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1998
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9-11 September 1998

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Please note: Papers not received by press time for the Conference Proceedings were not included, however, EPA substituted the authors' abstracts for their missing papers when available.

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Session A, Track 1: Monitoring, Measurement, and Modeling I

Wednesday, September 9, 1998
10:45 a.m. - 12:35 p.m.

Chair: Gregg Dempsey, United States Environmental Protection Agency

Workshop Summary: Rapid Radioactivity Measurements in Routine and Emergency Situations

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ABSTRACT

While Europe is fascinated with the prospect of a rapid response to another Chernobyl-type incident, North America is more focused on rapid radioassay methods for environmental remediation and South America is concerned with the rapid determination of natural radionuclides. The UK, along with many of the other European countries, has an accident response plan. Planning for accident response will include three phases: a) <24 hour using a preestablished early warning survey system; b) about 24 hours to assure appropriate decision making for the quarantine of foods and water; and c) >24 hours for long-term implications. Under an accident scenario, logistics will be very important to assure appropriate distribution of samples, sufficient supplies for radiochemical analyses, data collation and interpretation. Regardless of the underlying reasons for needing rapid radioassay methods, it was generally felt by the Conference participants that the basic measurement tools were generally available. The natural growth of science will, of course, continue to evolve toward more rapid, simpler, less expensive and less polluting radioassay methods.

INTRODUCTION

Over the past decade, rapid radioanalyses have been called upon to provide initial evaluations of emergency incidence, and for ongoing assessments for environmental remediation and decontamination and decommissioning programs. It is timely to reflect on the current state-of-the-art and chart a course for a rational development of new investments in methods and instruments to meet future needs. The Conference on Rapid Radioactivity Measurements in Emergency & Routine Situations was held at the National Physical Laboratory (UK), co-sponsored by the International Atomic Energy Agency, International Committee on Radionuclide Metrology, and the Royal Society of Chemistry - Radiochemical Methods Group, to: a) define the state-of-the-art, b) document the results of the presentations and discussions, and c) develop recommendations on what should be improved and developed, the rational for these recommendations, and determine priorities (based on purpose, drivers, requirements). The conference was attended by representatives from Austria, Canada, Croatia, Czech Republic, Finland, France, Italy, Japan, The Netherlands, Norway, Republic of China, Russia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and the United States of America. Conference proceedings will be published by Fall '98, and selected papers will be published in

Radiochemistry and Radioactivity at the same time. Measurement issues included in the papers and posters presented are listed in Table 1.

DISCUSSION

Programmatic Issues

Emergency response is a high visibility issue in Europe because of Chernobyl. The major objectives for rapid radioanalyses are to identify and quantify the radionuclides present in order to assess the source term and potential doses to the most sensitive populations. Since the impact to food and environment must be accessed quickly, less accuracy can be tolerated, and the cost of the analysis is generally not an issue. In the EU, the regulatory limit for radioactive contamination in food is <1 kBq per kg.

Since 1987, the IAEA responded to requests by member states to help set up laboratories with rapid methods to monitor food supplies and the environment by providing a six-year Fellowship Training program to improve the accuracy of measurements and teach the principles of the measurement techniques. The participants, however, had varying agenda, depending of their site of origin (Emergency Response was the chief focus of EU participants, Remediation was the focus of those from South America, and Decontamination and Decommissioning (D&D) was the focus of those from North America).

Table 1. Conference Issues

Monitoring Programs	Survey Modes	Analytes	Matrices	Radiochemistry	Detectors and Instruments
France	Aircraft	Actinides	Air Filters	Sample Dissolution	Calibrations
Spain	Sea Floor	Activation Products (^{60}Co)	In-situ	Preconcentration	γ-Spectroscopy
UK	Vehicle	Gamma Scan	Bioassay	Bioavailability	ICP-MS
		Gross Alpha/Beta	Nuclear Waste	Column Extraction	Liquid Scintillation
			Soil		
		Fission Products (^{3}H, ^{14}C, Noble Gases, ^{90}Sr, ^{134}Cs, ^{137}Cs)		Ion Chromatography	Mobile Systems
			Swipes		
					Monte Carlo
		Natural Nuclides (Rn)	Urine	Method Validation	
			Water		SIMS

In the UK, LARMACC and RADMIL exemplify the local authority monitoring effort, while RIMNET is supported by the national Department of Environment, Transport and Regions (DETR) for international incidents. Each nuclear establishment and authority has the responsibility to have an emergency plan for preparedness that includes: a) radioanalytical laboratories, b) means to handle data flux, c) sample distribution, d) data methodology and evaluation, and e) means for interpretation of the data for the authorities. RIMNET consists of ninety-two automatic gamma ray sensitive Geiger-Müller detectors with associated data collectors throughout the UK which are accredited by external bodies, intercompared on a regular basis, and maintained on a regular basis. Resulting data are released into the public domain by the DETR.

The UK universities may contribute to the LARMACC/RADMIL/RIMNET systems but are not generally part of the decision process and are not generally set up for routine analyses. However, some universities, such as Southampton University, have begun to install rapid methods and set up laboratories under contract with local authorities. The rapid measurement requirements are generally not well defined (accuracy and minimum detectable activity, MDA), and will remain so unless a customer driven issue creates investment resources for their development, and for accreditation programs as well. Reporting of analytical results will be by the university investigators rather than a local or national authority.

The UK hospitals (and, indeed, many other laboratories) can input supplementary analytical data into the RIMNET database if approved to do so by DETR. However, it was suggested that these institutions be part of an ongoing intercomparison system to establish their baseline and demonstrate comparability.

It was also suggested that information is released from one central point to avoid confusion and conflicting assessments and statements.

Remediation, D&D and effluent release programs, on the other hand, are more concerned with determining the amount of radiation emitted and radionuclide content for regulatory compliance (surveillance, process control, process assessment, long-term monitoring) to control waste released from plant/site, and for environmental management. These programs are health regulation driven and measurements of minimal cost are desired. Measurement accuracy must be acceptable which is more important than analytical speed. High analytical throughput, however, is desired because of the economic incentive of fast turnaround times, potential for higher profit, ease of training analysts and robustness.

Investment of resources to develop and implement specific analytical methods are strongly influenced by a country's priorities. In South America, the emphasis for radioanalytical methods is primarily dictated by remediation and effluent release of natural radionuclides. North America focuses its radioanalytical methods on measurements on D&D and environmental remediation from nuclear weapon production and nuclear power; Europe has emphasized monitoring effluent release from nuclear reprocessing activities.

Derived Release/Emission Limits are estimated by: a) using the regulated dose limits for all radionuclides through multiple pathways, b) identifying critical exposed groups, c) identifying the most significant critical group per radionuclide, d) reducing the derived release/emission limit by a safety factor (100-1000), e) comparing the measured release to the reduced derived limit, and f) reviewing the procedure and limits periodically since the critical group can change. Population exposures to non-environmental sources are limited to 15-25 mRem per year per person in the U.S., < 1kSv per critical group per year in Canada, and < 0.4 Bq per gram in all matrices in the UK. In some countries, the reduced limits are managed on a per year basis. In other countries, the safety factor is continually increased as experience demonstrates that the increased safety factor is achievable and verified by measurements. When ICRP 60 is invoked, the reduced limits are further constrained because of the possibility of exposure to multiple sources. ICRP 60 recommends a limit of 0.3 mSv total exposure for the critical personnel.

As technology progresses, radioanalytical methods will evolve toward more convenient, faster, and cheaper techniques, and should be able to maintain measurement quality. Measurement issues include: a) establish criteria for accuracy and precision, b) performance testing and accreditation programs to establish credibility, c) define required MDLs, d) policy for handling negative numbers, e) statement of uncertainty that is easily understood by customers, and f) investment resources to establish and verify measurement methods

Selected Papers

The conference presentations were outstanding and addressed critical rapid methods issues. A few issues, particularly, should be highlighted to indicate recent progress. The references noted here are to be incorporated in the conference proceedings.

The Italians (De Felice et al. *The Validation of a National Standard for Rapid Measurement of Strontium Isotopes in Milk*) were the first to establish a national standard radiochemical procedure for the determination of ^{89}Sr and ^{90}Sr in milk for emergency situations. The paper describes the validation of the method through an intercomparison exercise, much like that used by the U.S. American Society for Testing and Materials (ASTM). The method was validated to $\pm$15 percent, and is sufficiently good for emergency situations.

Croudace et al. (*A Highly Efficient Technique for the Determination of Actinides, Particularly Plutonium and Uranium, in Soils Following a Borate Fusion*), Uchida & Tagami (*A Rapid Separation Method for Determination of ^{99}Tc in environmental Waters by ICP-MS*, and Tagami and Uchida (*Use of a Combustion Apparatus for Low-level ^{99}Tc Separation from Soil Samples*) focused on utilizing mass spectrometry-based measurements for long-lived radionuclides such as uranium, thorium, plutonium and technetium. It is anticipated that mass spectrometric measurements will demand the creation of new tracer Standard Reference Materials (SRMs) to meet their measurement needs.

Bojanowski et al. (*Sources of Bias in Rapid Methods for ^{89}Sr and ^{90}Sr Assay in Environmental Samples*), and Warwick & Croudace (*Review of Techniques for the Rapid Identification and Determination of pure β Emitters*) recognized the importance of measuring long-lived pure β-emitting radionuclides. Bojanowski's paper summarized sources of bias for the generally miserable measurement of radiostrontium isotopes. Over a dozen papers focused on the determination of ^{89}Sr and ^{90}Sr. Although there are several very good laboratories in the world that can probably reliably measure ^{90}Sr, there is a need to develop the capability to measure equally well many other pure β-emitter radionuclides.

Radionuclide speciation issues (Beresford et al. *The Comparative Importance of Bioavailability: An Assessment of Rapid Prediction Techniques to Determine the Bioavailability of Important Radionuclides for Transfer to Animal Derived Food Products Following a Contamination Event*) was not a major focus of the Conference because it is generally thought of as a secondary concern. However, this issue will become recognized for its utmost importance in understanding the source term, fundamental influence on strategies to be used for radiochemical measurements, and the effects it will have on a radionuclide's transport through the environment and food web.

Additional flexibility in calibrating gamma-ray spectrometers by computational tools is beginning to augment standards-based instrument calibrations (MacDonald et al. *In-situ γ-ray Spectrometry*, Likar et al. *Monte Carlo Calculations with GEANT for in-situ Measurements*, and Bronson *ISOCS: a Laboratory Quality Ge γ Spectroscopy System That you can Take to the Source for Immediate High Quality Results*). While the national standard laboratories can develop benchmark reference sources, the community requires increasingly diverse calibrations for their project/program-specific needs. The measurement community's research efforts to derive virtual calibrations must invest a focused effort to develop and validate its computational skills with increasingly complex benchmark standards.

CONCLUSION

Radioanalytical issues that need to be carefully addressed include:

- Communications between analysts and clients that include: planning, training, and establishing action levels.
- Screening methods that are important for early decision making.
- Routine measurements that balance turn-around-time, cost and quality. Under emergency situations, however, turn-around-time with as much quality possible overshadows the cost of the analysis.
- Rapid radioassay methods that must be supported by as much verification/validation, traceability, and quality assurance/control as used for routine measurements.

Future research will need to assure that only known amounts of quality is sacrificed while developing more rapid, simpler, less expensive and less polluting radioassay methods. If critical steps in a radiochemical method are to be eliminated, their effect on measurement quality must be quantified. As a result, additional efforts must be invested in the validation and verification of any new method.

Although a critical high-priority call for new research and initiatives will probably not be recommended to the International Atomic Energy Agency or International Committee for Radionuclide Metrology, there will be a need for coordinated development of Reference Materials for intercomparison studies and accreditation programs to validate and verify new and standard protocol radioassay methods and processes. Furthermore, additional effort should be placed on developing SRMs for screening measurements.

EPA's Environmental Radiation Ambient Monitoring System (ERAMS) Role in Post-Emergency Response

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INTRODUCTION

The U. S. Environmental Protection Agency is currently reconfiguring the Environmental Radiation Ambient Monitoring System (ERAMS). ERAMS is a national monitoring program which collects and performs radioanalysis on over 7,600 samples per year. EPA launched the ERAMS network in 1973 by consolidating a number of existing radiation monitoring networks.

These existing networks were mainly intended to monitor fallout. The ERAMS mission expanded to include monitoring radiation emergencies, following trends in environmental radioactivity levels, and providing data for dose calculations. Currently, ERAMS is the nation's only comprehensive radiation monitoring network, with over 300 sampling stations distributed across all 50 states and the American Territories. These stations regularly sample the nation's air particulates, precipitation, drinking water, surface water and milk, provide broad geographical coverage, and cover many major population centers. During its twenty five years of operation, ERAMS has been most successful in developing an environmental radiation database, providing information about weapons testing, and reporting on significant releases of radioactivity into the environment, such as the Chinese weapons tests of 1976 and 1977, and the Chernobyl incident in 1986. The overall responsibility for ERAMS falls under the EPA's Office of Radiation and Indoor Air (ORIA). The system is operated by the ORIA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

DISCUSSION

Mission Statement

The mission statement developed for ERAMS as a result of the ORIA reconfiguration efforts retains some of the elements in the original mission, but the primary focus is nuclear emergency preparedness. This focus is especially significant in light of current global politics, aging nuclear reactors in many parts of the world, and the potential threat of terrorist activities involving nuclear material.

The reconfigured ERAMS has the following mission: *To monitor environmental radioactivity in the United States and its Territories in order to provide high quality data for assessing public exposure and environmental impacts resulting from nuclear emergencies and to provide baseline data during routine conditions.*[2] This mission will be achieved by addressing three main objectives: (1) providing data for nuclear emergency response assessments; (2) providing data on ambient levels of radiation in the environment for baseline and trend analysis, and (3) informing the general public and public officials about levels of radiation in the environment. Although the primary objective of the proposed system is to provide data for the assessment of a national nuclear emergency in the short and long term, the ambient monitoring component is essential to maintain system readiness, competency, and high quality data. Both operational modes, energy and ambient, will provide information to the public and public officials.

ERAMS Reconfiguration

Based upon the mission and objectives, all elements of ERAMS, from sample collection through analysis, data reporting, and dissemination, were analyzed according to specific criteria. The conclusions that were developed resulted in recommendations for system changes designed to provide an optimized national radiation monitoring system.

Several factors guided the selection of media to be sampled in the proposed system. Paramount among these were the objectives of the system and the intended uses of the data generated. The following media selection criteria were developed: principal transport medium of radioactivity during a nuclear incident or release, short and long term indicators of health and environmental impacts, significant human pathway, Federal, State and Tribal interest in baseline data for comparison to facility and site monitoring, and concern by the general public and public officials. Based on these selection criteria, the following media were selected: air particulates, precipitation, drinking water, and milk. In addition, gamma monitors are proposed to provide real-time measurement capability to the system.

Given the resource requirements of sample analysis, a major consideration in determining sampling frequency is an approach that allows for minimal sampling frequency while ensuring the system meets its objectives. For air particulate sampling, the sampling equipment determines the sampling frequency, which in most instances would be twice weekly. For other media, the routine sampling frequency needed to maintain system readiness is judged to be two collections per year. In the event of a nuclear emergency, the sampling frequency would be increased to daily collections, with the exception of precipitation, which would be increased to each precipitation event.

The overall strategy for locating ERAMS sampling sites is based on the system's fundamental mission of supporting emergency and post emergency preparedness and response and developing national baselines and trends of environmental levels of radiation. This strategy, to the extent possible, will utilize the existing set of sampling sites. Air particulate, drinking water and precipitation sampling sites will provide for maximum major population and geographical coverage, and add U. S. border monitoring. Population coverage is further augmented by sampling at several population centers near major nuclear sites. Sampling sites for milk collection will focus on the top 20 milk producing states, which account for 85% of the milk consumed in the U. S. Real-time gamma monitors are proposed to be initially employed at each of the ten EPA regional offices and at ten U. S. border locations. Another influence on sampling site locations is the fact that all station operators are volunteers who have a limited range of geographical mobility.

Emergency and Post-Emergency Response

In the event of a major nuclear incident, data from ERAMS will be used to determine the immediate and long-term environmental and public health impacts. Specifically, in terms of public health, data from the monitoring system will be used for dose assessments. Depending on the results of the dose assessments, this information could be used by the EPA, States, and Tribal governments to protect public health by issuing warnings and protective action recommendations to the public. Other Federal agencies may also utilize the data for their respective roles during a nuclear emergency. Given the public's perception of radiation, the data will be used extensively to respond to public officials and the public. Since a major nuclear incident could potentially affect the world community, data users may include the governments of other countries and international organizations. EPA's role under the Federal Radiological Emergency Response Plan is long-term monitoring in the vicinity of an incident following control of the actual incident. ERAMS will assist in providing valuable data in support of this agency responsibility.

During a major nuclear incident, the EPA will place all or selected ERAMS stations on an accelerated status. The number of stations activated will depend on the type, location, and scale of the emergency. These stations will provide daily samples for analysis. The ERAMS stations will continue to operate on an accelerated status until radiation levels return to baseline levels. The data can then be compared to baseline data available in the ERAMS database and Environmental Radiation Data (ERD) reports. The ERAMS database and ERD reports provide valuable baseline and trend information used to determine elevated levels of radioactivity released to the environment during a radiological emergency.

The analytical schemes in the reconfigured ERAMS employ cost-effective screening methods, such as gross alpha and beta analysis, which are effective in measuring overall changes in the levels of radioactivity in the environment and detecting action levels to trigger more resource intensive radionuclide-specific analyses. For emergency and post emergency response, the screening methods will still be employed, but the number of nuclide-specific analyses will increase significantly. The type of nuclide-specific analyses performed will be based on the nature of the emergency, with priority given to radionuclides that are significant contributors to dose.

Results of analyses are compiled, reported and distributed quarterly in the ERD reports by NAREL. Sample composite analyses are performed and reported annually. An excerpt of an ERD air particulate composite report is provided in Table 1.[3] ERAMS data can also be accessed on the Internet at: "www.epa.gov/narel/erdonline.html".

Table 1. Plutonium and Uranium in Airborne Particulates, July-December 1994 Composites.

Location	^{238}Pu aCi/m^3 ±2σ	$^{239-240}Pu$ aCi/m^3 ±2σ	^{234}U aCi/m^3 ±2σ	^{235}U aCi/m^3 ±2σ	^{238}U aCi/m^3 ±2σ
VA: Lynchburg	0.2 0.3	0.3 0.3	131 10	3.4 0.8	10.6 1.5
VA:Virginia Beach	ND	0.1 0.2	13.9 1.4	0.8 03	12.7 1.3

CONCLUSION

The assessment of ERAMS has strongly affirmed the importance and need for a nationwide ambient radiation monitoring network, especially in the event of a major nuclear incident. The primary consideration in designing the proposed monitoring system is the assessment of public health and environmental impacts resulting from national and international emergencies. Since emergency and post emergency response is contingent upon a system being in place and operational at the time of an incident, significant design attention was paid to the routine operations of the system. Under the reconfigured system, ERAMS stations can efficiently be placed on an accelerated status, during an emergency. This will provide rapid sample collection and analysis, the data from which can then be compared to baseline and trend analyses data available in the ERAMS database and ERD reports. The reconfigured system also will provide real-time gamma measurement capability, increase population coverage, minimize expense, and make data evaluation results available electronically.

REFERENCES

1. U. S. Environmental Protection Agency (EPA), "Environmental Radiation Ambient Monitoring System (ERAMS) Manual". (EPA 520/5-84-007,008,009), May, 1988.

