides and the estimation of doses from external and internal irradiation, as well as problems of uncertainty analysis. The EU is sponsoring a workshop on dose reconstruction methods, which will take place in Bad Honnef, Germany, from 6 to 9 June 1994, and the First International Conference of the European Union, Belarus, the Russian Federation and Ukraine on the Consequences of the Chernobyl Accident that will be held in Dresden, Germany, from 12 to 16 June 1995.

### Cataract Study

The protocol for the cataract study is under scientific peer review in the U.S. Anspaugh and Bouville were asked by Prof. Basil Worgul, Columbia University, to provide comments to DOE (Ed Washburn) on the dosimetric aspects of the protocol. Such comments have been forwarded.

We had an interesting meeting with Dr. Vadim Chumak, who is the dosimetrist in Likhtarev's Department (Repin's group) in charge of the dosimetric aspects of the cataract study and who speaks English well. Dr. Chumak appears to be a very good scientist. He is working on the technique of electroparamagnetic resonance of tooth enamel as a means of biological dosimetry. Dr. Chumak gave us data on one of Likhtarev's teeth, these data will be compared with the dosimetric data determined by the FISH technique by Drs. Straume and Lucas on a blood sample drawn from Likhtarev.

### Leukemia Study

Prof. Likhtarev believes that the leukemia study has very little scientific value and does not want to be involved in it. Viktor Repin is maintained as the Ukrainian dosimetrist.

The overall study was also discussed with Dr. Romanenko (see below).

The situation regarding biological dosimetry is not completely clear. Our understanding is:

- ESR will be performed on the teeth of clean-up workers by Repin for the leukemia study and Chumak (who works for Repin) for the cataract study. They have so far analyzed 250 teeth from clean-up workers and found doses greater than 0.2 Gy for only 15% of those people. Joint study with Ukrainian scientists on the ESR technique in the U.S. is not desired before the leukemia protocol is signed. Anspaugh recommends that any such studies be done at the University of Utah (Ed Haskell);

- the GPA technique is not very popular in Ukraine. Maria Pilinskaya, who will participate in the biological dosimetry studies, wants to perform any such studies in Ukraine, and she and others do not want merely to be a source of material for U.S. researchers. There appears to be a reservoir of bad feeling on this subject;
- the FISH technique is also being developed by Maria Pilinskaya, and we hope to achieve a significant collaboration with Drs. Straume and Lucas at LLNL. She was planning to send in the next few days 12 blood samples to Tore Straume for analysis. Maria Pilinskaya was invited by Lynn Anspaugh to spend some time with Tore Straume before, during, or after the Health Physics meeting in San Francisco; she was also invited to extend her visit to the U.S. for three weeks by Neil Wald. In addition, we learned that a FISH laboratory, not related to our studies, might be set up in Kiev by the Houston people (?) for Dr. Bondyar who spent a few months in Houston to be trained on the FISH technique,

### Joint Publication On Internal Irradiation

The main purpose of the joint publication on internal irradiation is to compare the dose estimates obtained from measured  $^{137}\text{Cs}$  concentrations in foodstuffs (milk, potatoes, forest products, etc.) and from measured whole-body burdens. This comparison should provide valuable information on the efficiency of countermeasures used to reduce  $^{137}\text{Cs}$  doses from internal irradiation. The paper will focus on the measurements from two Oblasts: Gitomir, where countermeasures are known to have been applied, and Rovno, in which countermeasures were minimum or nonexistent.

The processing of the data on whole-body burdens is essentially complete. The data available on  $^{137}\text{Cs}$  milk concentrations in Ukraine are only for the years 1991 to 1993. However, it is known that data for the years 1986 to 1990 are kept in notebooks at the Ministry of Health and may be made available for "official" use. Ilya Likhtarev will, in the next few days, attempt to get hold of those data, and, if his efforts are successful, will begin to process the data.