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3. U. S. Environmental Protection Agency (EPA), "Environmental Radiation Data Report 80". (EPA-402-R-97-003), February, 1997.

Combined Use of Modelling and Measurement Results in Post-Accidental Situation

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INTRODUCTION

Immediately following an accidental deposit of radionuclides in the environment, modelling is the only means of assessing the seriousness of the situation from a radiological viewpoint and deciding on possible emergency measures for the protection of populations. The ASTRAL software has been developed by the French Nuclear Protection and Safety Institute (IPSN) for this purpose. ASTRAL is an acronym for « radioprotection in post accidental situation ». It allows to assess rapidly the evolution of radionuclides concentrations in the environment and in the food chain, derive from that the potential internal and external exposure of concerned populations, forecast the evolution in time of this exposure and propose different scenarios of remediation actions in the contaminated zones. The starting point of the evaluations is the deposited surfacic activity (Bq/m2) of radionuclides which can be previously estimated using an atmospheric transfer model or air and rain water measurements. The results given by ASTRAL are then compared to the admissible limits and intervention levels. Different simulations of management of contaminated zones, by implementation of countermeasures may be conducted. So, the ASTRAL software constitutes an element of decision making as soon as the announcement of the accident is made (Maubert et al 97).

Fairly quickly after the deposits, measurements are made in the environment. ASTRAL can then be used to establishes the correspondence between the deposited surfacic activity and the specific activities of some selective representative products in order to draw a map of the mean surfacic activities.

The purpose of this document is to present the method using these two means of investigation applied in France for the characterisation of the deposit and the reconstruction of the doses following the Chernobyl accident (Renaud et al 97).

DISCUSSION

Description of the method and results

After the Chernobyl accident, the measurements on French territory were made starting in May, 1986 by various national agencies responsible for the inspection of agricultural commodities and livestock and for public health. The Office for Protection against Ionising Radiation (OPRI) is in

charge of the control of radioactive levels of different samples among which soil, plants and cow milk. Soil and plants measures are only representatives of local deposits and often vary on a wide range. With such natural variability, a great number of measurements is needed to assess the average surfacic activity of wide areas. Milk samples are of a greater interest. From spring to winter a cow grazes a surface of several tens of square meters per day. The sampling protocol used by OPRI specify that the milk is taken from district collection centers. Thus, these samples are representatives of a wide area at the scale of a French district (4000 to 8000 km2).
The interception and the retention of radionuclides by plants during deposits depends of the relative contribution of the wet (during rain) and dry deposits, as well as the amount of precipitation during the passing of contaminated air masses. Therefore, these parameters constitute the data to be supplied to the ASTRAL software before any estimate can be made. After the Chernobyl accident, from the 1st to the 5th of May 1986, air and rain water samples been measured. Derived from the that, the ratio between wet and dry deposits for ^{137}Cs and ^{134}Cs at a few locations have been estimated. They usually rank between 2 and 7, which shows a clear predominance of the wet deposit contribution : it corresponds to 66 to 88 % of the total deposit. There are, of course, places where precipitation was very low and for which dry deposits predominate (central France). It is eastern France, with precipitation in excess of 20 mm, which was most affected by the fallout. Many towns or locations received wet deposits exceeding 2,000 Bq/m2 of ^{137}Cs. The central strip received deposits seven times smaller on the average, resulting from an amount of rainfall under 10 mm. Western France, though having received more rain, was even less affected because of the depletion of the air masses in radionuclides (washing of the cloud).

With these data, ASTRAL can simulate the evolution of milk specific activities for different values of the deposited surfacic activity. As it has been shown in figure 1, it is then possible to classify the milk measurement results and their originating districts.

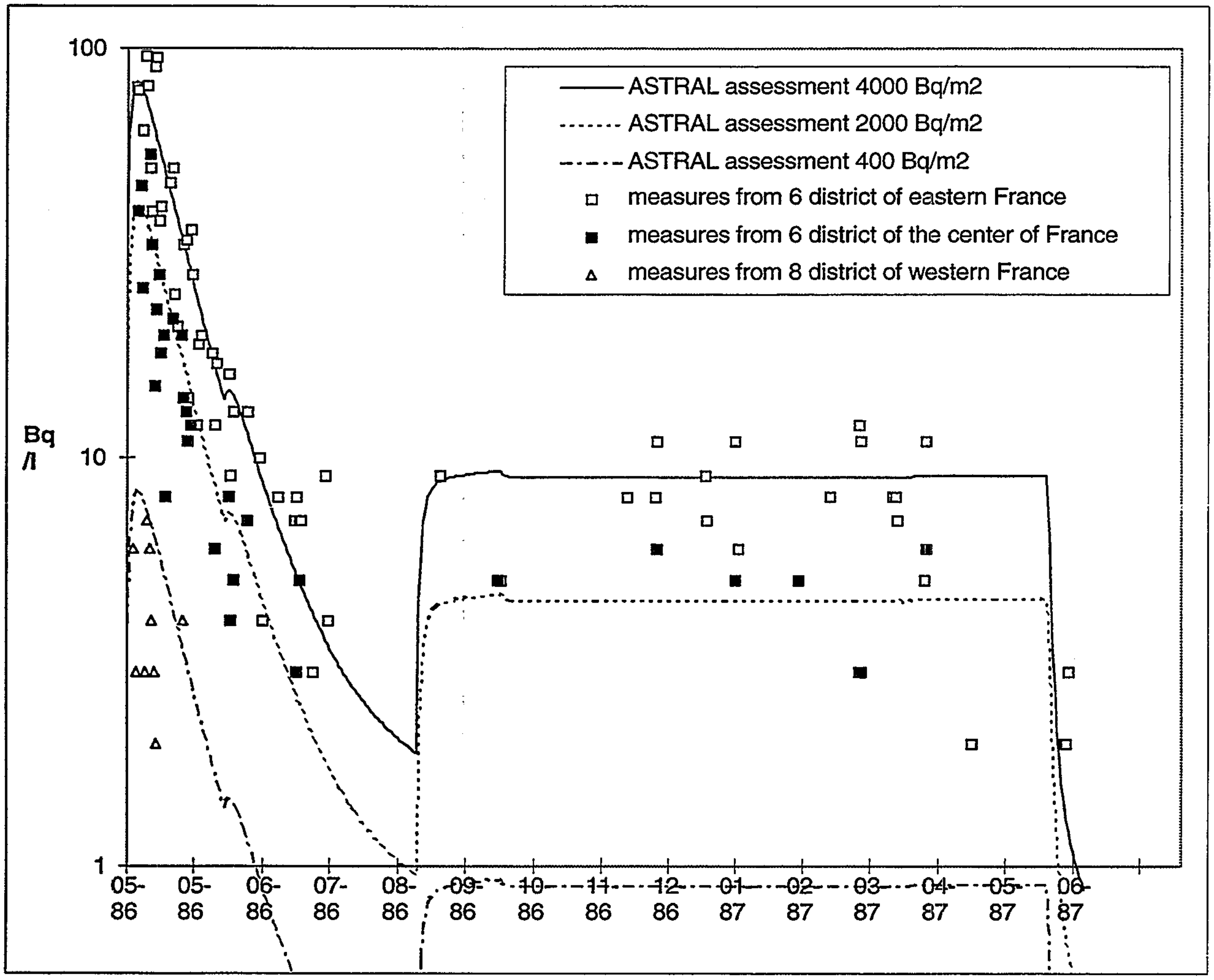
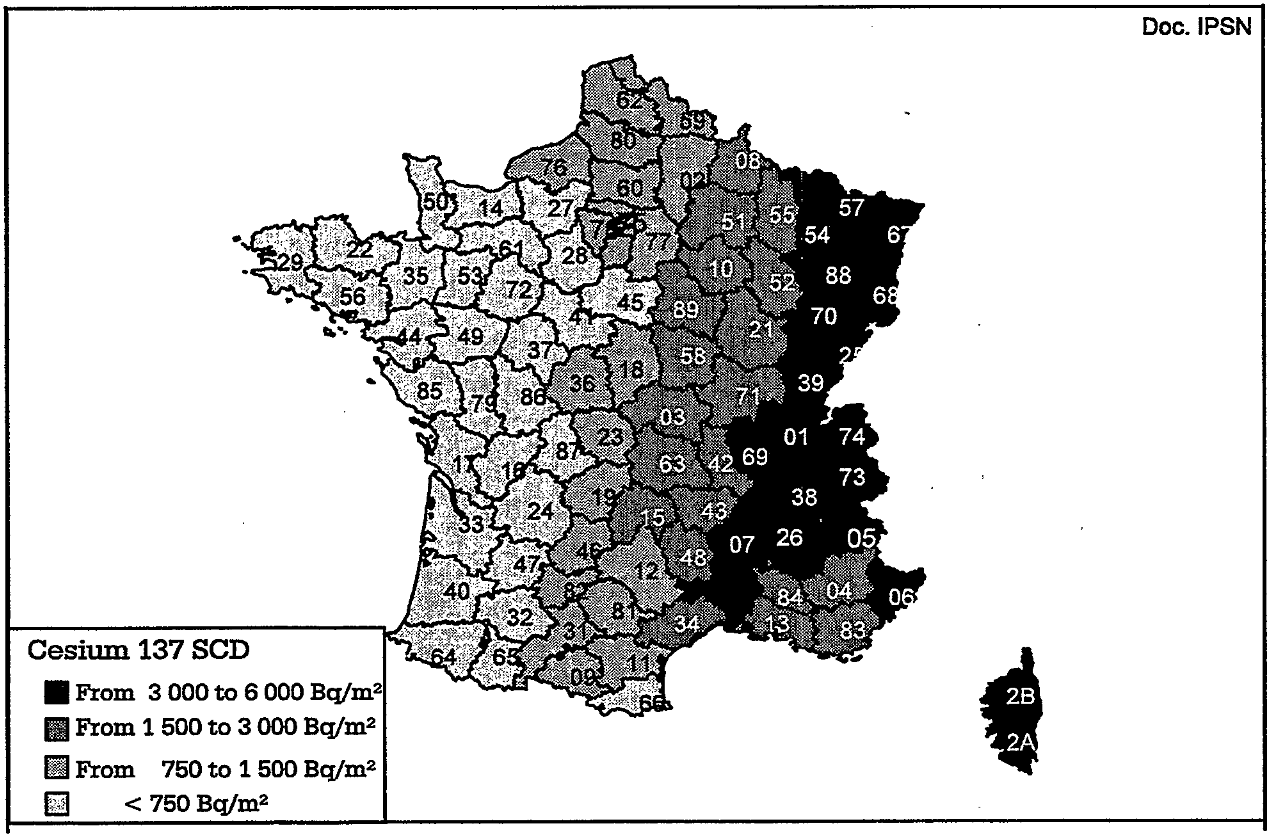


Figure 1 : Evolution of the concentration of cesium 137 in milk in different french districts and simulations given by ASTRAL for different corresponding deposits

This figure clearly differentiates between districts contaminated to a level of 3,000 to 5,000 Bq/m2 (eastern France), those less affected, with values of 1,000 to 3,000 Bq/m2 (center of the territory) and those with very low deposits. The scatter in milk measurements for a single district is fairly low given the time dependancy of the specific activity. These observed kinetics and ASTRAL forecasts show a good agreement. It is characteristic of summer grazing, and winter feeding using mainly spring hay. During the pasture period, the activity of the milk decreases with that of the grass ; during winter, it increases and stabilises : the specific activity of hay harvested in spring or in summer decreases only by radioactive decay. In the spring of 1987, the return to pasture - with renewed grass - led to a final fall of the milk contamination, with ^{137}Cs concentrations sinking below detection thresholds.

A study of this type was conducted for all districts of France, which allowed to draw a map of showing mean deposited surfacic activities of ^{137}Cs (figure 2). As inferred from wet deposition determinations, there is a strong surfacic activity decrease from east to west in a result of plume depletion. This map is in good agreement with the one established by OPRI on the basis of results of "ground + plant" sample measurements.

Figure 2 : Average cesium 137 surfacic activities deposited on agricultural surfaces and meadows after the Chernobyl accident



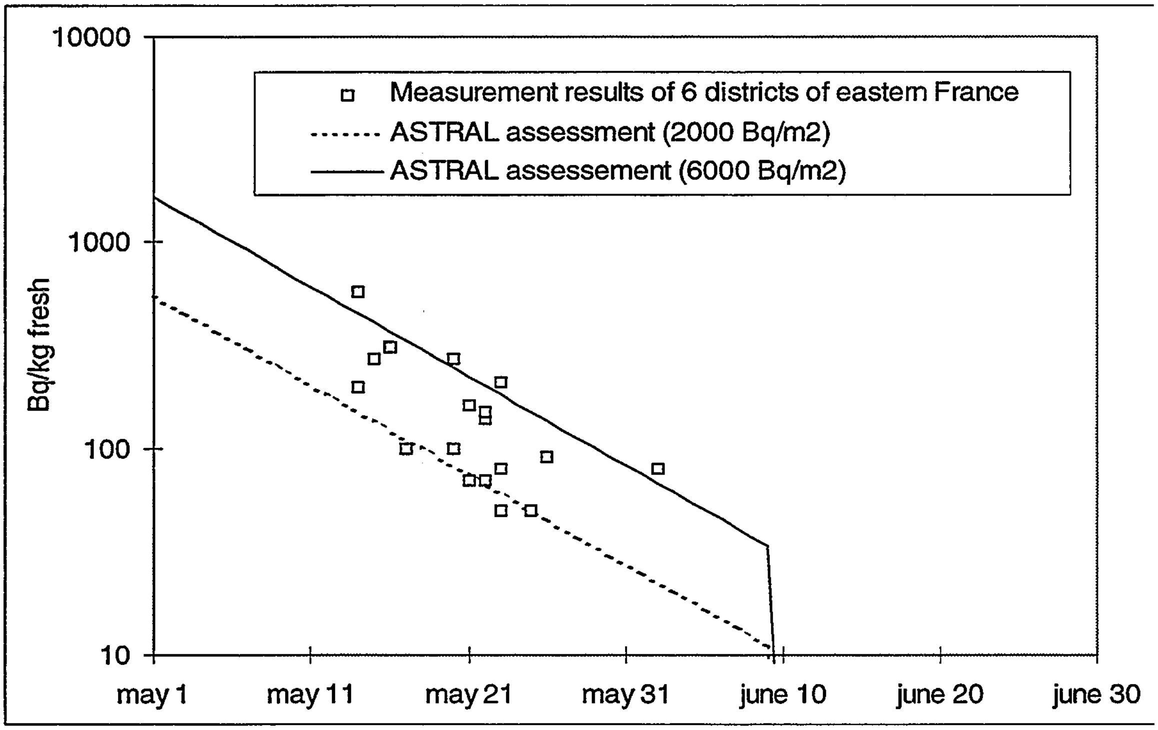
Maps of ^{134}Cs and ^{131}I have been drawn also. The well-known ratio $^{137}Cs/^{134}Cs$ of 2 is confirmed. For iodine the mean surfacic activity of the eastern most severely contaminated part of France range between 20,000 and 50,000 Bq/m^2. In the least contaminated zone (western France) activities of this radionuclide are lower than 5,000 Bq/m^2.

Among others foodstuffs regularly sampled by the french ministry of Agriculture are the leafy vegetables : salad, spinach...ASTRAL can be used to verify the coherence between these measurements and milk ones for each district. Figure 3 shows the measurement results for leafy vegetables sampled in the six districts of eastern France chosen in the figure 2. It appears that specific activity of cesium ^{137} in leafy vegetables and milk are coherent.

Leafy vegetables present a greater variability of their specific activities due to their greater sensitivity to local variations of the deposits. In eastern France, their specific activities is sometimes representative of surfacic activities as high as 6,000 Bq/m2.

ASTRAL also allows to compensate for inadequacies affecting certain types of measurement or certain time periods by assigning them theoretical values, validated by comparison between measurements and calculations when this is possible. Thus this comparison has been done for few cereals sampled punctually after the first three harvests in 1986, 1987 and 1988, for hay during the winter 1986-1987, for grass from 1986 to 1987 but only in particular places, and for beef and sheep meats. Usually, ASTRAL assessments and measurements results are in good agreement with sometimes the need to adapt some parameters, mainly dates of harvest and feeding practices for animals.

Figure 3 : Evolution of the concentration of cesium 137 in leafy vegetables in different French districts and simulations given by ASTRAL for different corresponding deposits



At the end of this work we have got a complete set of validated data : maps of deposited surfacic activities and foodstuff specific activities with their evolution in time during the firsts three year. ASTRAL may then be used to assess the evolution of the daily human intake of activity. The comparison of these assessments with anthropometric measurements is the last level of validation before dosimetric estimations. Whole body gamma counting and urine measurements are usually made in France by OPRI and different nuclear operators for the health protection of workers. The evolution of the intake of cesium for different time steps have been derived from these measures. The discrepancy with ASTRAL assessments is about 20 to 50 % except during the firsts three months where ASTRAL overestimate the cesium intake by a factor 2 to 3. This is probably due to the use in ASTRAL of conservative values for the consumption rates of leafy vegetables and milk.

CONCLUSION

The combined use of modelling and measurement results developed in this paper allows to characterize radioactive deposits for a widespread contamination of the environment, with a limited number of measurements. Using milk as pilot, the mean surfacic activity deposited over few thousand square kilometers can be evaluated with less than a few tens of samples distributed over three months. Some complementary measurements of grass or leafy vegetables enables experts to valid these assessments and to study the heterogeneity of deposits. The advantage is to keep the rest of the measurement capacity to locate the most affected areas in relation with rainfall, altitude, orography or wooded surfaces.

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Agricultural Impact Of Accidents Postulated For Missions Proposed For The US DOE Pantex Plant

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INTRODUCTION

Two new missions are currently under consideration for the USDOE Pantex Plant. The first mission would involve conversion of the plutonium metal center of the warhead, referred to as a "pit," into one of two forms. The first option possible would be to convert a plutonium hemi-shell into a solid metal "puck," of declassified shape. The second option would be to convert the plutonium into plutonium dioxide (PuO_2) powder. The former outcome is the most acceptable for storage of weapons-usable material. The latter outcome is a necessary precursor to MOX fuel production. These processes would be performed in the disassembly/conversion facility (DCF)[1]. The second mission would involve fabrication of mixed-oxide (MOX) reactor fuel. MOX fuel fabrication would take place in the MOX fuel fabrication facility (MOXF)[2]. To date, various steps in the conversion process have been tested successfully at the laboratory scale. MOX fuel fabrication has been accomplished at production-scale for the past several decades in Europe.

DISCUSSION

An independent, scoping-level health-risk and environmental impact assessment of the proposed missions was performed at the request of the Governor's Office of the State of Texas. Four groups of professionals were assembled by the Amarillo National Resource Center for Plutonium (ANRCP), to perform the assessments: process identification, risk assessment, environmental transport, and agriculture issues. The primary goal of the study's initial phase was a comparative societal risk assessment wherein the impact of proposed missions would be compared to that of existing missions.

The preliminary risk assessment considered a wide range of accident scenarios. Bounding postulated accidents were chosen for further study, as this approach would give the citizens of Texas a perspective on "worst case" impacts. As such, no fault tree analysis was performed. Rather, the research team used environmental impact statements (EISs), environmental assessments (EAs), safety analyses reports (SARs) and a battery of source and reference documents consistent with existing DOE analyses, due to the comparative nature of the study[1-5]. The "bounded" approach above had the advantage of allowing the assessment to go on without the need to obtain fault trees possibly beyond the scope of the Freedom of Information Act. Results were based on the best information deemed available in the professional judgement of assessment team members. Site specific data were used where possible, e.g., meteorological data and some accident probability frequencies[4]. Surrogate facility data were used in the absence of site specific data, the emphasis being on DOE facilities that had handled PuO_2 in powdered form[6,7].

During the risk assessment, it was noted that the usual endpoint in an environmental impact statement was a collective or population dose. No account was taken of potential impacts on local agriculture, impacts that may prove quite severe if the locale adjacent to the nuclear facility is dependent upon some form of agribusiness. Therefore, in addition to the differential risk assessment, computational models were used to determine the impact of postulated accidents on agricultural areas surrounding the Pantex Plant.

Areas of land contaminated to different levels by an accident are a measure of agricultural consequence. Derived response levels (DRLs) were calculated, which correspond to Environmental Protection Agency (EPA) Protective Action Guides (PAGs) for the intermediate phase of an accident[8]. These values were used in conjunction with the HotSpot computer code to determine the areal extent of land where calculated deposition levels for the various accident scenarios, and various deposition pathways, exceed the DRLs corresponding to particular PAGs[9]. Determinations of the areas affected were made for both DRLs based on the dose to bone surfaces (generally the limiting case for plutonium) and DRLs based on the committed effective dose equivalent.

A DRL is the level of a measured indicator that corresponds to a particular limit of interest. For example, deposition of radioactive material on the ground can be correlated with dose to an individual or group of individuals. This correlation allows protective action decisions to be made based upon deposition measurements.

For this analysis, only a subset of the possible accident scenario exposure pathways was chosen. These were: inhalation of resuspended material following deposition; ingestion of fruit, vegetables, or grain directly contaminated by deposition; ingestion of beef from cattle grazing on contaminated forage; ingestion of milk from cattle grazing on contaminated forage; and ingestion of leafy vegetables grown in contaminated soil. Values for many parameters must be determined or assumed in order to calculate DRLs for the various pathways. Information for these calculations came from publications of the International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP), National Council on Radiation Protection and Measurements (NCRP), U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the U.S. Nuclear Regulatory Commission (NRC).

The HotSpot code uses a straight-line Gaussian dispersion and transport model[9]. The default deposition velocity used in HotSpot for determining the rate of deposition of plutonium onto the ground is 1.0-cm s^{-1} and was used for these calculations. All calculations assumed a release height above the ground of zero. Meteorological data typical for the Pantex Plant was used in the calculations: stability class D and a wind speed of 6 m s^{-1}. These meteorological conditions corresponded to those used by DOE.

There are many variables that affect the extent of the area contaminated following an accident. The calculations performed for this evaluation give estimates of the areas potentially involved, but cannot be presumed to be exact predictions of the areas that would be contaminated in the event an accident were to occur. Results are shown in Table 1. These are the areas for which dose mitigation techniques would need to be implemented in order to keep the offsite dose below the PAG level. As can be seen, DRLs for ingestion of vegetables directly contaminated with plutonium are more restrictive (by a factor of approximately 400) than the DRLs for vegetables grown in contaminated soil, which become subsequently contaminated via root uptake (no wash-off or rain-off was assumed).

Table 1. Acres affected for selected accident scenarios based on PAGs (typical meteorological conditions: D Stability Class, 6-m s^{-1}).

Value Based on BSD (Based on CEDE)		Acres affected Based on bone surface doses (BSD) (Based on committed effective doses (CEDE))						
$\mu Ci\ m^{-2}$	$g\ Pu\ ha^{-1}$	A*	B	C	D	E	F	G
0.6	0.04	--	7	30	60	110	250	4,940
(2.1)	(0.15)		(2)	(6)	(20)	(20)	(50)	(960)
0.5	0.04	--	8	30	80	130	320	6,180
(1.6)	(0.12)		(2)	(8)	(20)	(30)	(80)	(1,360)
0.5	0.04	--	8	30	80	130	320	6,180
(1.7)	(0.12)		(2)	(8)	(20)	(30)	(70)	(1,360)
0.8	0.06	--	5	20	40	80	180	3,460
(2.8)	(0.20)		(1)	(5)	(10)	(20)	(40)	(670)
22	1.6	--	--	1	1	2	4	50
(43)	(3.1)			(0)	(1)	(1)	(2)	(20)
43	3.1	--	--	--	1	1	2	20
(160)	(12)				(0)	(0)	(0)	(5)
180	13	--	--	--	--	--	--	5
(710)	(52)							(1)

A: BEB** Cell fire -- 0.64 g Pu * -- is negligible dose
B: Fire on the loading dock -- 9.0 g Pu **BEB is Beyond Evaluation Basis
C: Truck (diesel fire) -- 30 g Pu ***A/C is Aircraft Crash
D: DCF oxyacetylene explosion -- 64 g Pu
E: BEB (maximum credible) earthquake (DCF) -- 100 g Pu
F: A/C*** into DCF -- 200 g Pu
G: A/C into oxide storage -- 2,000 g Pu

CONCLUSION

Modeling results indicate that material would be released beyond Pantex Plant boundaries under certain accident scenarios, for certain assumed siting decisions. Areal deposition is possible wherein EPA PAGs can be exceeded. Such deposition would require protective actions to be taken; therefore, a study that features methodology such as this may prove useful as an emergency response planning tool for personnel at Pantex Plant should the siting decision dictate that either of the proposed material disposition activities be placed on Texas soil. In addition, such a study would afford the State of Texas an informed input in the siting decision prior to ground breaking. A similar study would provide results of similar nature for any disposition option-siting candidate.

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Session A, Track 2:
Lessons Learned from Chernobyl I

Wednesday, September 9, 1998
10:45 a.m. - 12:35 p.m.

Chair: Thomas McKenna, United States Nuclear Regulatory Commission

Consequences of the Chernobyl Accident and Emergency Preparedness in Norway

Ole Harbitz, Lavrans Skuterud and Per Strand

Norwegian Radiation Protection Authority, Norway

INTRODUCTION

Heavy precipitation from the air masses during the critical days after the Chernobyl accident led to wet deposition of considerable amounts of radioactive fallout in Norway. It was estimated that 6% of the total released radioactive material was deposited in Norway (Backe et al. 1987). Due to highly unusual meteorological conditions, these deposits concentrated in some sparsely populated regions in southern and mid-Norway, while densely populated areas received less fallout. The mountainous and forest areas with large amounts of fallout (in spots, up to 600 kBq m-2 of radiocesium) are important production areas for certain animal products.

The most severely contaminated foodstuffs were produced in semi-natural ecosystems. These included meat from sheep, reindeer, game and cattle (to some extent), and milk from goats and cattle. Radiocesium levels up to 150 kBq kg-1 in reindeer meat and 40 kBq kg-1 in sheep were observed. Freshwater fish also showed high radioactivity levels (up to 35 kBq kg-1).

DISCUSSION

In June 1986, the Norwegian Directorate of Health imposed intervention radioactivity levels for the nuclides ^{137}Cs and ^{134}Cs. The intervention levels were 370 Bq kg-1 for milk and baby food, and 600 Bq kg-1 for all other foodstuffs. To maintain reindeer breeding in Norway and to reduce the social effects for the Sami reindeer breeders, it was necessary to consider a higher intervention level for reindeer meat. In November 1986, the intervention level for reindeer was increased to 6000 Bq kg-1 and in July 1987, the level for wild freshwater fish and game was also increased to 6000 Bq kg-1.

Dietary advice was given to the parts of the population consuming high amounts of reindeer meat or freshwater fish. This advice was published by the health authorities as a brochure in 1986, and gave guidance as to how often people could eat the most affected foodstuffs, depending on their activity levels (kg of meat or fish per year and as meals per week). The brochure also included some examples regarding how to prepare food to reduce the radiocesium content. The main goal of the dietary advice was that nobody should have an intake of radiocaesium exceeding 400 kBq the first year after the Chernobyl accident and exceeding 80 kBq y-1 during the subsequent years.

In 1986 about 35% of all lambs were contaminated at levels above the intervention level at the normal time of slaughter. Between 1986 and 1997 the proportion has varied between 30% and 5% of the total livestock. In 1997 about 10% of all lamb and mutton, and 27% of reindeer had activity levels above the intervention levels. Thus a persistent need for pre-slaughter countermeasures is existing. After 1986, countermeasures have been very successful in reducing the amount of meat declared as unfit for human consumption to a negligible fraction. Cesium binders (Prussian Blue - AFCF) in salt lick, boli and mixed in concentrate, and special feeding of lamb and sheep are the extensively used countermeasures. During the period 1986-1994 a total of 1,566,000 lamb and sheep have been involved in special feeding programs; 320,000 of these in 1986. Compensation paid to the farmers for their additional workload amounts to a total of 23 mill USD for the whole period.

The human population was subject to irradiation from three sources after the fallout; external radiation from deposited radionuclides, inhalation of radionuclides from the air and ingestion of radionuclides through foodstuffs. Figure 1 shows the monthly doses from intake of food together with the monthly doses from external doses due to the fallout on the ground. The first few months after the accident, the external exposure was the major contributor to dose. After this period the exposure from contaminated foodstuffs was the major contributor. However, the prognoses for the coming 50 years is that the external exposure again will be the major contributor. The total individual dose over 50 years will in average be in the order of 2 mSv, giving a collective dose over 50 years to the Norwegian population (4 million people) in the order of 8000 manSv. There are however groups of the population with special dietary preferences receiving significantly higher doses than the average: The reindeer herding Samis, but also persons with higher consumption of game than the average. Among these groups, dietary advices have been very efficient in reducing doses. While the average total dose received during 50 years have been estimated to 20 mSv to these groups, it could have been 5-10 times higher if no advices were given.

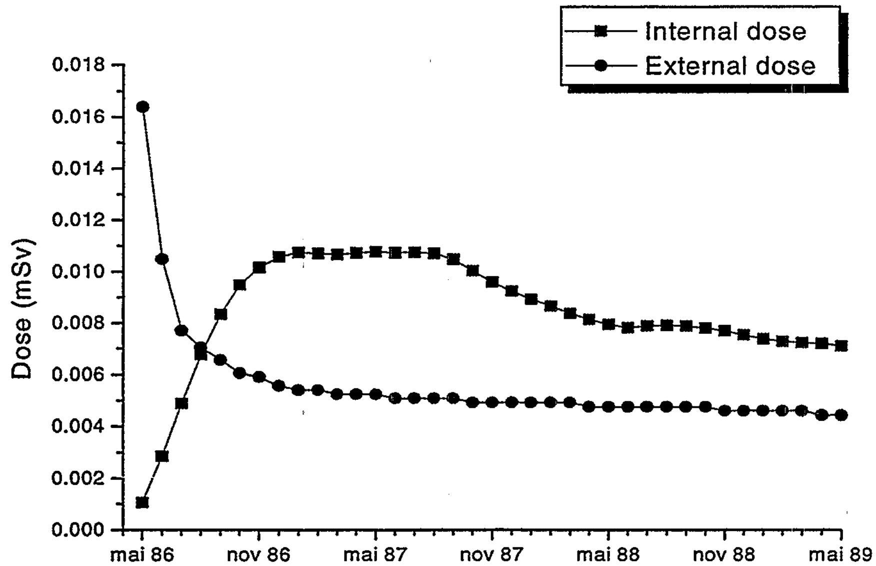

Figure 1 Average monthly doses from the Chernobyl fallout to the Norwegian population (Strand 1994).

Countermeasures and Cost-benefit Analysis

Six types of countermeasures have been introduced in Norway to reduce radiation doses following the Chernobyl accident: Interdiction of food, special feeding, fertilization of natural pasture, use of cesium binders in animals, changing diet and changing the slaughtering time for reindeer and sheep. Countermeasures considered, but not implemented, were relocation of animals to uncontaminated areas and restrictions on some agricultural production in contaminated areas. The monetary cost of averted radiation dose (in units of manSv) has been considered. It is assumed that the relationship between dose and effect is linear. The cost of detriment is therefore equated with the collective dose multiplied by α. The α value is dependent on society's willingness to save a statistical life. The willingness is compared with other risks faced by society. Currently, in the Nordic countries, an 'α' value of 100,000 USD per manSv is recommended. Countermeasures with a cost of averted dose below this value are justified, and this was the fact for almost all countermeasures introduced in Norway after the Chernobyl accident (Table l). Thus, from a radiation protection point of view the implementation of countermeasures in Norway after the Chernobyl accident was justified. The countermeasures implemented reduced the doses and the potential health risk. This, together with social and economical considerations established the basis for the mitigation strategy in the aftermath of the Chernobyl accident.

Table 1. Cost of countermeasures in terms of man.Sv saved (Strand 1994).

Countermeasure	USD man.Sv-1
Interdiction of sheep	170,000
Interdiction of reindeer	57,000
Special feeding	42,000
Change of slaughter time	16,000
Giese salt (AFCF) concentrate	170
Dietary advice, 1987	6

The cost effectiveness of different countermeasures varied considerably in Norway (Table 1). However, this simple cost-benefit analysis does not show the total cost for society. The economic losses for agriculture could have become considerable due to the population's decisions to avoid contaminated food. Immediately after the accident the situation was not clear due to insufficient knowledge of the fallout and its consequences. In Norway, as in several other European countries, the health authorities introduced intervention levels at an early stage after the accident. There was little room for optimization in the situation. Later, after some rationalization, a clearer radiological protection philosophy was introduced.

Ideally, a countermeasures contingency program should have been drawn up in preparation for an accident so that correct decisions could have been made promptly and correctly. In the event, the countermeasures applied were carefully monitored and a more or less optimum situation was achieved. In retrospect, it was shown that most of the countermeasures employed were justified. The maintenance of confidence in the foodstuffs on the market is extremely important when considering the social costs to society. Thus, it is necessary to compare more than just the costs of the countermeasures as such and the averted dose, when estimating the total societal costs.

A decrease in the sale of some agricultural produce represented a potential economic loss considerably higher than the cost of the implemented countermeasures. Not all the countermeasures would have had the desired effect in satisfying the consumers. The implementation of intervention levels was of great importance in this respect. It resulted in an active implementation of countermeasures in agriculture and only in some limited use of dietary advice to critical groups.

The use of dietary advice alone instead of special feeding would perhaps have given the same adverted dose at a lower direct monetary cost. However, the special feeding program led to activity levels in food below the intervention levels and no active involvement by the consumers was called for. The combination of the different countermeasures took this into consideration and hopefully gave the maximum reduction of the total negative consequences. A decrease in consumption of some of the most affected foodstuffs (e.g. lamb) occurred. The decrease in consumption of lamb was about 5 to 10% in the first years. This represented a loss of about $8 to $15 million USD for the producers. On the other hand, if no countermeasures except interdiction had been used, and intervention levels were maintained, the costs would have been about $15 to 60 million USD each year. Without countermeasures, lost sales of lamb could have been considerable.

CONCLUSION

From the discussion above one may conclude that the measures introduced to protect the population from negative health consequences of the Chernobyl accident were relatively extensive and resource demanding. Their main purpose was to reduce the physical health effects by reducing radiation dose. The dose was reduced and the relationship between cost and reduced dose was acceptable. Without the implementation of countermeasures the agricultural community could probably have suffered much greater losses through an extensive decline in the sales of the sensitive foodstuffs (e.g. lamb and reindeer meat).

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Session B, Track 1: Lessons Learned from Actual Events (Non-Chernobyl)

Wednesday, September 9, 1998
2:05 p.m. - 4:20 p.m.

Chair: Charles Willis, United States Nuclear Regulatory Commission

Experience Managing the Response to a Damaged Source at Goiânia - Brazil

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INTRODUCTION

The radiological accident

Probably on September 13th, 1987, a strong radioactive ^{137}Cs source (~51 TBq at the time of the accident) was removed from an abandoned building in Goiânia and ruptured by some individuals in a backyard. They aimed to sell the obtained lead from the shielding as scrap material. This source was formerly used by a radiotherapy clinic in a teletherapy (^{137}Cs) machine. After they dismantled the machine and ruptured the source capsule, the material with commercial value (lead and steel) was sold to a junkyard store. It was reported that they noticed a blue light in the dark coming from the ruptured capsule source. This light caused fascination in several persons that came to see it. Small parts of the source were given to friends and relatives, causing external irradiation and internal and external contamination. Due to the constitution of the source (cesium chloride salt), it was highly soluble and easily dispersible in the environment by resuspension of the deposited material. The contamination was spread out over the city. This accident caused 4 casualties and at least 28 people injured with radiation burns. The symptoms of the injured people were not initially recognized as radiation syndrome. A few days later, one person established a relationship between the source and the symptoms presented by the people and took the remaining material to the local health authorities. This action led to the discovery of the accident. A local physicist was called and he assessed the scale of the accident, evacuating two areas. The Brazilian Nuclear Energy National Commission - CNEN was informed and dispatched a team to the city in the same day.

DISCUSSION

CNEN arrangements for emergency response

The response of CNEN to radiological emergencies in the non-nuclear power sector ensures that there is a central person to contact, who is able to arrange the appropriate assistance. The head of the Department of Nuclear Installations (DIN) was in charge of coordinating the response in these events.

There was also an emergency plan for nuclear facilities. In this case, several groups were involved and have their own structure to respond. At least, a few people of each group were kept in standby to provide initial actions and activate the emergency response centers. During emergency situations the decisions would be taken by a joint coordination committee formed by major Government agencies such as CNEN, Federal, State and Local Authorities and from the utility. CNEN has, in the plan, its executive group to coordinate all the actions of the response, a technical group to assist in decision making, two groups for plant safety evaluation, the field emergency monitoring and evaluation group of the Institute of Radiation Protection and Dosimetry and the administrative and logistical support group.

The initial response

CNEN headquarter was contacted through the head of DIN on September 29th, 1987 at 18:00 in Rio de Janeiro, soon after he arrived at Goiânia with two more technicians from São Paulo. They arrived at Goiânia at 00:30 of September 30th. This team first went to the abandoned building where the source was and after a survey, finding no radioactive source or trace of radioactivity, they went to the local health authorities building and found the leftover of the source. The dose rates at 1m from the source was 0.4 Sv.h-1 indicating that about 10% of the source was still there.

The CNEN team and the local physicist proceeded to the other identified sites and confirmed the initial surveys. The dose rate value of 2.5 Sv.h-1 used to evacuate an area by the physicist and local authorities was based on simple criterion of the occupational limits, knowing that for the public the limit used to be ten times lower. The CNEN team, taking into account political aspects, decided not to change this value.

At 03:00 the CNEN Coordinator evaluated the situation as critical and demanded additional resources from CNEN headquarter. On that morning, the team dealt with the leftover source, which was over a chair. The team decided to bury it in a sewer pipe filled with concrete. This simple action reduced s significantly the dose rate.

At 06:30, another team from CNEN arrived with one physician and two physicists and start dealing with the contaminated or injured persons. A soccer stadium was designated as a temporary screening area where those persons were send. A physician from Tropical Diseases Hospital - first to recognize the possibility of radiation overexposure - had been overnight at the stadium. 22 persons were identified with symptoms of radiation exposure and sent to that hospital. By the end of the day, the two physicians, with the support of the physicists, had examined about 60 contaminated persons and took the first actions to decontaminate them.