The following outline was accepted for that publication:

#### A. INTRODUCTION

1. Purpose of paper
2. Description of accident and post-accident situation

#### B. DESCRIPTION OF MODELS

1. General scheme of models
2. Estimation of daily intake of  $^{137}\text{Cs}$  using the  $^{137}\text{Cs}$  concentrations in foodstuffs as a basis ( $q_{\text{ref}}(t) = \sum C(i,t) \cdot CR(i)$ )

3. Estimation of daily intake of  $^{137}\text{Cs}$  using the  $^{137}\text{Cs}$  body burdens as a basis ( $q_{\text{real}}(t) = a_1 \exp(-\lambda_1 t) + a_2 \exp(-\lambda_2 t)$ )
4. Estimation of the doses from radiocesium on the basis of the daily intake of  $^{137}\text{Cs}$
5. Estimation of the doses from radiocesium on the basis of the body burdens of  $^{137}\text{Cs}$

#### C. PARAMETER EVALUATION (MEAN $\pm \sigma$ ; PARAMETER DISTRIBUTION)

1. Concentrations in foodstuffs
2. Food-intake values
3. Rate of disappearance from food ( $\lambda_1, \lambda_2$ )
4. Whole-body counter data and  $a_1 + a_2$
5. Dose-conversion factor

#### D. RESULTS AND DISCUSSION

1. Comparison of  $q_{\text{ref}}$  and  $q_{\text{real}}$
2. Derivation of countermeasure parameters
3. Comments on the body burdens
4. Comments on the dose

#### E. CONCLUSIONS"

We agreed on the following deadlines:

- end of April (meeting in England between Bouville and Kovgan): skeleton of paper to be provided by Lyna Kovgan; [in fact, Lyna only reported that the data on Rovno were readily available and were being processed; the data for Gitomir seem to be more difficult to obtain];
- end of May (meeting in France between Bouville and Likhtarev): first complete draft to be provided by Ilya Likhtarev;
- July (meeting in Ukraine): final draft to be approved by participants.

#### Joint Publication On External Irradiation

The joint publication on external irradiation was briefly discussed. Its main purpose is to use the available time series of exposure-rate measurements to derive information on the distribution of radionuclides deposited on the ground as a function of direction and distance from the Chernobyl reactor. The current draft is in relatively good shape. A revised draft will be prepared by Bouville to be discussed in July. Bouville will need some information from Anspaugh (long-term migration of  $^{137}\text{Cs}$  in U.S. soils) and from Kovgan (Taifun data for the first day after the accident). The paper will be presented at the workshop on external irradiation that Anspaugh and Beck plan to

organize at EML in August or September (possible foreign participants: Balonov, Likhtarev, Savkin, Jacob).

#### MEETING WITH DR. ROMANENKO.

Dr. Romanenko is very much interested in the leukemia study. He acknowledged the receipt of the revised draft protocol from Gil Beebe and indicated that his comments on the previous draft were almost completed. [They were given to Bouville by Lyna Kovgan in England and transmitted to Beebe.]

Dr. Romanenko was very critical of the GPA technique of biological dosimetry and concerned that this technique was given prominence in the draft protocol. He was told that one of the purposes of Phase I of the study was to test different techniques (FISH, ESR, GPA, along with physical dosimetry) in order to establish how the doses can be best estimated in Phase II. He seemed to be convinced that the U.S. was not trying to privilege the GPA technique. He indicated that he was doubtful about the validity of the results obtained for the liquidators from the Baltic States, that he could not establish a cooperation with Ron Jensen, and that work on biological dosimetry should be conducted in parallel in the U.S. and Ukraine (with new laboratories in Ukraine).

Dr. Romanenko expressed the wish that a meeting be organized in September to finalize the protocol. He indicated that WHO was making preparations to embark on a new program and that he could not refuse to collaborate with WHO; in order to avoid conflicts between the two programs, the U.S. should act quickly.

He expressed the wish to meet Dr. Bruce Wachholz in July, if Bruce were to go to Kiev during that month.

#### VISIT AT THE NATIONAL REGISTRY.

On 14 April, we visited the National Registry (Director: Volodomir B. Shuljenko). There are records for about 400,000 people in the Registry, divided into four categories:

- liquidators,
- evacuees,
- residents in controlled areas, and
- children.

It was acknowledged that the dosimetric information in the National Registry is not of good quality.

The goal is to include 3.5 million people in the National Registry. Data are received from the oblasts, the raions, and other organizations (Ministry of Defense, Ministry of Internal Affairs, Academy of Medical Sciences, etc.). Data are communicated by E-mail as much as possible. The role of the 40 sanitary-epidemiological stations scattered throughout the country is important for this process. Dr. Shuljenko gave us free access to his files, but could not provide written information to us during the visit. He promised to send us the following information, which we had requested from him, via Olga Tsvetkova:

- a copy of the input forms,
- the number of liquidators in the National Registry broken down according to year of work (1986, 1987, etc.), and
- the number of thyroid-cancer cases in the Registry, by oblast.

Dr. Shuljenko made clear that the cooperation with the U.S. was very important and requested, within that framework:

- the modernization of his equipment,
- legal software, and
- one-month training in the U.S. of the computer people.

Salaries at the Ministry of Health are very low, so that Dr. Shuljenko finds it difficult to keep good computer people. In fact, it seemed fairly obvious that they had substantially more room and computer terminals than they had people to occupy them. They also had a large main-frame Russian made computer, which appeared not to be working.

#### MEETING WITH DR. E. GARGER

At the request of Dr. Evgenii Garger, Director of the Institute of Radioecology, Dr. Anspaugh visited this Institute briefly. Discussions were held concerning the status of the not yet completed paper being prepared by Dr. Garger and Dr. Shinn of LLNL. They had worked on this paper during recent meetings in Oak Ridge, but the completion is awaiting more work by the two authors.

Dr. Garger also had followed Anspaugh's suggestion of long ago to secure data relating to the resuspension of aerosols immediately following the accident. Garger had secured two good sets of data, and has made substantial progress

in analyzing them and comparing them to the more popular current models of resuspension. The results seem to indicate that the some of the currently used models are very conservative. Dr. Garger proposed to continue work on this paper and invited Anspaugh to be a co-author. This invitation was accepted with the understanding that it would have to be a small effort, as the resuspension work is now considered to be completed. However, the data on resuspension at early times are more important than the other work that has been done on the resuspension at later times, and it seems important to pursue this additional information and to see that it is properly analyzed and published.

#### MEETING WITH OLGA BOBYLOVA.

During the last day of our visit in Kiev (Friday 15 April), Olga Tsvetkova invited Olga Bobylova (Department Head within the Ministry of Health) to have lunch at her apartment with Anspaugh and Bouville. During that lunch, we discussed:

- the status of the Thyroid Cohort Study Protocol: we made it very clear that the delay in the scientific peer review was not NCI's or DOE's fault and that everything possible was being done to finalize the protocol very quickly; the possibility of Bruce Wachholz going to Kiev in June or July to discuss the scientific peer review and to prepare the submission to the Institutional Review Board was very well received;
- the status of the Leukemia Study protocol: We gave a summary of our meeting with Romanenko and of our visit at the National Registry. Olga Bobylova did not show much interest;
- Olga Bobylova's opinion concerning Battelle's involvement in our cooperative studies: she indicated that the Health Ministry neither has the time, the money, nor the manpower to work with Battelle. She indicated resentment that Battelle's goal appears to be to sell data from the National Registry. It seems likely that her opinion reflects that of the Minister.

#### MEETINGS IN RUSSIA

Drs. Anspaugh and Bouville proceeded to Moscow to meet with the personnel at the Institute of Biophysics. Most of our time was spent with Drs. Valeri Khrusch, Yuri Gavrilin, and Sergei Shinkarev, who are being paid by the Belarussian Minister of Health to assist with the calculation of thyroid doses for the epidemiological studies being done in Belarus.

Our primary goal was to discuss the calculations of thyroid dose that are being done for the children in the thyroid-cancer case-control study. Our Russian

colleagues had, in fact, completed the calculations for all of the 119 cases and the 238 controls according to the agreement reached during our February meeting in Minsk. This agreement essentially was to treat all of the cases and controls the same (in a dosimetric sense), regardless of the more complete information available for some of the cases. This "minimum level dosimetry" had been specifically requested by the epidemiologists. Our Russian colleagues did, in fact, provide the requested calculations and, in addition, also provided their best estimate based on more complete information where available. This information was provided to us, and this has now been provided to the U.S. epidemiologists for their further use.

We also discussed extensively the procedures that had been used to make these calculations. The basis of the reconstruction is the derivation of the thyroid dose in relation to the ground-deposition density of  $^{137}\text{Cs}$  and the ratio of  $^{131}\text{I}$ -to- $^{137}\text{Cs}$ . It is disheartening that this relationship does not pass through zero, and that there is enormous scatter in the data. After long discussions and other runs of the existing data, we agreed that there was nothing better that could be done within the limits of the current data and the time available. We agreed further to continue work together on this important problem and to process some of the data, so that papers for scientific peer review could be prepared and published.

During our visit to the Institute of Biophysics, we also made brief visits to Dr. Angelina Guskova and Acad. Leonid Ilyin.