The evolution of the response team

At 17:00 of September 29th, the Director of IRD was contacted and asked to prepare a team to send to Goiânia. Composed by the former IRD director, two physicians and health physicist support staff, this team arrived at Goiânia at 16:00 of September 30th. The former director acted as deputy emergency coordinator. The team faced a crowd of people in the stadium, including the press, which was looking for information, wondering if they were or not contaminated as they had been alarmed by the isolation of areas around the city.

The stadium was now designated as the place where people should go to be screened. In total, till the end of response, 112 000 persons were monitored and 249 found with detectable contamination.

The CNEN team established a headquarters at the State Health Authority facility. One main goal of this team was to conduct a well-documented survey of the contamination levels for planning purposes. All the main foci of contamination were found and isolated.

In the following days, more technical staff arrived at Goiânia. At this point, with the need for record keeping and logistical support for the response team indicated the need of an administrative staff.

The response team was divided into subgroups. Four of them to deal with cleanup of the most contaminated areas (Junkyard I, II and III, the house where the source was ruptured and others). One team was involved in the screening of persons at the stadium. There was also a specialized team for chemical decontamination of small areas, vehicles, personal belongings and small objects. The administrative staff was increased and subdivided in maintenance of equipment, logistic (laundry, material, finance etc) and administrative issues.

At this time a great volume of radioactive waste started being generated and a group was created to plan and develop the managing of that waste. This was one of the major logistical problems. There were no suitable assembles in the market, Brazil did not have a disposal site and there were only a few trained persons in this field.

The other resources

The need for ensuring that the control over the accident was gained, demanded additional aerial and terrestrial monitoring to be performed. The aerial survey found another important site contaminated in a sanitary waste deposit. The road network of the city was monitored with a vehicle equipped with a large detector of NaI(Tl) and GM probes for low and high dose rates. This survey found several spots of contamination of minor importance. Teams for either physical or chemical decontamination were settled for dealing with these small spots of contamination.

A whole body counter was designed and mounted at the State Hospital. A complete infrastructure at the hospital was settled, including heath physicist staff and decontamination room. An entire infirmary was reserved to the care of injured and contaminated internally or externally persons.

An environmental assessment group designed and executed a monitoring program performing more than 1300 measurements of 137CS in soil, vegetables, water and air. A small radiometry laboratory was built in Goiânia with sample preparation support. This group was also responsible for the decontamination of yards. The resuspension and dispersion of cesium was the major path of contamination of the environment. Based on a critical group dose bellow 5mSv, several remedial actions levels were derived, e.g., decontamination of property, restriction of home grown produce and removal of contaminated soil.

The long term phase

Some of the activities enter in a steady state. Most of the groups were well organized. Three medical care centers were working for different levels of radiation injury severity. Two of them were in Goiânia and the other, for the high severity injured people in Rio de Janeiro. Planning and beginning of decontamination processes were being carried out by the groups As might been expected, adverse reactions to matters related to radiation arouse from the public, some authorities and press. The choice of the site for the radioactive waste deposit was not only a technical decision but also a political concern. There were legal aspects to be taken into consideration. Finally the State Governor accepted a site 20-km away from the city.

As the deposit was crucial for the decontamination of the major foci, and the logistical and political difficulties tended to increase, a decision from the President of CNEN was taken. He decided to move his office to Goiânia and lead directly the CNEN task force and put large amount of resources in managing the situation. This action not only reduced the steps in decision making processes but, as well, compromised the CNEN headquarters and its Institutes, providing total support for logistic, analytical and dosimetry services as needed. The date of December 21st was established for the end of the decontamination of the main areas. The construction of the waste deposit was accelerated and, by mid of November, the removal and transport of waste started. Before this, the decontamination actions were restricted to preparation and prevention from deteriorating of the situation.

The total staff involved increasing up to 250 professional or technical staff plus 300 other staff for supporting the decontamination, transport and disposal of the waste, plus all the other activities. The date of December 21st was achieved with an effort of a 12-hours working shift.

CONCLUSION

The lessons we should learn and practice

- Radiological accidents become worse as time of discovery elapses.
- Records of radioactive sealed sources should contain information on physical and chemical properties.
- A general public information system should be set up on radiation matters.
- A social and psychological support should be provided for either the persons affected by the accident and the response team.
- International assistance depends on the local infrastructure. Emergency training and courses should be provided for this kind of accidents.
- Mobile system of first aid by air should be available.
- Equipment should be suitable for working in field adverse conditions.
- Records of available personnel resources in each area of interest should be kept.

- Temporary storage facility near the accident area is to be considered essential.
- Decision making and organization hierarchy should be well defined.
- Inspection programs are important and should be connected with an effective enforcement system.

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Operation Morning Light: Recovery of Debris from Cosmos 954

H. Alan Robitaille
Maple Bay, Canada

INTRODUCTION

Cosmos 954 was launched on 18 September 1977, carrying an estimated 100 kilowatt (thermal) nuclear reactor. Such a high power level was necessitated by the fact that Soviet ocean-reconnaissance satellites of the time employed active radar as the remote-sensing technology. The satellite was estimated to have a mass of 4,000 kilograms, 50 kilograms of which was attributed to the U^{235} core. The reactor was taken to criticality shortly thereafter, but the satellite never functioned properly. Attempts were subsequently made to separate the satellite into three modules; two of which were expected to burnup on re-entry to the earth's atmosphere, while the core itself was to be boosted to a much higher orbit, allowing sufficient time for adequate radioactive decay before subsequent re-entry. All such attempts ultimately proved futile. Additionally, in early January 1998, attitude control of the satellite was lost and it began to tumble uncontrollably, thus greatly shortening it's space-borne lifetime.

The projected impact date at that time was 23 January 1978, somewhere on the earth's surface between 65^0 North latitude and 65^0 South latitude. The reactor core was anticipated to contain some 100,000 Curies of activity, mostly due to the isotopes Cs^{137}, Sr^{90}, Ce^{144}, Zr^{95} and Np^{239}, given its burnup history. On 22 January 1978 various nuclear emergency assets in Canada and the United States were put on a two-hour notice, through the NORAD agreement.

Actual re-entry occurred at 0353 (Pacific Standard Time) over Great Slave Lake, in Canada's North West Territories. Debris was expected on the ground along the satellite's final track from Yellowknife to Baker Lake, a distance of some 500 nautical miles, in a direction of 062^0 True. A few (mostly inebriated) eyewitnesses observed the re-entry visually from the city of Yellowknife. Thus in the early morning of 24 January 1978, "Operation Morning Light" (a randomly-selected code name) and the world's first (only?) predictable nuclear emergency began.

DISCUSSION

Operation Morning Light was, from its beginning, a joint operation between Canada and the United States of America, including assets drawn from the Canadian Department of National Defense, Department of Energy, Mines and Resources, the Atomic Energy Control Board and the American Department of Energy. The Canadian Forces Base at Edmonton, Alberta was activated to conduct the operation. A Canadian Nuclear Accident Support Team (22 personnel) was deployed to Yellowknife and at 1630 PST two American C-141 Starlifters arrived from Andrews Air Force Base, carrying the DOE's Nuclear Emergency Search Team and their equipment. Approximately six hours later, at 0015 PST 25 January, the first search mission was initiated; a Canadian C-130 Hercules aircraft carrying US radiation detection equipment. This consisted of an array of twenty-eight 4" x 4" Sodium-Iodide scintillators. Five gamma-ray spectra were obtained per second as the aircraft flew at an altitude of 1000' above ground along the satellite's estimated re-entry track (Figure 1).

Later that same day additional assets from both the USA and Canada arrived at Edmonton and an additional search team was deployed to Baker Lake, at the terminus of the re-entry track. By the end of the day a total of twelve aircraft were involved in the search (4 Hercules, 3 Twin Otters, 1 Convair (US) and 4 helicopters) carrying four NaI detector arrays (three American and one Canadian, provided by the Geological Survey of Canada). Search missions conducted that day involved three Hercules flying in formation (½ mile apart) at 1000' along the satellite's re-entry track, and on both sides of it.

The following day (26 January) at 1900 PST the first radioactive anomaly ("hit") was detected, at the northeastern end of Great Slave Lake. A ten-mile square grid at ½ mile spacing was then established around this point and searched by a second aircraft. No additional hits were detected, but the original one was confirmed. Airborne infrared search missions were also flown over the entire search area, being completed the following day, with no anomalies reported.

On 28 January a large piece of non-radioactive debris was found by chance by two of six persons engaged in a fifteen-month dog-sled expedition across Canada's northern wilderness, recreating the 1926/7 journey of an English explorer, John Hornsby. The debris was found in the Warden's Grove area within the Thelon Game Sanctuary. Additionally, that same day three more radioactive anomalies were located in the McLoed Bay area, two of which were confirmed to be satellite debris and one a natural outcropping of Thorium.

Around this time the search was becoming much better organized (Figure 2) with specific responsibilities and lines of communication allocated to individual elements. In addition, the search area itself was much more methodically defined and prioritized. From theoretical calculations of re-entry and atmospheric observations at the time, a wind-corrected debris track was estimated. Winds aloft blew from the North at the time of re-entry, thus it was expected that smaller and lighter objects would be found widely dispersed south of Great Slave Lake, while higher Beta (i.e., mass-to-drag ratio) objects would be found further down-range and closer to the actual re-entry track. (This was eventually confirmed.) It was also expected that some objects with a Beta of up to 300 lbs/ft^2 would be found closer to Baker Lake, although as it eventually transpired, none of that size was ever found.

However, objects of lower Beta were being found in the Thelon River area, near Warden's Grove, and a decision was made to relocate the recovery team at Baker Lake to what eventually became known (as it is to this day) as Cosmos Lake, in the Thelon Game Sanctuary. This relocation commenced on 29 January 1978.

By the end of January many more fragments had been identified and located, most radioactively but some not - these had been observed visually during airborne searches. Also around this time a concept of search operations began to evolve. Instrumented C-130 aircraft, operating out of Edmonton, systematically flew parallel track lines at 1000' AGL, in each search sector. Hit co-ordinates were then passed to recovery teams based in Yellowknife and Cosmos Lake. An instrumented helicopter would then be flown to these co-ordinates to further localize the hit. This flight would not land, for fear of contamination which might render the aircraft useless for further operations. Instead it would drop brightly-coloured markers to locate the hit. A second helicopter mission would then be flown to extract the debris from the ice, since most melted into it, and to assess the extent of the radiological hazard. If practicable, the debris would be recovered at this time. If it were too bulky or too radioactive for standard shielding containers, a special container would be fabricated at the University of Edmonton and then shipped to the field on one of the daily re-supply flights. Another helicopter mission would then recover the object for subsequent shipment to, and analysis at, the Whiteshell Nuclear Research Establishment, in Manitoba. A final, instrumented, helicopter mission would then be flown to the same site, to ensure that the recovered fragment had not masked other debris of lesser activity.

On 1 February the most radioactive fragment found to date was located, measuring some 200 R/hr near contact. This was thought to be a structural element of the reactor core, with some spent fuel condensed on its exterior.

Operations continued until the end of March 1998. By that time a total of 608 airborne search missions had been flown. Numerous large objects had been found along the track between Artillery Lake and Cosmos Lake, including six Beryllium cylinders (about 3" in diameter and 8" long), all virtually intact, and many more Beryllium pencils of much smaller size.

Additionally, literally thousands of small particles of spent fuel were discovered from Great Slave Lake south to the Alberta border. These were typically about 200 microns in diameter and were dispersed unevenly over an area of some 20,000 square miles. Individual particles were retrieved if they emitted in excess of 100 microR/hr at one metre, or if they were found in populated areas (e.g., the towns of Snowdrift and Fort Reliance), since in Winter the local Innuit melt surface snow as a source of potable water.

On 28 February a small piece of spent fuel was recovered, comprising about one cubic centimetre, and emitting over 500 R/hr near contact - this constituted the most radioactive fragment found during the entire search.

CONCLUSION

Approximately 100 objects were ultimately recovered, constituting some one percent of the estimated radioactive inventory. The remainder was concluded to have been spent fuel which had vaporized upon re-entry and eventually settled over a very large area surrounding the search area, and perhaps worldwide. There is a high level of confidence that all major pieces of debris were located and retrieved, many of which consisted of Beryllium metal - thought to be part of the reactor's combined reflector and criticality control system.

LESSONS LEARNED

There were four major lessons learned from Operation Morning Light, two of which remain valid today and two of which have since been superceded by the intervening twenty years.

Firstly, many NaI crystals were lost due to cracking in the extremely cold weather. These must be protected by sufficient insulation to limit their rate of thermal change to less than about 2^0 Celsius per hour.

Secondly, in adverse environments such as Canada's North, it required three times as many personnel as would have been required in more moderate climates to do the same amount of work, due to fatigue and the loss of manual dexterity to bulky survival clothing.

Thirdly, at the time a bottleneck developed in computational capability. It took four hours to analyze the data from one hour's worth of flight time, using the PDP 8/e's and PDP 11's of the period. This should not be a problem today.

Finally, navigational repeatability was a major problem early in the search, when trying to relocate debris which had been previously identified. A microwave ranging system was deployed as a solution, but at considerable cost and inconvenience in relocating the beacons and changing their batteries daily. Today, inexpensive ($100) hand-held GPS receivers would easily solve this problem, given their typical 10-metre precision.

One other lesson was also learned, of particular relevance to Canadians. When operating in an environment where the daytime high sometimes reaches forty degrees below zero, be sure to bring along a heated toilet seat!

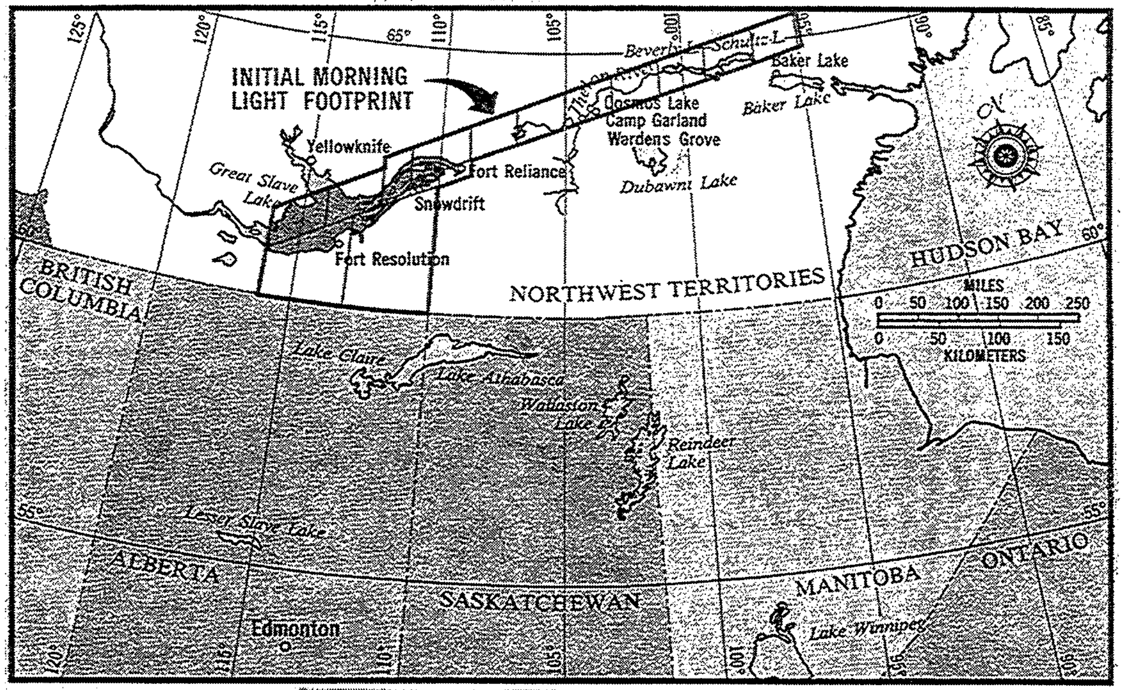

Figure 1: Cosmos 954 Search Area.

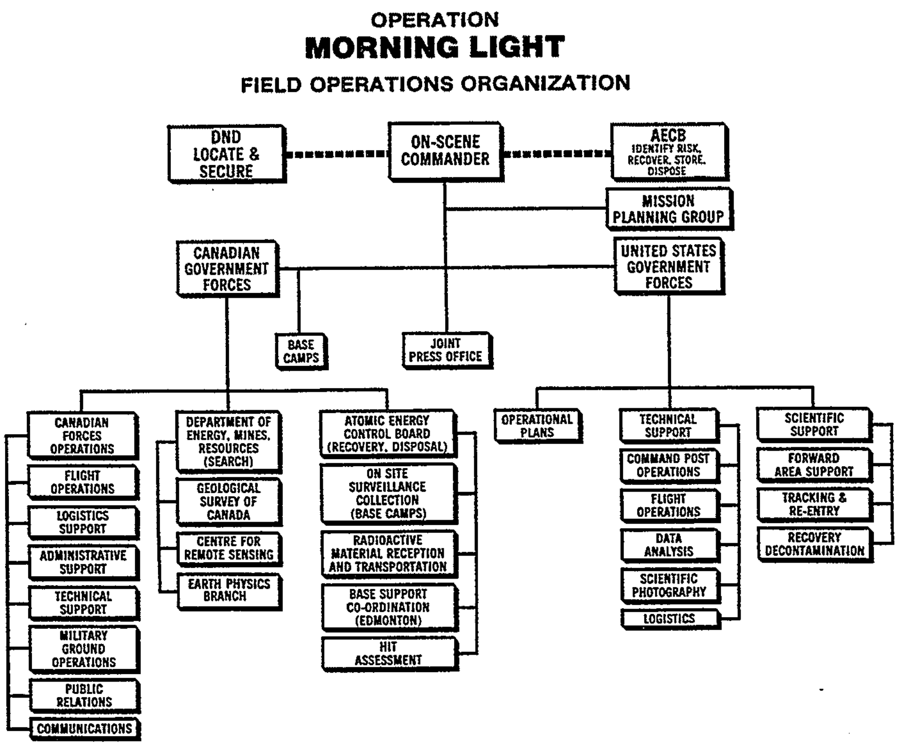

Figure 2: Search Team Organization

Post-Emergency Management Issues Following Inadvertent Melting of Radioactive Sources

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INTRODUCTION

Steel manufacturers are encountering radioactive sealed sources in incoming scrap metal inventories that are, on occasion, not detected, even though monitoring and detection instrumentation is being used. Unfortunately, they end up being melted in the mill's furnace, resulting in the emissions control system and supporting facilities being contaminated with radioactive materials. This paper briefly describes a recent incident where a facility was contaminated by such an event. The remediation and resulting facility recovery, though successful, is often not the event that has the greatest impact on facility operations and financial resources. It is the post-emergency activities that have a greater impact on the steel manufacturer involved in such an event. It often results in facility alterations to operations because of the generated radioactive wastes that remain onsite following completion of remedial activities. The impact on operations and financial resources are described below.