Dr. Guskova is the physician who treated the patients most severely afflicted with acute radiation syndrome following the accident at the Chernobyl Nuclear Power Station. Drs. Anspaugh and Bouville have known her for many years, due to their common attendance for many years at the annual meetings of the UNSCEAR. Dr. Guskova indicated that she is still following many of these Chernobyl patients. She also stated that she worked at MAYAK for ten years; she showed us a list of former workers there that she is still actively following. The yearly and cumulative doses on this list were surprisingly large. Many of the annual doses were above 100 rads, and the cumulative doses were frequently in excess of 400 rads.

In spite of the fact that Dr. Guskova knows very well that we are not physicians, she took pleasure in showing us some of her patients. She treated all of them with great affection and respect, and they obviously love her. One patient had been badly burned by radiation exposure of his hand; several fingers had been lost and work on reconstruction was continuing. Another patient had suffered from the passage of a highly focused beam through his head.

Dr. Guskova also introduced us to Dr. Baronov, a well-known hematologist who does bone-marrow transplants. Together they showed us a young man

who had been irradiated with 12 Gy and had then received a bone-marrow transplant as treatment for leukemia. This appears to be a fairly routine treatment at this hospital. The young man was in good condition and good spirits, although he obviously was still quite ill and had not yet recovered from the irradiation.

We also visited with Acad. Ilyin, whom we also know from UNSCEAR. He is Director of the Institute of Biophysics and formerly enjoyed tremendous prestige within the USSR. Now his Institute is under severe financial constraints and space is being rented to commercial tenants. Dr. Ilyin was quite cordial to us. He did, however, express some skepticism that radiation was indeed responsible for all a large increase in thyroid cancer in Belarus and Ukraine. His reasons were as follows:

- Why should there be an increase only in Belarus and Ukraine, but not in Russia, where exposures were also high. Perhaps there is some problem related to ascertainment or to some other confounder.
- Other factors may be at least partly responsible for any impact. He specifically mentioned that he believed that there had been large doses of stable iodine administered in Belarus long after the accident. He also stated that large doses of selenium had been given to children in Belarus.

c. Traveler's Role

My role is described above in Part B. Dr. Bouville and I are the two U.S. dosimetrists working within the context of cooperative studies of the epidemiology of radiogenic cancers in Ukraine and Belarus following the Chernobyl accident.

d. Recommendations

Our joint studies are progressing well, and should be continued. Some bureaucratic activities are proceeding too slowly, however, and should be speeded up. All protocols should be completed as quickly as possible.

e. Information Pertinent to Energy Postures

None.

f. Security-Related Concerns

None.

## SECTION C: APPENDIX

a. Itinerary

4/9/94	Left Washington
4/10/94	Arrived Kiev via Frankfurt
4/11/94	Business began
4/15/94	Left Kiev
4/16/94	Arrive Moscow and begin business
4/20/94	Left Moscow and arrived Washington via Frankfurt

b. List of Persons contacted

See Section B.b.

c. Literature Acquired

Several Russian papers on thyroid dosimetry.

## 7.2G – LEUKEMIA STUDIES

**EH Monthly Detailed Summary**  
**Chernobyl Studies: Summary of Financial Status**  
(1,000 Dollars)

**Project:** 7.2G Leukemia Studies (Lynn Anspaugh) LLNL No: 6288-12  
DOE No: 94-ES-1031

Cost Item	Months													Year-to-Date
	1993			1994										
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep		
Salary/Benefits							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Travel							0.0	0.0	3.2	0.0	0.0	0.0	0.0	3.2
Procurement and Expenses*							0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Technical Information Department							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Facility/Service/Distributed Charges							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LLNL Overhead+ /Taxes**							0.0	0.1	0.6	1.3	0.0	0.0	0.0	2.0
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	3.8	1.3	0.0	0.0	0.0	5.7
Liens/Preliens														
Budget	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	5.7	5.7		
Funds Available	80.0	80.0	80.0	80.0	80.0	80.0	79.5	79.4	75.6	74.3	0.0	0.5		
* Includes supplies; procurements; cost incurred from IUTs, ICOs, subcontracts														
** General & Administrative (G&A)														
+ LDRD; Division and Directorate Overhead, etc.														

## EH-40 Monthly Report

March—September 1994

**Project Title:** Chernobyl Studies  
7.2G Leukemia Studies

**DOE Project Number:** 94-ES-1031

**LLNL Project Number:** 6288-12

**Principal Investigator:** Lynn Anspaugh

**M&O Contractor:** Lawrence Livermore National Laboratory

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*Address each item, if applicable.*

- I. Project Objective
- II. Current Project Status / Monthly Progress
  - Administrative (meetings organized).
  - Technical accomplishments (research highlights, publications or presentations, services provided, deliverables).
  - Travel. Include copy of foreign trip report.
- III. Significant Problems/Issues/Concerns
  - Substantial changes in project expectations, protocol, funding.
  - Problems occurring or anticipated (corrective actions).
- IV. Assistance Required of EH-40 Staff
  - Identify EH-40 staff member(s) with each requests.

### I. Project Objective

Develop a protocol (study plan) for a systematic epidemiologic and etiologic study of the post-Chernobyl experience with leukemia. Obtain new information on time-response, dose-response and influence of dose rate on radiation leukemogenesis by conducting a project with the aims to (a) develop a leukemia registry to establish two cohorts (clean-up workers and fall-out victims) and plan a case-control study of clean-up workers; (b) standardize and validate diagnoses of leukemia, promote physical dose reconstruction, and explore the potential of biological dosimetry for a case-control study of clean-up workers; and (c) identify and facilitate ancillary training needs for selected former-Soviet Union scientists.

The primary goal at this time is to conduct a study of leukemia incidence among liquidators (or other highly exposed individuals) in cooperation with Ministry of Health officials in Ukraine.

The epidemiological aspects of this project are being undertaken by scientists at the National Cancer Institute, who are assisted with funding from the Department of Energy, Office of Health. The goal of the work described here is to provide radiation doses to the bone marrow for the individuals to be studied (this work is being performed by Ukrainian scientists with the advice and assistance of Lynn Anspaugh and André Bouville of the National Cancer Institute).

## II. Current Project Status / Monthly Progress

Discussions took place with the Ukrainians in Kiev in July regarding the protocol for this study. The revised version of this protocol is being translated into Russian and it is hoped that it could be ready and possibly completed for signing in October. As of September, the protocol is not ready and probably will not be completed and ready for signing until early in calendar year 1995. See attached June foreign trip report by Lynn Anspaugh.

Also see August foreign trip report by Lynn Anspaugh in Section 7.2F.

## III. Significant Problems/Issues/Concerns

N/A.

## IV. Assistance Required of EH-40 Staff

N/A.

## FOREIGN TRIP REPORT

Lynn R. Anspaugh

Risk Sciences Center  
Health and Ecological Assessment Division  
Environmental Programs Directorate  
Lawrence Livermore National Laboratory  
Livermore, CA 94551-9900

Contract No. W-7405-Eng-48

August 29, 1994

Approved by:



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V. Alan Mode  
Acting Deputy Associate Director  
Environmental Programs Directorate

8/30/94

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Date

## SECTION A: SUMMARY

a. Traveler

Lynn R. Anspaugh, Director, Risk Sciences Center  
 (510) 424-6409  
 Health and Ecological Assessment Division  
 Environmental Programs Directorate  
 Lawrence Livermore National Laboratory  
 University of California  
 Livermore, CA 94551-9900

August 29, 1994

b. Dates and Destinations

7/16/94-7/29/94

Scientific Centre for Radiation Medicine,  
 Kiev, Ukraine

c. Purpose of the Trip

The initial purposes of this trip were to continue work (with two U.S. epidemiologists) on the childhood-thyroid-cancer case-control study and to continue work on joint papers on dosimetry, particularly the protocol for dosimetry research. I also had an opportunity to continue some work on resuspension papers with Dr. E.K. Garger and to discuss work on the study of radiogenic eye cataracts in liquidators.

d. Abstract

The trip of the U.S. epidemiologists was canceled by the Ukrainian side at the last minute, so Dr. André Bouville and I focused on the preparation of papers on dosimetric research. Particular attention was given to the paper on internal dosimetry as guided by whole body counting of  $^{137}\text{Cs}$  and to preparation of the dosimetry-research protocol. I also met with Dr. E.K. Garger to discuss the completion of our work on the resuspension of toxic aerosols. Dr. Bouville and I also met with Drs. Basil Worgul and Cecily Medvedovsky of Columbia University and their Ukrainian counterparts concerning the protocol for research on an epidemiological study of radiogenic eye cataracts in Chernobyl liquidators.