DISCUSSION

In April of 1997, a steel manufacturer located in Kentucky experienced a radioactive source melt event in which a radioactive cesium-137 (Cs^{137}) source, in an unidentified form, was inadvertently melted. The sources vaporized during the smelting process in the electric arc furnace (EAF) which resulted in contamination of the emissions control system and EAF dust handling equipment. The emission control system consists of the entire inside of the baghouse, the EAF dust conveyor system including portions of the railcar filling area, the main ventilation duct and associated components from the melt shop. The event was discovered when a railcar containing EAF dust was sent to an offsite processing facility where it set off the facility's fixed railcar radiation monitor. Upon detection, the Commonwealth of Kentucky, Department of Health, was notified and all operations at the steel mill were ordered to be terminated. The remediation contractor responded within 24 hours upon the steel mill's request to assess the extent of contamination. A contract was provided to the remediation contractor for decontamination and survey work scope to return the mill to operational status. The contractor assessed the extent of the radioactive contamination, provided onsite remediation support, and developed the work plans for decontamination of the facility. The remediation contractor used a combination of decontamination techniques to accomplish the guidelines established by the Commonwealth of Kentucky to remove the radioactive contamination and return the facility to unrestricted use. The efforts of the contractor enabled the steel mill to commence operations within 12 days after the incident. The contractor received a bonus payment from the customer's insurance company for completing remediation ahead of schedule, allowing the company to resume steel-making operations, and minimize the insurance company's liability. In addition, the contractor enabled the company to comply with the guidelines for unconditional release of land areas, slag, and EAF dust from the Cs^{137} contamination incident. Currently the contractor is conducting periodic sampling activities of the emissions (EAF dust) to insure compliance with the requirements of the Commonwealth of Kentucky and Department for Public Health with additional survey activity for metal scrap survey oversight.

After the remediation was completed and resumption of plant operations the company was left with two new management variables that they previously did not have to deal with operationally or financially. The first was the establishment of a controlled area with restricted access for the storage of the radioactively contaminated materials generated from the remediation. The second is the financial burden of the management efforts and waste disposal costs incurred as part of the incident. The company was left with a considerable quantity of mixed waste (radioactive and hazardous materials) that require special handling. Instead of being able to send the EAF dust on to a recycle center for recovery of certain useful metals, the steel mill is faced with disposal at a specially licensed burial site. Other debris, which could generally go to unrestricted commercial or industrial landfills, must also be disposed of at a licensed burial site. To further complicate matters the radioactively contaminated EAF dust and other production residues are considered a mixed waste because of the presence of the radioactive component and the presence of hazardous component heavy metals. This escalates the cost of disposal because of the mixed waste category for the dust and other debris.

For most companies, the final disposal of the waste often lags behind the remediation. There are several reasons for this occurrence. First of all, companies are unfamiliar with the requirements for restricted disposal options. There is a learning period during which company representatives become acquainted with requirements which have not previously been dealt with, which are different from the usual disposal environment with which they are familiar. The second reason is the complexity of disposal site criteria. This usually includes characterization and waste stabilization activities that companies are generally not knowledgeable concerning waste preparation for disposal. Thirdly, companies are not set up for waste processing for stabilization and shipment. They have neither the equipment, procedures or regulatory licenses/permits to perform such activities. This usually necessitates going to an outside service supplier to perform these operations for the company which results in an added expense over and above the waste disposal costs. Finally, waste disposal is usually delayed because of the expense of disposal itself. As a general rule, the cost of disposal for these generated wastes are higher than the cost of remediating the facility equipment, systems and structures. In the cited case in this paper the cost of the remediation was slightly greater than $1 million while the cost of waste dispositioning (stabilization, packaging and disposal) was higher.

The generation of radioactive wastes during remediation activities requires companies to set up controlled, restricted areas for the purposes of radiation protection and contamination control.

This means giving up site space and/or facilities that may normally be dedicated to routine site operations. This may require re-engineering of site activities to accommodate the interim storage of the radioactive wastes. Depending on the planned time for onsite storage, regulatory authorities will require a company to obtain a radioactive material license authorizing the possession and storage of the radioactive waste. This obviously adds a new administrative burden which the company has not encountered before. The company must now expend resources for posting and maintaining a restricted area. This involves setting up an organization with designated duties and responsibilities, posting the area with "Caution-Radiation Area," and "Caution-Radioactive Material" signs, developing and conducting a training program for designated radiation workers, assigning personnel dosimetry, and implementing site access control and surveillance programs, in short, setting up a radiation protection program.

The expense of waste disposal represents a financial challenge to the company if the unplanned funding must come from internal resources. Funding mechanisms need to be identified within the company if insurance coverage was not available at the time of the incident. It is interesting to note that some insurance companies have bulked at paying coverage claims in cases where a company incident is a second event of the same kind. One current client is experiencing such a response from its insurance carrier which subsequently has escalated into litigation.

Returning the site to normal conditions requires the intervention of State regulators from both the Division of Solid Waste Management and the Division of Radiological Health. This becomes costly to the company as a post emergency measure. These agencies require the company to show proof that the materials have been removed, or are properly containerized for short or long term storage. Showing proof that the materials have been removed is a costly expense as it requires several types of surveys to be performed by a qualified vendor. Typically, the regulators have specific criteria that the site must meet to be released for unrestricted use. Storage of these materials includes compliance with the requirements for hazardous/radioactive container inspections. The Division of Solid Waste typically requires a weekly container inspection and the Division of Radiological Health typically requires surveillance on a similar frequency. Additionally, both agencies require the responsible individuals to have appropriate initial training with refresher courses at some frequency.

Once a company has completed all activities associated with an inadvertent melting of a radioactive sealed source, serious attention must be given to minimize the recurrence of a subsequent event. The company should review its operations and install monitoring/surveillance systems at strategic points. The company must understand the strengths and weaknesses of any monitoring system including radiation detector sensitivity, scan speeds, and therefore, vehicular speeds in monitoring incoming inventory. The maintenance of the detection system is important since it is often operated in harsh environmental conditions. The investigation of a system alarm is important so that the operator(s) can become familiar with operational characteristics of their monitoring system, this being able to differentiate between positive indicators and false positive alarms. It is inherent that a company understand that even under the best circumstances and ideal conditions, a radioactive source may go undetected.

CONCLUSION

Steel manufacturers who have successfully remediated their facilities are faced with a greater challenge in the post emergency phase because of the complexities of waste management associated with facility remediation. Steel manufactures are typically not experienced in handling radioactive waste and often do not have the financial resources to deal with the waste management consequences. It is recommended that a steel manufacturer consider preparing an emergency plan that covers termination of operations in the event of a radioactive source melting incident. It should contain points of contact for governing regulatory authorities as well as describing area isolation instructions for the establishment of restricted areas, clean up procedures and instructions and criteria for returning the facility to normal operations. Waste management and disposal issues should be generally described with available options. The plan should be periodically reviewed and updated for applicability and incorporate any regulatory changes that will impact these activities. While it is not required, the steel manufacturer should meet with the appropriate regulatory agencies to learn before hand the expectations of those offices should an event occur. This proactive posture by the steel manufacturer will help minimize mistakes during any subsequent cleanup.

The Response To Depleted Uranium Turnings Dumped In Northamptonshire

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INTRODUCTION

The discovery, by HM Inspectorate of Pollution (now part of the Environment Agency), of a substantial quantity of depleted Uranium Swarf scattered about derelict land on a farm in East Northamptonshire, UK, sparked a full scale emergency, where the National Arrangements for Incidents Involving Radioactivity (NAIR) Scheme were invoked.

Major users of radioactivity are required by UK law to have appropriate emergency plans.[1] The NAIR Scheme, co-ordinated by the National Radiological Protection Board (NRPB), provides advice to the Police on accidents involving radioactivity in cases where no emergency plan applies, or if such a plan fails. The Scheme envisages two stages of response - an initial response by local experts, usually from a hospital physics department; and a second stage, if the incident is large or requires specialists, from companies in the Nuclear Industry.[2] The Medical Physics Department at Northampton General Hospital was the local NAIR I contact.[3]

DISCUSSION

The first stage was an inter-agency meeting on Friday, the 13th of January, 1995, to discuss the discovery and its implications. The agencies present included the Police, Fire Service, Public Health, Ambulance, Mr. Denman as NAIR Stage 1, County Council, HMIP, District Council Environmental Health and a USAAF representative.

Discussion centred on whether, as the swarf was on private land, the farmer should be required to clean up the site, or whether the material was a sufficient public health risk that NAIR should be invoked. As the area had no gate, and was used as an adventure playground by children of nearby USAAF residents, and was a general illegal dump, it was decided that there was a public risk, and, as there was no other obvious emergency plan, NAIR was invoked. Without visiting the site, NAIR Stage I decided that the clear-up was beyond their capabilities, and invoked Stage II directly.

The most at risk group were the children in USAAF Accommodation 100 metres away, and it became a priority to meet residents. Senior USAAF Staff were briefed at 15.00, and a residents meeting called for 18.00. Press were briefed at the site at 16.00. The Health Help-line was established by 18.00 with the twin aims of finding anyone who had been on the site and reassuring other members of the public. NAIR Stage II, AEA Technology, Harwell, arrived at 17.30. At the Meetings with USAAF staff and residents, and at the Press Conference, Dr Morgan and Mr Denman, together with the HMIP Inspector, Adrian Bush, provided expert comment.

The possibility of radioactive waste being on the farm had been raised when a consignment of metal waste set off a radiation alarm in a Sheffield scrap-yard. The company had only fitted the alarm recently in order to detect contaminated metal from sources such as Scandinavian steel with raised Caesium content following Chernobyl. Subsequently, a paper in Health Physics noted 38 incidents of radioactivity in scrap, worldwide, in the period 1983 to 1994 [4], and incidents continue at the rate of 3 each year.[5]

The passage of the waste had been tracked back by HMIP, via another scrap-yard in Northampton, to the farm. Originally suspected to contain Caesium, the material had, by the start of the NAIR incident, been identified as depleted Uranium Swarf, - that is metal turnings, 0.25 by 1 inches of almost pure Uranium-238, an α-emitter with half-life of $4.5 * 10^9$ years, decaying to radioactive daughters emitting α and β-radiation.[6] The Annual Limit of Intake is 0.5 MBq orally and 50 kBq for inhalation (minimum dependent on form).[7] It is pyrogenic, and should be stored under oil; otherwise oxidises to yellow\green oxide. It is also a chemical hazard with a daily limit 2.5 mgm, and a threshold limit in air equivalent to an ALI of 10 MBq. The risks are ingestion of oxide and inhalation of smoke if it burns. Additional information about depleted Uranium was obtained during the incident from the NRPB, British Nuclear Fuels (BNFL) and the NHS National Poisons Unit.

The swarf had been dumped in black unmarked drums; some had been opened and emptied and others had been knocked over, spilling the contents, so that most of the swarf was exposed. The initial assessment was that 50 kgm had been spilt.

AEA took several days to investigate the extent of the uranium and to plan the strategy to remove it. The swarf was spread over a sizable area on the ground amongst brambles and on the concrete roadway, pressed into the surface by vehicles. The estimate was revised upwards, and AEA eventually removed almost 1000 kgm of swarf from the site. AEA were concerned that the metal could catch fire when moved, and therefore proposed to make the piles safe with oil and transfer these piles to large oil-filled drums. The latter was the most hazardous operation. This required special protective suits and fire-fighting equipment.

This raised the possibility of a fire and radioactive plume, and consequent hazard to the public. A series of inter-agency meetings were held over the weekend to consider the implications, and Neil McColl, as NAIR Coordinator, ran computer simulations at NRPB to consider the risk from a plume in view of the current wind direction. The calculation assumed that 1% of the uranium would be sufficiently vaporised to be carried off-site. The projected radiation risk was low compared to NRPB Sheltering Limits [8], but it was decided that the USAAF personnel should be asked to stay away from their accommodation, or shelter in it throughout the 7 hour operation.

The Police set up road-blocks at convenient junctions half a mile away, and an ambulance, fire tender, and Mr Denman were on stand-by near the scene throughout. The operation was carried out safely, with the bulk of the uranium being removed that day. AEA took several months to completely clear the site, including scrubbing the concrete roadway, and removing a substantial amount of top-soil. This procedure was only completed in early 1996.

The Health Authority set up the telephone Help-line, 6 lines manned all week-end. Details were taken from callers, and these were prioritised following the guidelines in Table 1. This process was aided by a map of the site, initially cryptic, showing location of the swarf. Callers were reassured that they would be contacted again, starting with those of highest priority. 73 calls were received, and a further 21 were contacted as a result of these calls. The numbers of people (callers, USAAF residents, and people contacted) in each category is also shown in Table 1.

Table 1- Priorities used by Help-line

Priority	Definition	Numbers	of People
		Contacts	Physics Visits
5	Took swarf away. Ate it	0	0
4	Handled Swarf on site	3	3
3	Definitely saw and trod on swarf	3	3
2	Walked all over site, including drum area	22	20
1	Walked on site, not near drums	12	9
0	Never visited site (includes drive past)	134	17

A surprising number of people had been on the site as shown in Table 2.

Table 2 - People who visited the site

American Children Playing	American Resident jogging	Waste Regulators
Pigeon Shooters	Pheasant Shoot and Beaters	Fox Hunt Followers
Metal Sculptress	Aircraft memorabilia Group	Apple Scrumpers
Old bottle collector	Car scrap-dealer	Some-one dumping car
Farm Workers	Fly Tippers	Lovers

CONCLUSION

It was concluded that any contamination would be on outdoor shoes, door-mats, ground floor carpets, out-door clothing; and bike and car tyres, and so people were monitored in their own homes. The USAAF residents were monitored first, with the rest of the monitoring starting on Monday using three teams of two - one from the local Medical Physics Department, and two from NRPB. In total 52 people were monitored, (see Table 1), and all found to be negative. Eight people at greatest risk were offered whole body monitoring using the shielded germanium detector system at NRPB. Two took up this offer and were both found to be negative. Those not visited were advised by letter of the negative results for those at greater risk.

The only radioactivity found off-site was a small amount in the bottom of a drum - one of those used to transport the uranium. This had been removed from the site by a farm worker to a housing estate in a large town and used as a garden incinerator. Fortunately the area around the drum was clear, suggesting that the drum had been emptied before use.

From the quantity which was discovered on the site, it was surmised that a further empty drum must have been taken from site. This was no doubt an unmarked black drum like the others, of which there are many lying around the countryside. As the drum would be empty the risk to the public would be very low. It was concluded that there should be no public appeal to locate the drum.

The Police Press Office took charge of dealings with the Press. Their preference was to release the news as early as possible, to prevent speculation. This, of course, was prior to a full examination of the site by Stage II. At that time, the risk to people going on to the site was compared to a few chest X-Rays. The Press demanded pictures and hence access to the site, and had to be tested for contamination afterwards which sidetracked staff from public monitoring. The discussions about the fire risk to local communities did not excite the public greatly, even though news leaked out that this was being considered. Further, the Press missed the potential significance of the drum that was found off-site.

Public reaction to the incident was to a major extent determined by local, national and international press coverage. Would the incident have had a higher profile without the on-going story of public demonstrations over live export of calves? The national press aided by spokesmen from pressure groups such as Friends of the Earth made much of the environmental concerns with subsequent comment developing a political dimension - "how could it happen?" - "could it happen again?" - rather than local health risks.

The Health Help-line number was carried by the national media, but given more prominence in the local press in Northamptonshire. The incident occurred 1 mile from the county border, but no one who lived outside Northamptonshire called the Help-line. Some callers were concerned that rats on the site could have carried the uranium off site to contaminate workers in an industrial complex half a mile away. Two ladies had scrumped apples, and made pies, and were concerned that the apples were contaminated.

By contrast, the American Residents had greater knowledge of the risk from uranium, because of health concerns over Uranium Mining. The residents were anxious for their children, but the concern dropped markedly once the site entrance and children's playground were found to be uncontaminated.

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Graded Decision Guidelines for Public Health Activities -- Lansdowne, Pennsylvania

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INTRODUCTION

In 1991, the Environmental Protection Agency (EPA) Region III office requested that the Agency for Toxic Substances and Disease Registry (ATSDR) initiate preliminary public health evaluations of radiologic hazards associated with several residential properties in Lansdowne, Pennsylvania. Because of the presence of radium, radon, and asbestos in the house at 133 Austin Avenue and an adjacent warehouse as reported by EPA, ATSDR determined an imminent public health hazard existed and both agencies expressed concern about the potential for structural fires, intrusion, or other unauthorized events. Because of ATSDR activities, and with concurrence of EPA, the site was included on the National Priorities List (NPL).

On June 13, 1991, EPA Region III contacted the EPA National Air and Radiation Environmental Laboratory (NAREL) to help in the initial site evaluation at 133 Austin Avenue. This two-family rental unit was believed to be contaminated with radium-226 (Ra-226) processed during the early 1900s at the adjacent warehouse at 36 S. Union Street. EPA Region III informed ATSDR that the rental house was occupied by two families, including a woman who was approximately 6 months pregnant. On the basis of limited sampling information, ATSDR concurred with the EPA Region III recommendation that all residents in the house be relocated. This relocation occurred during June 17 - 23. On June 19, NAREL collected radiologic data at the site, including external gamma radiation readings, levels of fixed and removable contamination, and radon levels in the house and adjacent warehouse.

DISCUSSION

NAREL released the results of this survey on June 28, 1991. The reported levels of external gamma radiation ranged from background levels (15 microroentgens/hour; μR/h) to 1.2 milliroentgens/hour (mR/h) in the master bedroom on the first floor. The maximum removable alpha contamination in the basement exceeded 30,000 disintegrations per minute (dpm). Radon measurements indicated that the highest levels in living areas were greater than 20 picocuries per liter (pCi/L), even with a relatively high rate of ventilation during the measurements. Because of this high rate of ventilation, NAREL requested that charcoal canisters be placed in the house. Results from the canister measurements showed that radon levels on the first floor ranged from approximately 49 pCi/L to 63 pCi/L. On the second and third floors, levels ranged from approximately 19 pCi/L to 29 pCi/L. NAREL also surveyed the warehouse and found elevated levels of gamma radiation (190 μR/h to 1.2 mR/h) and radon (23 to 36 pCi/L); removable contamination on the first floor was 60 dpm.

EPA performed expanded site investigations and identified 40 residential properties contaminated with radium and/or radon in excess of levels thought to be safe for human exposure. ATSDR and EPA Region III collaborated to determine what, if any, actions should be taken to protect the public health of these residents. As a result of these guidelines, over 15 persons were relocated. The actions included a set of graded decision guidelines that would support actions ranging from no action to immediate relocation. The process used to develop these guidelines and the evaluation of standards as they existed in 1991 is discussed below.

The Uranium Mill Tailings (UMT) standards (40 CFR 192)[1] provided guidance for cleanup of properties contaminated with UMT. This established an action level at 4 pCi/L of radon and 20 μR/h gamma radiation above background in houses, which is similar to the situation at the Austin Avenue site. The UMT rule provided clear guidance for the decision to initiate cleanup action; however, the rule does not address the problem of relocating the occupants of the property in the interim.

For gamma radiation, several guidelines were available. In 1991, the Nuclear Regulatory Commission (NRC) allowed an exposure of 500 millirem (mrem) per year to members of the public.[2] The estimated annual cancer risk of such an exposure was about two extra cases in a population of 10,000 per year of exposure. The International Council on Radiation Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) currently recommend an annual exposure limit of 100 mrem per year above background.[3,4] The annual risk of 100 millirem is about 5 in 100,000. It is generally assumed that the limit of 100 mrem per year above background also is intended to apply to exposures that might be repeated for many years. The risks quoted above are calculated using an additive model that applies a linear-nonthreshold assumption and does not allow for the dependence of effects on dose rate.

At the other extreme, the standard for nuclear workers is 5.0 rem per year[2], but occupational exposures are kept as low as reasonably achievable (the ALARA principle). This level of risk is tolerable in an occupational exposure for which a commensurate benefit results from the exposure. A standard this high is inappropriate for an involuntary exposure to a member of the public, especially when no compensating benefit to society exists.

The final, and perhaps most relevant guidance, was EPA's Protective Action Guides (PAGs) for nuclear power plant accidents.[5] These guidelines focus on the relocation of persons from their residents after a nuclear accident and discuss risks and social and economic costs of relocation. The guidance allows a maximum of 2 rem the first year and a maximum of 500 mrem any other year. The 2 rem per year maximum in the first year is based on the typical radionuclide mix from a power plant accident and is intended to achieve 5 rem over 50 years because of decay. The 5 rem included the 2 rem in the first year and results in an average dose of 100 mrem per year over 50 years. Because radium has a 1,600 year half-life, it can be treated as if it does not decay, and the 2 rem maximum would therefore not apply. However, the 0.5 rem guide for any other year is designed to protect against hazards accrued over only a few years. Because the contaminated houses were to be cleaned up within a few years, the longest that nonrelocated persons will be exposed in the future is only a few years. Thus, the 0.5 rem guide fits well. It also should be noted that the PAGs do not consider past exposure. The guides are aimed specifically at preventing the effects of future exposures which is better explained in the PAG document. It also is intended that the relocation is based on exposures before cleanup measures are applied. Therefore, a person who is not relocated after a first-year dose of 1.9 rem would probably receive only 0.5 rem after rudimentary cleanup is performed.

Using these guidelines, ATSDR reviewed and categorized the addresses encompassed by the Austin Avenue site into three distinct categories: Category 1 – relocation if radiation exposure exceeds the 500 mrem action level (seven addresses); Category 2 – ATSDR and EPA discuss actions if radiation readings are greater than 200 mrem per year but below 500 mrem per year (four addresses); and Category 3 – no actions necessary if expected annual exposures are less than 200 mrem per year (10 addresses). Table 1 lists each of the addresses and information regarding measurement levels, EPA actions, and categorization.

Radiation levels at addresses in Category 1 exceeded the ATSDR-recommended limits and relocation was offered to residents. Several elderly residents declined relocation despite elevated gamma radiation exposure rates and the elevated radon levels in their homes.

Addresses in Category 2 contained residences at which the expected external gamma radiation level was between 200 and 500 mrem per year. For each location, the demographic characteristics of the residents and the potential for additional exposure were considered. ATSDR met with EPA and discussed the four locations. EPA determined the annual gamma radiation exposure estimates after interviewing these residents. The estimates were time-weighted averages based on the estimated time, over a year, that residents would spend in each radioactively contaminated room. After reviewing the exposure estimates and the EPA rationale, ATSDR concurred with EPA's decision not to offer relocation.

Category 3 contained locations at which the expected external gamma radiation level was less than 200 mrem per year. As stated previously, when levels below 200 mrem were estimated, ATSDR recommended no EPA action. For each location, the demographic characteristics of the residents and the potential for additional exposure were considered. On the basis of annual gamma radiation exposure estimates, ATSDR concurred with EPA's decision not to offer relocation, except to one person, a medical radiologist who resided at 237 N. Lansdowne. This relocation was offered because of concern that the resident's cumulative occupational and residential exposures could exceed 500 mrem annually.

CONCLUSION

With the development of these graded decision guidelines, ATSDR and EPA were able to apply a uniform process to assist the on-scene coordinators and the remedial project managers in the performance of their duties. The guidelines also have been applied in Idaho (i.e., in conjunction with phosphate slag issues) and their use has been considered in Connecticut (i.e., in several contaminated buildings used previously in the watch manufacturing).

Table I. Location, estimated radiation levels, radon levels, and EPA actions

Location	Category	Gamma Radiation	Radon	EPA Actions
211 Penn Blvd.	1	Not Determined	34 pCi/L	Relocation offered but declined
25 Lexington Ave.	1	0.7 rem/year	8	Relocation offered but declined
137 Lexington Ave.	1	2.3	5	Relocation offered
25 Beverly	1	1.8	30	Relocation offered
216 Wayne Ave.	1	0.67	ND	Relocation offered
218 Wayne Ave.	1	0.52	19	Relocation offered
500 Harper Ave.	1	0.47	50	Relocation offered
3723 Huey Ave.	2	0.3 rem/year	4.6	No offer
617 Pine St.	2	0.3	2	No offer
619 Pine St.	2	0.26	1.4	No offer
623 Pine St.	2	0.21	1.3	No offer
126 Owen Ave.	3	Background	5.7	No offer
237 N. Lansdowne Ave.	3	0.12	Not Determined	One relocated, occupational exposure
6 Plumstead Ave.	3	0.02	6.1	Radon reduction system installed
10 Plumstead Ave.	3	Background	8 in basement	No offer
310 Shadeland Ave.	3	0.07	ND	No offer
64 S. Clifton Ave.	3	Background	12.8	Unoccupied at time of measurement
621 Pine St.	3	0.1	3	Below action levels
346 Owen Ave.	3	Background	ND	Below action levels
151 Lexington Ave.	3	0.13	17	Radon reduction system installed
504 Harper Ave.	3	Background	ND	Below action levels

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Session B, Track 2: Social and Humanitarian Issues Following a Radiological Accident

Wednesday, September 9, 1998
2:05 p.m. - 4:20 p.m.

Chair: Marcia Carpentier, United States Environmental Protection Agency

Red Cross Programme Responding to Humanitarian Needs in Nuclear Disaster

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INTRODUCTION

Large scale nuclear disasters are fortunately very rare. So far, international humanitarian assistance has been requested in only one case, following the explosion in reactor N 4 at the Chernobyl Nuclear Power Plant (CNPP) in Ukraine on the 26th April 1986. Apart from the immediate and better known emergency effects, the world took some time to discover the extent of the damages on the environment. It took even longer to assess the consequences on affected populations. Cross border effects, large number of population affected spread over three countries and limited information on the long term consequences are only but a few of the constraints faced by humanitarian organisations in the aftermath of that disaster. The International Federation of Red Cross and Red Crescent Societies (hereafter called the "Federation") has developed a unique programme aiming at meeting the humanitarian needs in affected communities. The following is a review of this programme, its background, its activities and the lessons learnt and to be shared with the entire humanitarian community.

DISCUSSION

Historical Background

Immediately after the Chernobyl disaster became known, the Red Cross National Societies (NSs) and the Government authorities of the three affected Soviet Republics of Ukraine, Belarus and Russia were involved in the provision of immediate relief to the affected population. This was carried out under the umbrella of the Alliance of Red Cross and Red Crescent Societies of Soviet Union.

In 1990, following a request for additional international assistance, the Federation sent a needs assessment mission to look at possible humanitarian intervention. The mission reported that a lot of information was missing concerning the levels of radioactivity as well as on the possible health effects on people living in contaminated areas. The first programme was designed which included use of hand held dosimeters distributed to people in villages in the most contaminated areas.

In 1992, the Red Cross Chernobyl Humanitarian Assistance and Rehabilitation Programme (CHARP) second step was launched with the introduction of 6 Mobile Diagnostic Laboratory (MDL) vehicles, two for each affected republic. The aim was to collect information at the community level in the most remote villages and provide immediate feedback to people. Health status of local populations was checked and levels of radioactivity were measured both in human beings and in the environment. In most cases, results were found to be within acceptable limits set by the governments. In 1994, ultrasonic scan for detection of thyroid gland cancer was added to the programme's activities.

The "New" CHARP

In 1996, following the second evaluation of the programme, it was decided to adapt and reshape CHARP to better meet the needs of affected populations. The following adaptations were recommended:

a) Measurement of radioactivity was restricted only to gamma radiation in most contaminated areas. Measurements of alpha and beta radiation in the environment were discontinued since four years of experience had not shown dramatic increase in the levels measured. Whole body monitoring to assess the internal accumulated radioactivity in persons was discontinued. It was relying on heavy and expensive equipment and this modification allowed use of lighter vehicles. Monitoring of radioactivity in food items was also discontinued in the MDL's. It remained in a few places only (Red Cross dispensaries) as an extraordinary service. The MDL's health screening by medical doctors as well as blood and urine examinations were also continued. Particular attention was paid to the teenagers and those who were children at the time of the accident.

b) Prioritised detection of thyroid gland cancer through enhanced capacity in the MDL's: more sophisticated equipment and better trained personnel. The reported increase in the number of this type of cancer in children appeared to be the major health consequence of the disaster. (See table for Belarus, next page). The target population was now focused on children and teenagers (as the group most at risk consists of children who were between 0 and 2 years of age at the time of the accident, in 1986) and screen 90,000 people per year, an increase of 50% from 60,000 previously. The health screening is still backed up with a full medical check up and blood and urine laboratory tests.

c) Distribution of non contaminated food items (milk powder and vitamins plus micronutrients) to specific target groups (children in institutions) continues. For most of these children, this food supplement is the only source of non contaminated animal proteins and vitamins during the winter and part of the spring each year.

d) The fourth recommendation was to develop a psycho-social rehabilitation programme so as to meet the psychological needs of the affected population. At large, these needs were unmet (and sometimes not even recognised), and required careful attention as they prevent effective rehabilitation from taking place. The development of a pilot project in Belarus took place, centred around the already existing network of Red Cross branches and MDL's. Through dissemination of simple, reliable and understandable information made by specially trained volunteers and personnel, it is expected to reduce the anxiety of the targeted populations.

e) [To increase the sustainability in each national part of the programme was put forward as essential.] It is currently addressed by the National Societies of the three affected republics, now fully independent countries.

Collected data is computerised and shared with relevant authorities in the three countries, mainly Ministries of Health. Even though it may appear to be a sophisticated programme, CHARP is a humanitarian programme, aiming at improving quality of life in affected population, and neither a scientific nor research exercise. Close co-operation with scientific and technical communities as well as establishment of good relationship with International Organisations such as WHO, UN/OCHA, IAEA and UNESCO, are important in order to establish and further develop the programme's credibility.

Achievements

Twelve years after the explosion in CNPP, the need to continue humanitarian assistance is more obvious than ever. Despite that the only major health consequence detected so far is the dramatic increase in the number of thyroid cancer cases, all health consequences remain yet to be fully assessed.

The psychological impact of the disaster overtakes by far the physical consequences. The Federation Programme is one among the very few that addresses those needs. It requires both a careful and long term approach as there are great needs to be met, especially to restore confidence in the affected populations. During its seven years of activity, CHARP has gained credibility and recognition amongst the affected communities and this made the acceptability of the psycho-social rehabilitation pilot project much easier as people trust the Red Cross programme.

The socio-political disturbances that followed the disintegration of the former Soviet Union dramatically increased the negative health impact of the disaster as most health care services became rudimentary, especially in remote areas. It left people in a bad position to deal with any disease or ailment. The level of distrust developed against authorities is such that rehabilitation will take decades. Programmes, such as the Federation one, helps to accelerate the process, demonstrating the possibility for affected communities to regain self confidence and to decide on their future.

CONCLUSION

The effects of technological disasters require careful exploration using new and innovative approaches to detect, identify and manage health consequences. Characteristics such as cross border effects and long term consequences are obvious today. For example, first reports about thyroid gland cancer increase appeared more than 5 years after the disaster and when the most suspected causative agent, radioactive iodine, had completely disappeared from the environment.

For humanitarian organisations, the management of such type of disasters requires development of new skills. Links with both scientific and technical communities have to be established and further developed in order to provide the most appropriate response on the one hand and to re-enforce the organisation's credibility, on the other hand.

The time frame is also different compared with other humanitarian activities. Long term perspective is required and political as well as financial long term commitments are needed so as to ensure adequate response during all the phases of the post-disaster period.

Given the potential for other disasters of the same type, it is critical that humanitarian organisations draw lessons from past experiences and get prepared for both action and advocacy. Since long term humanitarian needs are frequently overlooked in technological disasters and technical and economical aspects are given the priority, it is important that somebody highlights the humanitarian needs during longer periods and what exactly is needed in the affected communities.

Constructing More Effective, Post-emergency Responses: the Human Services Component

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ABSTRACT

Recent studies and an accumulating body of experience have demonstrated that environmental accidents can have both short-term and long-term effects on the social, psychological and psychosocial well-being of people in affected communities. It has, therefore, become evident that there is a need for an expanded and more sophisticated human services component in post-emergency response, several factors, however, are hindering the development of this human services component. First, there is presently a lack of a formal role for human service professionals in most emergency and post-emergency response mechanisms. In coming years it will be important to better integrate human service professionals such as environmental sociologists, community psychologists and social workers into post-emergency planning and response bodies. Second, education and training related to environmental hazards has not yet been included in most human services training programs. While several programs have recently moved to incorporate material on environmental accidents into the curriculum, additional work in this area will need to be undertaken. Third, the exchange of information on human service assistance efforts after environmental emergencies has thus far been spotty. To facilitate systematic improvements in the human service component of post-emergency response, a better means for sharing experience and cumulating knowledge will need to be developed.

Modelling Social Psychological Factors After an Accident

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INTRODUCTION

The situation obtaining in the long term post-emergency phase of a major nuclear accident is as complex as any to be found in society. As time passes, the original event and its immediate consequences set in train a long process of action and counter-action designed to improve the situation. Each action is capable of generating further change so that overall complexity increases. Social and psychological factors appear as outcomes and can interact with radiation protection measures in ways which may reduce the effectiveness of those measures. For example, expected dose reductions may be compromised and populations left distraught when the intention was otherwise.

Studies conducted in the regions affected by the Chernobyl accident have demonstrated that psychological factors can interact to affect behaviour and, consequently, to affect dose. Thus, there is a need for social psychological factors to be taken into account in the planning and execution of radiation protection policies. But how to do it? In an EC funded study on Social Psychological Aspects of Radiation Protection after Accidents (SPARPA)[1] the roles of the various factors are being examined in the context of socio-cognitive structural models. The main aim of these studies is to explicate the situation of people living in contaminated territories in order that decisions about countermeasures may be based on a better understanding of the key factors. Thus, one outcome of the research will be a decision aid for radiological protection.

This paper introduces socio-cognitive models, discusses how empirically based structural behavioural models can predict behaviours and/or psychological distress in response to the accident, or to countermeasures, and reviews the implications for decision aiding for radiological protection.

DISCUSSION

Socio-cognitive models

Social cognitive models have been developed by social psychologists to take account of the ways in which people think and act in a given type of situation. In general, such models measure beliefs, perceptions and attitudes in an attempt to predict intention to pursue specific behaviour[2]. In the context of health related behaviour there have been several such theories applied in recent years[3], particularly in the examination of protective behaviours[4]. One synthesis of these attempts has characterised the main dimensions of such models as comprising two main phases[5]. According to this approach, the first phase is concerned with motivation, which leads to the formation of intention to act. It includes four components: self-efficacy expectations, outcome expectancies, threat and intention. The second phase is concerned with the taking of action and includes planning, behavioural and situational components.

It is instructive to examine these components in the context of the radiation situation obtaining in the contaminated regions. Self-efficacy expectations have emerged as very important elements in the modelling of a wide range of health related behaviours. They refer to the extent to which people believe they are capable of taking the appropriate actions needed to provide protection from a threat. Such expectations are not mere reflections of some individual self estimate of strength of character or similar generalisation but may consist of very practical considerations or judgements about the situation. For example, even if people know that they should eat uncontaminated food, do they believe that such food is actually available?

There is then the matter of the efficacy of the specific response. Simply put, this refers to the extent to which people believe that the available response will actually produce the desired or recommended outcome. For example, do people think that limiting their use of forest produce, such as mushrooms, will have an effect on their dose? In general, if people believe that a given action will reduce their dose, and believe that they are capable of taking that action, then they are more likely to perform the behaviour.

Outcome expectancies also play a major role in the formation of intentions to act. Here both specific and generalised outcome expectancies may play a part. Both refer to beliefs about the likely outcomes of behaviours and answer for the individual a question like what will happen if I do x. For example, people often do things because they expect a familiar outcome and, if there is a risk associated with the behaviour which does not immediately challenge that assumption, then changing that behaviour may be problematic. For example, where people habitually pick wild mushrooms and expect to gain from the activity, and cannot detect any problem with that activity, merely telling them that there is a risk may not violate the expectation of reward. Generalised outcome expectancy is a similar element in the explanation of behaviour but refers to overall views of the consequences of action. It has not featured strongly in many of the existing health behaviour models but there is evidence of its role[6] and one measure based on this concept has been found to be an important predictor of dose in Russia[7].

Outcome expectancies may include costs and benefits associated with particular protective behaviour. In the above example, the avoidance of wild mushrooms clearly involves a cost. In the context of a fairly poor rural economy this includes both a monetary loss of free food but also a loss of non-monetary benefit, such as the enjoyment derived from the traditional foraging for wild produce. Expectancies can also include the behaviour of family or friends. People often rely on the guidance or example of others to help determine their own actions, either because they are encouraged to pursue courses of action deemed good for them or because they fear disregard if they fail to comply. Similar arguments apply to the social acceptability of countermeasures.

Characterisation by individuals of the threat posed to themselves clearly constitutes a major aspect of the approach. There are two main elements to this characterisation: the perceived vulnerability of the individual to the threat, in this case the perceived level of exposure to contamination; and, the perceived severity of the threat, simply the subjective estimate of the severity of the consequences of exposure.

This apparently simple formulation does not capture all that is known with respect to protective behaviours. When people are faced with a threat, assuming that they have the information necessary to estimate the danger to themselves, they do not necessarily choose the recommended course of action. The process of evaluation itself may arouse fear or anxiety and this may then become a problem for the individual. The person is confronted with an immediate problem, the anxiety, and may resolve that problem in a way which prevents behaviour aimed at the primary cause. For example, being afraid of the consequences of exposure to contamination may lead people to deny the threat. Pursuit of such a coping strategy may involve the avoidance of information about the threat so that radiological advice is actively ignored.

Structural behavioural models

Empirically based structural models take the main elements of social cognition theories and hypothesise relations between them by positing causal pathways between measured variables. Such measurements use conventional psychological scaling methods based on questionnaire responses. [In the SPARPA approach settlements that have been surveyed and scales developed from items in the questionnaire which represent concepts in the models.] Such scales combine a number of items which have been developed to measure the same concept in order to produce a new variable representing this concept. By combining the responses to a number of items, a more reliable estimate of the concept is obtained. The internal consistency of the resulting scale can be estimated by examination of the way in which all of the items correlate with one another. An index of this internal reliability is available and hence some aspects of the quality of the measurements may be estimated.

The structural behavioural models being developed in the project take the social cognition theories as a starting point, but variation in the approach is necessitated by the specific conditions obtaining in the contaminated areas. For example, in most applications of social cognition theories there is not usually a convenient measure of behaviour, or of a proxy outcome for behaviour. In the case of the contaminated areas, however, there is the opportunity to measure ingestion dose which will have derived from individual behaviours, such as the consumption of contaminated local food. Furthermore, most of the approaches have the prediction of intention to act as their main focus. In the contaminated areas, however, there is already a considerable history of actions and recommendations so that past and existing patterns of behaviour have more significance. In this case a behavioural measure, such as avoidance of forest behaviour can be devised, based on self reports of avoidance of forest foods combined with reports of avoidance of visiting the forest. Within a model a composite behavioural measure such as avoidance of forest behaviour can be used to predict dose, based on Whole Body Measurements taken from individuals completing questionnaires.