## SECTION B: TRIP REPORT

### a. Purpose of the Trip

The initial purposes of the trip were 1) to continue work on the case-control study of the epidemiology of childhood-thyroid cancer caused by the exposure to radioiodine from the Chernobyl accident and 2) to continue work on dosimetry research with Prof. Ilya Likhtarev. I also met with other Ukrainian scientists, particularly Dr. E.K. Garger, to explore other work within the scope of Working Group 7 of the Joint Coordinating Committee on Civilian Nuclear Reactor Safety (JCCCNRS).

### b. Summary of Activities

At the last minute, Acad. Nikolai Tronko canceled the trip of the two U.S. epidemiologists, so Dr. André Bouville and I traveled to Kiev to continue work on the second purpose (listed above). By coincidence, two researchers (Dr. Basil Worgul and Dr. Cecily Medvedovsky) from Columbia University were also in Kiev at the same time to work on an epidemiological study of radiogenic eye cataracts. Thus, we also met with them and their Ukrainian counterparts, as Dr. Bouville and I are committed to help them in the dosimetric aspects of this study. I also visited with Dr. E.K. Garger of the Radioecology Institute to discuss the completion of some of our work on resuspension.

Most of our time was spent in preparing a joint publication that deals with the estimation of internal doses from radiocesium received by the inhabitants of the northern part of the Rovno Oblast. A central feature of this paper is the use of thousands of whole-body-counter measurements of radiocesium that have been made over several years. The data are being analyzed in order to develop a realistic dose-assessment model that inherently considers all of the dose-modifying factors that have been adopted formally by the authorities or informally by the people themselves. When we left Kiev, we had completed approximately 80% of the draft paper in good English; the remainder will be completed via electronic mail and express mail.

We also spent a substantial amount of time discussing and writing additional sections of the draft protocol on dosimetry research. This protocol is being prepared according to an agreement signed by the U.S. and Ukrainian Coordinators of Working Group 7: Dr. Terry Thomas (then of the Department of Energy) and Member of Parliament Yuri Spizhenko (former Minister of Health). We learned that Dr. Spizhenko has been invited for a visit to Canada in October and that he wishes to come to Washington with the idea of signing the protocols on the thyroid, leukemia, cataract, and dosimetry studies.

Drs. Basil Worgul and Cecily Medvedovsky of Columbia University were in Kiev to make progress on their study of eye-cataract formation in the liquidators. This is a fairly complex study, and three parts of it are being addressed to DOE, NIOSH, and NIE for possible funding. Dr. Bouville and I have agreed to participate in this study. We would be working on dosimetry with Prof. Likhtarev and his colleague, Dr. Vadim Chumak. The main person in Ukraine in charge of the overall study is Acad. Kondiev. All of us met at the Ophthalmology Institute for an extended discussion of this protocol; we also examined the equipment being used in the study of the liquidators' eyes. Separately with Likhtarev and Chumak, we also had extensive discussions of the dosimetry problems, which are very difficult due to the very short times of exposure to highly varying fields. We agreed that we should try to secure the help of Dr. Edward Haskell of the University of Utah, who is an expert on electron paramagnetic resonance analysis of teeth; we also agreed that the participation of Dr. Tore Straume was essential for this and the leukemia study.

I separately went to see Dr. E.K. Garger at the Radioecology Institute. We are preparing a joint publication on the validation of models of resuspension. Dr. Garger had completed most of a draft of this paper. We agreed to continue work on this paper, and to submit part of it for consideration at the IAEA International Symposium on Environmental Impact of Radioactive Releases to be held on 8-12 May 1995 in Vienna.

I also went to see Dr. Maria Pilinskaya (Dr. Olga Tsvetkova accompanied me), the cyto-geneticist who works at the Scientific Centre, but in a Department separate from Likhtarev's Department of Dosimetry and Radiation Hygiene. She had previously sent some samples of liquidator blood to Drs. Straume and Lucas at LLNL. I went through her laboratory. It is quite well equipped, although she expressed the need for a better fluorescent microscope and a continuing need for chemicals. We had previously discussed the possibility of a collaboration with her as part of our overall dosimetry work in Ukraine. She seems very willing to cooperate, but wants very much to be an equal partner and not just a supplier of blood to U.S. investigators. I assured her that our plan was to transfer our techniques of biodosimetry to her laboratory and that we hoped much of the work could be accomplished there.