The modelling process was begun with the specification of a generic model based on the logic of the social cognition theories. Empirical data were then collected and specific versions of this model were tested using a structural equation modelling technique[8]. Within this family of techniques, statistical procedures exist which permit the testing of hypothesised relationships. Because a great many models may be based on empirical data, a specific version may be tested against a base line model, where variables are assumed to be uncorrelated. In addition, measures of the predictive strength between variables are available as standardised path coefficients which can be evaluated to conventional confidence limits. The procedure is iterative so that a series of such models may be built on survey data and tested for fit. Relationships that are shown to be weak by statistical tests may be dropped. Subsequent surveys may be designed to improve the models.

CONCLUSION

Decision aiding

The SPARPA project aims to characterise, using quantitative methods, the nature and psychological impact of countermeasures, and the influence of behaviour on dose, in order to help develop guidance on the implementation of countermeasures. One clear implication for decision aiding for the radiation protection community is that a reliable framework for making sense of the social psychological elements of a decision should emerge. The building of structural behavioural models is one technique that should feed conveniently into decision aiding procedures currently used, or being developed. The conceptual structure is flexible and offers the opportunity for the diagnosis of failure in the implementation of what would otherwise appear to be effective protection measures.

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Emergency Events Involving Radiation Exposure: Issues Impacting Mental Health Sequelae

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Statements contained in this paper are solely those of the author and do not express any official opinion or endorsement by the Substance Abuse and Mental Health Services Administration.

INTRODUCTION

Understanding the psychological sequelae of disasters is rapidly increasing as a result of both emerging research as well as real life experience. In the United States, the primary experience base has been with natural disasters. There is much to be learned from experience with natural disasters that is very applicable to planning for, and response to, radiation emergencies.

This paper will not focus on general principles of disaster mental health preparedness and response. There are several good sources for this type of information[1,2,3]. This paper will propose a number of special considerations, which may be significantly *different* than dealing with natural disasters, for understanding human response to radiation emergencies. A number of very concrete suggestions will be offered in response to these special characteristics.

DISCUSSION

Context of Understanding

To begin understanding the psychological consequences of radiation exposure, regardless of the nature of the event, it is important to consider how most people view and understand radiation. Perhaps more accurately, how people *lack* understanding of radiation--therein is the key to understanding what we are up against in helping people cope with actual or perceived exposure.

Most people have very little understanding of what radiation is, how it works, and what it does to living things. What people do perceive is that radiation is very powerful (especially in destructive ways) and very mysterious. It is likely that most people, could not accurately answers very basic questions regarding the nature and effects of radiation and exposure. In the absence of accurate understanding, especially when coupled with often distorted beliefs and intense fear, it is easy to see how both acute and chronic stress responses can result from even *suspected* exposure.

Recommendations:

- Public education regarding the nature of radiation and its effects on the body should be encouraged, both as part of general public education, as well as emergency and disaster preparedness efforts.
- Education should include dispelling myth, assuring the validity of post exposure assessment, and educating about the nature and normalcy of stress reactions following perceived exposure.

Role of Blame

In responding to natural and other types of emergencies and disasters we have learned a great deal about the centrality of blame following traumatic events which are outside the range of usual human experience. Since, in natural disasters, people find it culturally and religiously unacceptable to blame God, people frequently turn their anger toward any individual or group that they feel is responsible for, or could/should have prevented, the traumatic event. In events where victims/survivors become focused on blame and the desire to seek retribution, stress and depression appear to last longer and delay health integration and resolution of the experience. When blame is not easily assigned, people tend to focus blame on a wide variety of authority figures, regardless of their involvement in the incident. In the case of radiation exposure, there will, in all likelihood, be fairly easy targets for blame.

Recommendations:

- In preparedness activities, help response official understand the normal nature of blame and provide specific training on how to deal with individual and group blame.
- In any counseling interventions following an incident, help victim/survivors understand the normalcy of blame as well as its adverse psychological consequences. Provide alternative coping mechanisms.

Impact of Unknown Health Consequences

In the best known nuclear power plant emergency in the United States, Three Mile Island, the most significant long term health effect was anxiety and depression resulting from unknown long term health consequences.[4,5] Stress resulting from acute and chronic health and medical conditions is significant and often not well treated. This situation is exacerbated if those exposed to radiation fear future illness (even into future generations).

Recommendation:

- Same as in next section.

Tracking and Follow-up with Those Exposed

Because of the fear of (real or imagined) long term health effects it is critical that those exposed are tracked for extended periods of time for screening and intervention purposed. As a result of the long-term nature of some emergency and disaster related stress, as well as its biological manifestations, mental health screening and intervention where appropriate and necessary should be a component of any follow-up program.

Recommendations:

- Include mental health screening as part of all follow-up programs.
- Have treatment interventions available for anyone who needs them.
- Provide ongoing accurate information to those exposed.

Importance of the Message and the Messenger

When faced with frightening and mysterious situations, people seek leadership and accurate information. In the hours immediately following radiation exposure, there is a need to provide the general public and high risk populations with a great deal of information. The content, format, and presenter of the information are important in reducing psychological sequelae.

Recommendations:

- Make every attempt to coordinate messages to reduce the potential of contradictory information. Few things will erode confidence more quickly than conflicting information from identified leaders and experts.
- Assure that the person(s) delivering the message has the highest credibility possible to reduce the potential of listeners discounting the message. All spokespersons should be free of perceived vested interest in "spinning" information.
- Assure that all public information is available in various formats (e.g., radio, television, written) and reflects the culture of the recipients.
- Include information related to stress as part of all massages. Normalize the experience of stress, provide suggestions for coping, anticipate special situations (e.g.., the stress of families sheltering in place for extended periods, availability of guns, alcohol, etc.), and provide information about where to get help.

- Repeat messages frequently. People under stress tend to retain information less will than when they are not stressed.

Screening for Exposure

In any large scale radiation incident, there will need to be extensive radiation exposure screening. While this will typically place a significant burden on the existing health care system it provides a unique opportunity to intervene in the mental health domain (if not labeled "mental health"). If mental health or stress assessment is made part of general screening it provides a great opportunity to assess stress, identify those most in need, establish a contact that can later be capitalized upon for future interventions, provide educational materials about disaster related stress.

Recommendation:

- Make mental health part of all radiation exposure screening and follow-up.

Impact of the View of Government

Most radiation incidents, with the exception of war, are the result of some type of accident or error. Various parts of the Federal government will be involved in activities following the incident even if not involved in the incident itself. There appears to be a significant, and perhaps growing, negative feeling toward government in the United States. This ranges from outright hatred and the perception that government is the enemy of the people (this type of view apparently resulted in the Oklahoma City bombing). Others view the government as involved in cynical attempts to experiment on and manipulate people. Still others, while not viewing the government as sinister, view the government as inept and incapable of adequately managing its affairs and protecting the people.

Emergencies and disasters of all types do not occur in a vacuum. They exist in a context of people's individual and collective experiences, beliefs, and perceptions. The perception of government will play a significant factor in how people cognitively structure their experience of radiation exposure. That cognitive structure will be the major determinant in determining the emotional impact of the exposure and behavior that follows.

Recommendation:

- Preparedness and response activities should include appreciation for, and training in, dealing with the sometimes hostile views of government. It is important for preparedness and response officials to understand that people's attitudes and behavior may have to do with *other* perceptions that have *little* to do with radiation.

Impact of Competing Priorities

The primacy of concerns about radiation exposure has varied considerably over time. Certainly, it reached its peak during the Cold War. It has always been in the forefront of the concerns for those who live and work in areas where there is ongoing concern for exposure. Even in light of this long standing concern, as noted at the start of is paper, most individuals remain extraordinarily naive and ill informed regarding radiation and its effects. Following the end of the cold war, attention to the potential of radiation exposure appeared to have waned as we adjusted to a world order that is different than what many had known.

With the World Trade Center and Oklahoma City bombings, the threat of terrorism on United States soil became a reality. It did not take long for concerns about radiation to reemerge in the context of the group of threats labeled Weapons of Mass Destruction (WMD). Very shortly after that, radiation exposure, at least resulting from terrorist threats, seems to have lost the spotlight again, probably as a result of the enormous complexity of the threat from biological terrorist events. There is a risk that the significant health and mental health consequences of radiation exposure will not receive the attention necessary to enable full preparation and response because of attention to other types of threats.

Recommendation:

- There should be reinforcement of the perspective that *all* WMD threats represent complex preparedness and response challenges, that the types of threats are *very different*, and that preparing for one does not necessarily make us better prepared for all.

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Public Reactions Following the Chernobyl Accident
Implications for Emergency Procedures

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ABSTRACT

The paper briefly sketches a general background of the public reactions to the Chernobyl accident in affected states of the former Soviet Union, Scandinavia and other parts of Europe. Fear of health effects, and trustworthiness of information, played central roles at the time of the event and in the development of the post-accidental situation. In the case of an accident, the importance of immediate, reliable information from trusted sources accompanied with behavioral recommendations is underlined. Furthermore, that various monitoring activities and countermeasures are sufficiently explained, and quickly focused on affected or vulnerable groups and areas. It should be noted that long-term physical and psychological effects will occur in the most affected groups even after the society at large has found a way back to normal life.

INTRODUCTION

General background

The Chernobyl accident is the largest nuclear accident which the entire world has recognized and experienced. Some of the lessons learned from the accident, however, may be quite specific to that time and situation. There have been other, large accidents involving radiation and severe contamination, e.g. the Techa River pollution (1947) and the "Kyshtym" accident (1957) in the Soviet Union (1). These catastrophes were not known to the world, and not officially acknowledged until 1989, when the Russian government declared the Chelyabinsk Oblast in the southern Urals an ecological disaster zone (2). The Chernobyl accident occurred in 1986, in a transitional political era, when the Soviet Union moved from silence to "Glasnost", even regarding nuclear issues, and was moving towards a political and geographic breaking up of the state. The explosion of the fourth reactor in Chernobyl, however, occurred within the "old mental framework", where silence, and remote, high level, decision making, belonged to the golden rules. The adapted policy affected information availability, relative to the immediately affected populations, as well as neighboring nations and the rest of the world. Retrospectively the accident has become associated with initial silence, no early warning and thus unnecessary harm to affected individuals, and a long heartbreaking and politically turbulent post-accidental situation.

DISCUSSION

Nobody was warned about the airborne releases of e.g. Iodine. Individuals living close to the plant actually watched the burning reactor, and some of those living in Pripyat misunderstood the clean-up activities of the city the following day as preparations for the first of May celebrations. Even after the evacuation of the population of Pripyat, people in neighboring areas were encouraged to participate in the first of May parades in the following week. This encouragement was salient in the minds of a group of youth and children in Novozybkov in 1992 (3). Trust in various information sources, e.g. authorities, scientists, journalists, was overall very low. This state of affairs created a dilemma, since people were dependent on, and expected help from, those instances which they did not trust. Thus, the conscious neglect of warnings, early information and relevant recommendations came to affect both the medical situation (e.g. thyroid problems), trust in subsequent information, and the anxiety attached to the event. People felt unprotected, uncertain about information, and lacked personal control in a potentially dangerous situation.

The first years' continuous measurement work, and the attached information, revealed more contaminated territories. The period involved relocation of large population groups and late introduction of countermeasures and e.g. massive health screenings. As time went by, the subdued fear and the personal experiences of helplessness developed sometimes into an aggravated waiting for long-term health effects. Some people in affected areas and elsewhere tried various ways to be classified as victims, to benefit from available compensation schemes. In the first half of the 1990s there was a marked exhaustion and listlessness in the most affected populations, and an increasing difference in reported well-being between those who still lived in fear of health effects and others. However, people had learnt something about radiation and radioactive contamination. Those living in more contaminated areas slowly returned to normal life, including restrictions to daily life, if they lacked alternatives. Some may even have adopted the optimistic attitude that they had become resistant to radiation. Others, and especially those who had been relocated from their previous homes, often faced a rather hostile new environment when they were to compete for jobs, various products and communal resources with those who already lived in a depressed economic situation. The newcomers were not seldom stigmatized, and their well-being often assessed as the lowest across investigated groups (4). People attributed various health problems and misfortunes to the accident. In addition, in the first part of the 1990s, claims of financial compensation and health monitoring surfaced from those who (or whose parents or grandparents) had been affected by the earlier nuclear accidents. Why should the Chernobyl victims be so well cared for when others had been subjected to far more serious conditions without any notice at all?

Western Europe was first puzzled by the indications of increased levels of radioactivity, and highly puzzled by the lack of information. The accident had happened on the night to Saturday, April 26th, but there was no official Soviet information about the accident until Monday evening. The morning had seen personnel at the Forsmark nuclear power plant on the east coast of Sweden lining up outside the plant, awaiting individual monitoring and control of the plant.

These protective actions, and the searching for a source, were followed by the hour in the local and national media (5). The excessive air distribution of radioactivity was surprising to experts, and the uneven dispersion, due to winds and rainfall, quite hard to understand for the public. The immediate, as well as the long-term, radiological situation therefore became both factually complex and complicated to communicate. Experiences of worry were related to degree of contamination and vulnerability (6). Local areas in Scandinavia measured a mean deposition of Cesium 137 of about 80 kBq/m2, e.g. the Gävle area in Sweden (7). The sudden event with its long lasting effects affected especially farmers and hunters regarding their daily life and general well-being. The Sami population was, in addition, threatened with respect to cultural traditions and self-identity (8).

The continuous reactions in Europe seemed to reflect the overall level of acquaintance with nuclear issues. And although the public opinion rapidly grew somewhat or very negative immediately after the accident, researchers could point to (9) a relationship between pre-accidental public debate and reactions to the accident. Public opinions reversed more quickly to a pre-accidental situation in countries where the public was more familiar with nuclear power issues. As measurements continued in the former Soviet Union, however, it became evident that people who had believed themselves to be unaffected, lived on rather or very contaminated land, e.g. in Belarus in 1987-88. Some villages were relocated, and others subjected to countermeasures (10). In our joint CIS/CEC studies investigating the social and psychological effects of the accident (11), we encountered people still awaiting relocation from small villages as late as 1992. Simultaneously did memories related to the Chernobyl accident fade in the rest of the world. Some influential persons even subscribed to the expression of "radiation phobia", which had spread in the former Soviet Union to stigmatize those still living in fear of radiation health effects (12). At the 10th anniversary of the accident it was concluded that social and psychological effects were among the most prominent and lasting consequences. It was also pointed out that these effects must be viewed in the overall context of the political, economic, social and cultural situation of the time and geographic area.

CONCLUSION

Implications for emergency procedures

Individuals' reactions to radiation and radioactive fall-out is foremost related to risks of health effects. People are especially concerned about children. Health effects certainly vary due to several factors and circumstances, but until more specific information becomes available the psychological reactions are linked to procedures connected with early warnings, information and recommendations, including reflections on the mastery of the evolving situation and general preparedness, e.g. availability of prophylaxes, etc. It should be noted that the first reaction to a disaster, or a potentially dangerous situation, very well might be indifference, i.e. what Quarantelli has termed "the normalcy bias" (13). The first reaction to the TMI accident has been described as unconcerned (14). People have to be convinced that there are good reasons to take action before they act. The reactions when a warning is heeded, involve observing others' behaviors and collecting and comparing information from several sources (15). As already noted above, general preparedness and early warning and information are among the vital factors (16) in the quality and development of public, and media, reactions. The handling of these factors seems to influence the subsequent phases of the post-accidental development. Furthermore, it is necessary always to provide sufficient explanations to issued countermeasures and recommendations. Emergency procedures would also be facilitated by involving known, efficient and trusted communicators. There are immensely important lessons to be learnt from Chernobyl, but it may not be feasible to compare reactions of people accustomed to dictatorship with populations used to totally different life styles. Neither should it be forgotten that the communist system offered some options which may not be available in democratic societies, e.g. to evacuate whole villages in a rather controlled and efficient manner, to implement far reaching decisions quickly and without discussion, etc. Thus, political, cultural and sub-cultural values and variations must, among other aspects, be seriously considered in the planning, as well as the implementation phase, of an accident.

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Session C, Track 1:
Lessons Learned from Exercises

Thursday, September 10, 1998
8:00 a.m. - 9:50 a.m.

Chair: Gary Goldberg, United States Department of Energy

Lessons Learned from the 1997 Lost Source Exercise

William E. Belanger

U.S. EPA, Region III

INTRODUCTION

During the mid to late 1990s, radiation detection systems have been installed in increasing numbers at waste disposal and processing facilities, as well as scrap metal facilities. During this time the States, the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency have noticed a significant increase in the number of radiation alarms reported by these facilities. This increase most likely reflects an increase in the number of radiation detectors present at waste disposal and scrap metal facilities rather than an increase in the amount of uncontrolled radioactive material. Nonetheless, there is a significant potential for radioactive sources to find their way into commerce, which NRC is working to reduce. Examples of these "lost sources" include the following.

In August of 1996, workers removed a radioactive gauge containing americium-241 from an industrial process in Racine, Wisconsin. The Radiation Safety Officer did not discover the unauthorized removal of the gauge until November of that year. The source was never recovered, and the licensee believes it was sent to a landfill.

In September 1997, a radiography camera was reported missing. The camera was located in a pickup truck and the truck was stolen. The incident happened near Tulsa, Oklahoma. The camera was subsequently recovered and was intact, but there had been the potential for it to enter the waste stream or the scrap metal market. Loss of a source of this type is the basis for the data used in the Lost Source Exercise.

In September of 1997, an americium-241 gauge was removed from an assembly line in Allentown, Pennsylvania. In this incident, the gauge found its way to an automotive scrap metal facility. Unlike the 1996 incident, the gauge went through the metal shredder and the container was breached. This resulted in approximately 40 cubic yards of contaminated waste, as well as the ruptured source, which the Department of Energy removed for disposal. This incident was noteworthy because, in responding to the State request for assistance, Federal Agencies followed the procedures described in this exercise.

In all, during 1996 (the latest year available at the time of this writing), NRC's Office for Analysis of Operational Data[3] reported 88 incidents where there was a loss of control of NRC licensed material, and 76 similar incidents of agreement-State licensed material. Lubenau and Yusko[1,2] have also described the occurrence of radioactive materials in recycled metals.

While the regulatory agencies may be able to reduce the number of incidents where there is a loss of control over radioactive materials, there will always be a potential for radioactive materials to enter the waste and scrap metal operations. It is not practical to reduce human error to zero and there are also foreign sources where United States regulatory agencies have no authority.

EPA, NRC and DOE share responsibility for supporting the States in radiological incidents in the public domain and are natural partners in radiological response. The Federal Radiological Emergency Response Plan (FRERP), dated May 8, 1996, designates a Lead Federal Agency (LFA) for radiological responses to emergencies. For example, the EPA is the designated LFA for responses to emergencies in which sources are of unknown, unlicensed, or foreign origin. By contrast, the NRC is the designated LFA for responding to incidents involving materials licensed by the NRC or an Agreement State. The DOE maintains an independent Radiological Assistance Program which may respond to State requests for assistance independently or as part of the FRERP.

The EPA also has the ability to respond pursuant to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended, and the National Contingency Plan (NCP) adopted under CERCLA authority. CERCLA and the NCP give EPA broad funding and response authority to protect the health and welfare of the public and the environment. This response may come as a part of the emergency response, or may be delivered in the post-emergency phase, or both, as long as there continues to be a "threat of release."