During the course of our stay in Kiev, we had many other meetings and gathered other information. The more pertinent data are summarized below.

### Thyroid Study

This protocol is nearly complete. The Ukrainians gave Dr. Bouville a letter for Dr. Bruce Wachholz that contained their reactions to the most recent U.S.

Comments. Dr. Olga Tsvetkova is working on the Institutional Review Board issue; it seems that this protocol should be ready for signing in October.

Drs. Boris Sobolev and Irina Kairo gave us a draft paper that summarizes the current Ukrainian experience with childhood-thyroid cancers following Chernobyl and compares that experience to what would be expected using either the USNCRP or the GSF models. They asked Dr. Bouville and I to be co-authors of this paper, and they suggested that either Dr. Wachholz or Dr. Shore might also be a co-author. Dr. Bouville and I offered to help on the paper; after returning home I sent a letter to Likhtarev with mine and Dr. Bouville's comments on how to proceed with this paper. If published, this would be the first paper on the subject with solid data and with elements of a risk assessment. They had originally thought to publish this paper in *Nature*, but they seem to have troubles with one of the editors. I suggested *Science*, or, failing that, *Health Physics*.

It does not appear that much progress will occur on the case-control study unless the U.S. workers camp out in Kiev long enough to define precisely what is needed to be done and how to do it.

### Leukemia Study

This study and its protocol were discussed at a meeting with Profs. Romanenko (Director of the Scientific Centre) and Likhtarev and Drs. Tsvetkova, Bouville, and Anspaugh. Romanenko affirmed that he is now in charge of this study, and not Dr. Bebeshko. He also made it very clear that he is very disturbed with Likhtarev's unwillingness to participate. (Prof. Likhtarev later said that he did not realize that Romanenko was now in charge, and that he is now willing to cooperate.) The revised version of this protocol is now being translated into Russian, and there is strong pressure to have this protocol completed so that it could be signed in October during the projected visit of Spizhenko. Romanenko wants very much for a U.S. delegation to come to Kiev in September in order to iron out any remaining problems with this protocol. (Probable members of the delegation are Drs. Wachholz, Beebe, Finch, and Anspaugh.)

There are clearly problems with dosimetry in the current version of the leukemia protocol. Romanenko is very distressed about the glycophorin A (GPA) technique. He was initially upset about the claim that the early analyses of liquidators had shown that the doses were three or more times higher than the officially recorded doses. He subsequently learned that Dr. Jensen had admitted that this was a mistake, and this has reaffirmed his distaste for this technique and its proponents. He is flatly refusing to have anything more to do with it. I agreed that the GPA technique has the following serious drawbacks: 1) it only works on half of the population at best, 2) it is useless in terms of describing individual dose, and 3) its results

could be affected by the disease itself and certainly by the treatment of the disease. I suggested that the FISH technique has much more promise to be useful, although it too would have problems with treated leukemia patients. Prof. Romanenko is also distressed that the promise of one GPA investigator to set up the laboratory in Kiev to do the analyses has not been fulfilled.

Romanenko is clearly so antagonized over the GPA problems that it would seem to be in the best interests of the U.S. side to drop this issue. I personally strongly agree with Romanenko on this issue.

c. Traveler's Role

My role is primarily that of the U.S. Leader of Working Group 7 of the Joint Coordinating Committee on Civilian Nuclear Reactor Safety. In addition I am a member of the Task Groups on Thyroid Disease and Leukemia, and I am the Leader of the Task Group on Dosimetry Research. I have also been asked to assist in the dosimetry problems pertaining to the eye-cataract study.

d. Recommendations

We need to forge ahead and to complete the research protocols so that they could be signed during the projected visit of Yuri Spizhenko in October.

e. Information Pertinent to Energy Postures

None.

f. Security-Related Concerns

None.

## SECTION C: APPENDIX

a. Itinerary

7/14/94	Left San Francisco and arrived Washington
7/15/94	Washington business (EMAB); Left Washington and arrived Kiev
7/18/94	Business in Kiev began
7/28/94	Business ended in Kiev
7/29/94	Left Kiev and arrived Vienna
7/30/94	Left Vienna and arrived Washington
7/31/94	Left Washington and arrived San Francisco

b. List of Persons contacted

This information is provided in Part B.

c. Literature Acquired

Draft papers as discussed in Part B.