DISCUSSION

The Lost Source Exercise, conducted in Coatesville, PA in September and October of 1997, was an opportunity for the EPA and the NRC to coordinate their response efforts with those of DOE and State and local officials to address a public domain incident using FRERP and NCP authorities. This exercise examined the ways that Federal assistance can be provided to State and Local officials by the EPA, NRC, and DOE pursuant to the FRERP and NCP during a public domain, private sector incident. The exercise scenario involved an unshielded, 100 Curie radiography camera arriving at a municipal waste landfill in a trash truck. This scenario provided ample technical as well as administrative challenges to the participants, who were drawn from all levels of government and from the private sector. The exercise was held in two parts, representing the emergency phase and the post-emergency phase. For the purpose of this paper, we define the emergency phase as the period when there is an imminent threat to public health, and the post-emergency phase as that period when the immediate threat has been controlled, but there may be substantial clean-up remaining. In this exercise, the post-emergency phase began when the trash truck had been (simulated) relocated to a remote area where it posed no immediate threat, but the source had not yet been recovered. The post-emergency exercise consisted of the recovery of a dummy radiography source and camera from a load of simulated municipal waste. The Federal response for both the emergency and post-emergency phases was provided pursuant to the National Contingency Plan.

The EPA and the NRC conceived and conducted the Lost Source exercise to demonstrate the capability to mount a regional multi-agency response to a radioactive material release in the public domain, since such releases in the public domain pose a different set of problems than those involving a fixed nuclear facility. In the public domain, there is no advance knowledge of where a release might occur, and the identity of the licensee or responsible party might not be known or the licensee might not have the ability to maintain financial responsibility. By contrast, releases at a fixed facility usually originate from a point somewhere within the facility, and the fixed facility has a known licensee or responsible party who can be held responsible for cleanup activities. Consequently, for releases in the public domain where the identity of the licensee is unknown or where the material is of foreign origin, the FRERP designates the EPA as the LFA.

This exercise involved EPA Region III, NRC Region I, the DOE Brookhaven RAP team, Pennsylvania DEP and PEMA (the cognizant State agencies in this case) local officials and solid waste industry representatives. Representatives from FEMA and the DOD Defense Nuclear Weapons School observed the exercise and discussed the capabilities which could be provided by their agencies. The response was conducted at the regional level for two reasons. First, the EPA Region III RERP was unique when the exercise was conducted because it included radiological incident response under the NCP. Second, the size and nature of the release were chosen to require only a response on the regional level, a situation which is typical of most releases in the public domain. The regional response reflected the provisions of the FRERP, while also examining resources available through the NCP that may be appropriate with the EPA as the designated LFA. Also, the reader should note that, in playing the cognizant State government, Pennsylvania represented the necessary interface between the Federal government and any State involved in a given incident.

In addition to demonstrating multi-agency response capability, the Lost Source Exercise yielded a number of ancillary benefits. For example, this exercise gave participants the opportunity to review current incident response plans, which are geared to the FRERP, and to determine how those plans may need to be better integrated with the NCP. In particular, this exercise examined the process for determining LFA responsibilities and other agency support activities. This is important, since the recent revisions to the FRERP have not otherwise been exercised under simulated conditions involving a spill of radiological material of unknown ownership licensed under the Atomic Energy Act (AEA), with the EPA designated as LFA. In that capacity, the EPA's primary intent is to coordinate Federal response and assistance activities from the scene.

CONCLUSION

As a result of the Lost Source Exercise, the participants learned the following lessons:

- The EPA Superfund Program encompasses substantial capabilities and authorities, which can be mobilized in the event of a radiation emergency (whether or not the material is licensed under the AEA.)

- Each responding entity has its own goals and priorities during a response. These goals and priorities are dynamic and may evolve as the situation develops. For example, in this exercise, private industry wanted to minimize the impact on business operations, solid waste agencies wanted to ensure that the continuing stream of municipal waste had a place to go, county officials handled the immediate threat, State officials had the ultimate responsibility to protect public health from the radiation threat, and Federal officials provided technical support and had the capability to mobilize significant resources. While it was not apparent in this exercise, these dynamic priorities might be expected to conflict at times throughout a response.

- Federal notification procedures are well defined within each Federal agency, but an individual agency's internal procedures are not well known among the other agencies. Consequently, the Federal community needs to develop a standardized notification scheme that applies to the Federal response as a whole. While the FRERP provides a standardized notification scheme among the agencies, internal procedures are not consistent from agency to agency. This can result in confusion as the Federal team is formed.

- The Unified Incident Command (UIC) concept was not familiar to all of the participants. This concept needs to be better explained in future exercises and training opportunities. By providing a practical scenario to apply the UIC concept, this exercise gave participants a valuable learning experience. Many participants suggested in their comments that this experience should be shared with others.

- Notification thresholds need to be better defined for each agency and office. The NCP specifies required notification of the National Response Center of releases of all chemicals (including radioactive materials) exceeding certain reportable quantities specified in the NCP. The agencies responding to radiation incidents are generally unfamiliar with this legal requirement. A courtesy notification at lower levels should also be considered.

- Federal officials need to recognize that the States differ greatly in their capabilities and their needs. This includes responsibilities associated with Agreement State status, different responding organizations within each State, and the roles of local government in emergency response.

- Early notification of the appropriate DOE RAP team should be routine. The RAP team needs to know of a developing situation, rather than simply being called in after the fact.

- Private sector capabilities and constraints are highly variable and will need to be considered on a case-by-case basis. Industry groups should be consulted when government emergency response plans and procedures are formulated.

- Local government may play a significant role in emergency response and must not be overlooked in either the planning or the response, in both the emergency phase and post-emergency phase.

- Agency acronyms and jargon should be carefully avoided when multiple agencies are acting in concert. There are many conflicting acronyms between agencies. For example, "NRC" may stand for the U.S. Nuclear Regulatory Commission or the EPA's National Response Center. Such conflicts and unfamiliar jargon restrict effective communication.
- The DOE and DOD possess a large body of expertise and resources, and the FRERP and NCP provide a means to access those resources. In addition, individual cooperative agreements between the various agencies can be used in addressing incidents. The Unified Incident Command gives a useful mechanism to employ these cooperative agreements.

- Many participants also commented that the opportunity to witness recovery of a highly radioactive source very valuable, and that the experience should be provided to others.

Overall, the exercise demonstrated the role of the NCP in the response to a radiological incident. This response need not be confined to the emergency phase. In fact, the resources available through the NCP may be more important in the post-emergency phase, as the cleanup effort becomes the focus of the response. This is especially true when EPA is the LFA under the FRERP, since EPA is designated LFA mainly in circumstances where there is no licensee or otherwise well defined responsible party who can conduct the cleanup.

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Nebraska's '97 Ingestion Exercise: Communication Through 2 Phases of Response

Cheryl K. Rogers, Emergency Response Manager

Nebraska Health and Human Services Regulation & Licensure

INTRODUCTION

The ingestion pathway exercise was demonstrated at Fort Calhoun Nuclear Station following a standard plume phase exercise in June, 1997. Ft. Calhoun is located on the Missouri River. Participants included the State representatives of Iowa and Nebraska from both the emergency management and health departments, now Health and Human Services Regulation and Licensure, HHS R&L, in Nebraska. There were no Federal participants or power plant representatives. This was in contrast to the 1993 Federal Radiological Monitoring and Assessment Center, FRMAC, which was conducted in June of 1993 with full Federal participation.

HHS R&L provide technical advice and assistance to the Governor's Authorized Representative from the Nebraska Emergency Management Agency, NEMA. The challenge in an ingestion exercise is to communicate technical information concerning the first two phases of radiological emergency response. The phases are Early or Plume Phase and the Intermediate Phase which is when the source and releases are under control. There are two components to the Intermediate Phase regarding Protective Actions. One component restricts access to areas which have projected doses of 2 Rem or greater. The other component restricts ingestion of contaminated food and water. The protective actions may be developed simultaneously.

DISCUSSION

The initial plume phase resulted in activity deposited to the northwest of the plant and located in Nebraska. Due to the fact that the wind shifted during the release, the area to the south and east of the plant out to 5 miles had also been evacuated as a precautionary measure. This area was not considered to have ground deposition. We did have the results of the Department of Energy, DOE, flyover, Figure 1, immediately following the plume phase.

The first lesson concerned the best use of the field teams. Even though this was simulated activity, we had to be very specific about where we wanted immediate information. We assumed that we had four field teams at our disposal. In addition to Ion Chambers for accurate dose readings, one field team was assumed to have the use of a portable multi-channel analyzer, MCA, which was borrowed from Iowa. The team with the MCA obtained field data from the area of ground deposition. By the following morning, we had identified and measured concentrations of the major isotopes. This information confirmed that the isotopic mix was

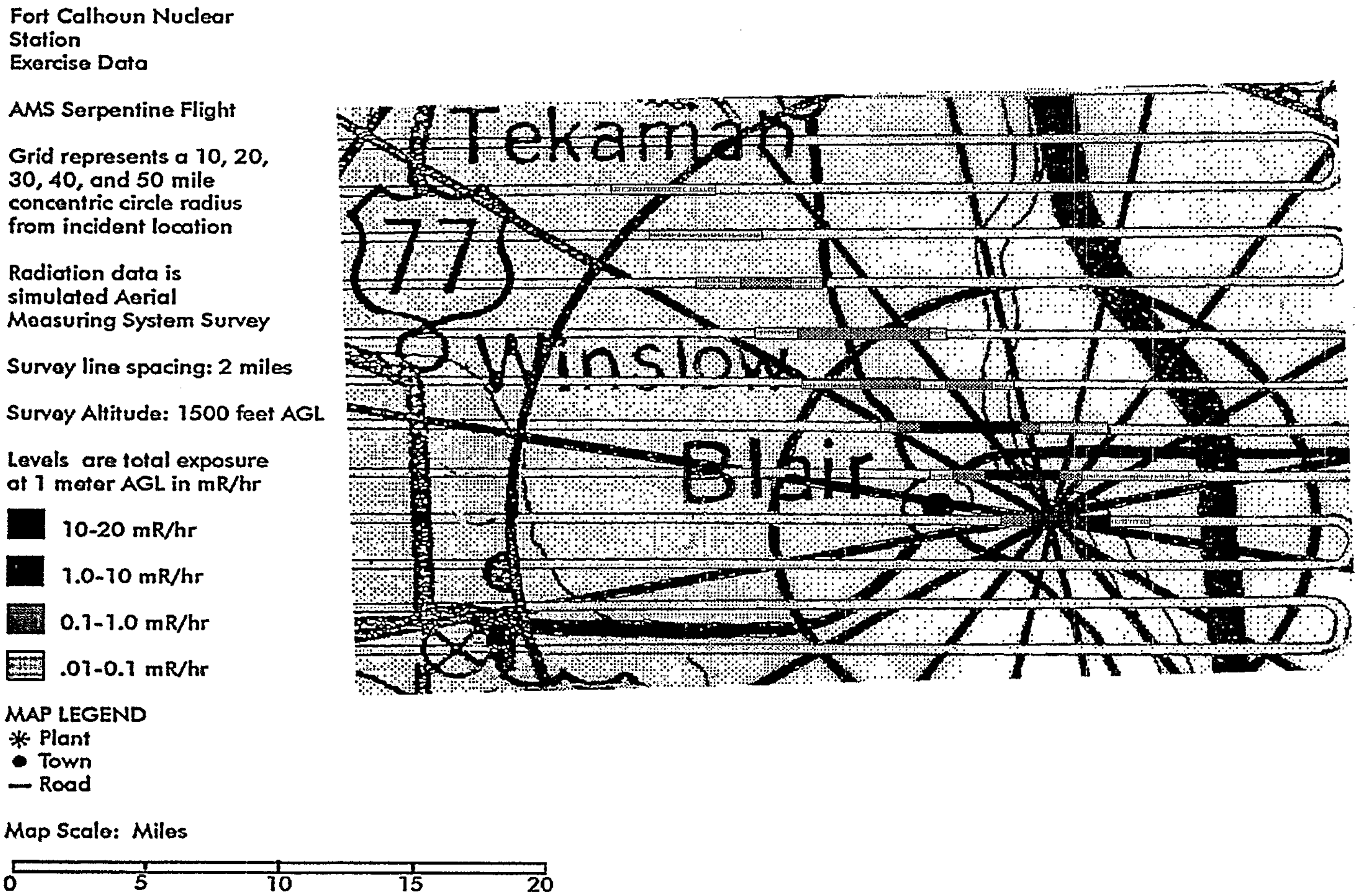

FIGURE 1 - DOE Flyover Showing Ground Deposition

uniform. We knew that the dose rate corresponding to 2 Rem/year for the restricted area was 3.7 mrem. Two other field teams conducted surveys along major roads and intersections to give us dose rates. These were used in conjunction with the gamma spectrometry information to identify the restricted zone. One field team was sent to confirm that there was no deposition in the clean area.

The next lesson learned involved our communication of the restricted area to the Emergency Management Agency. Figure 2 shows the restricted area based on the field team results. The restricted access area covered a sector and a half out to a distance of 5 miles. Our first communications obstacle arose when the restricted area map developed by HHS R&L staff indicated that the part of the town of Blair, (south of Highway 75), could be released, but the north area would subject its inhabitants to more than the recommended 2 Rem per year. Also, the Blair's water treatment system was located in the restricted area. The local authorities and

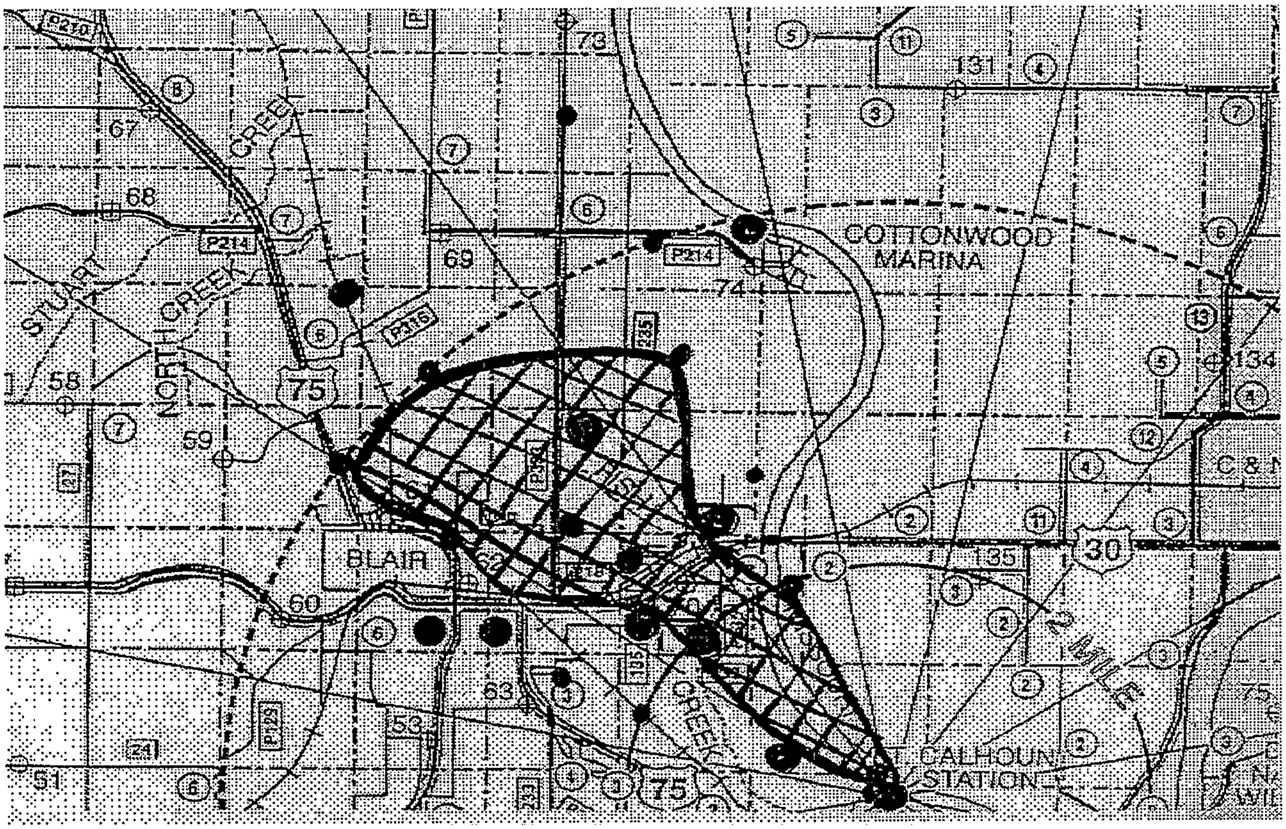

FIGURE 2 - Restricted Area Based on Field Team Results

NEMA had developed a standard policy of not splitting a town in half for evacuation. Therefore, initially at least, it did not make sense to them to split the town in half for purposes of restricting access. Their perspective, which carried over from the early phase, was that access to the entire town of Blair should be restricted.

There were health physics issues associated with the restricted zone. The "re-entry" check-point for those individuals with urgent business in the restricted zone required staffing in order to provide TLDs and survey meters. We were requested to determine probable dose rates, how to adequately monitor these individuals during their re-entry, and to provide training as individuals re-entering would now be classified as occupational workers. We were asked what would the dose limit be for these workers. The missing piece of information is how much time over the course of a year would an individual need to spend in the area. A recommendation would be to set some predetermined dose rates that would be acceptable. We utilized 2 Rem as our initial working limit, but our State Emergency Plan has since been updated to the 5 Rem which is recommended in EPA 400.

The final challenge or lesson concerned the timing and process of the ingestion pathway sampling. HHS R&L began requesting information from NEMA when the plume phase ended. Requests were generic and included: dairy, surface water, forage, produce, eggs and meat. In retrospect, a standard list in order of priority could be developed as part of the planning process and submitted to NEMA early in the intermediate phase. In addition, the USDA representatives suggested including food processing plants. The protective action guidance for ingestion was utilized during the exercise. The distances that were recommended extended out as far as 60 miles in areas that were not evacuated or restricted. There were separate recommendations for each type of food or milk product and the restrictions varied from 30 to 60 miles out. Figure 3 is a map showing the area restricted for milk ingestion. These new areas were initially discussed looking at the same map which identified the restricted area, which did cause some confusion. The area that had ingestion restrictions overlapped the restricted area and the various ingestion restrictions were not uniform. Considering public perception of risk, it seemed unlikely that anyone would want to remain in an area known to have ground deposition, despite assurances from government officials that it was safe. We considered and discussed how the local population would react to the safety recommendations such as: do not eat anything grown in this area, wash, scrub or peel all your home grown vegetables, and only let your children play outside a few hours per day. Options for presenting this information to the local population were reviewed, and it was decided that small group discussions would be best. Concerns were raised about whether any foodstuffs containing radioactivity would ever be released, regardless of the protective action levels. From our perspective, it was more likely that foodstuffs would be condemned for human use,(with a suitable buffer zone), to assure that the other agricultural products from the State would not be adversely impacted. For this exercise, we did follow EPA 400 and advised the Governor's authorized representative to:

- condemn milk and divert milk,
- not introduce meat livestock into commerce,
- condemn forage or divert to non-human use pathways,
- shrink the stored feed area for lactating animals, and
- condemn produce or divert to non-human food pathways.

CONCLUSION

In summary, our focus going into the exercise was primarily on the technical methods to be used to arrive at our recommendations. However, we should have utilized different maps for the restricted area and the ingestion pathway restrictions. Communications would have been improved by providing a clear introduction to the phase and component for recommendations (i.e., these are for the restricted zones and these are the ingestion restrictions). The same maps and forms for recommending protective actions may not fit the intermediate phase. New approaches may be needed to adequately frame the recommendations and to apprise the emergency management agency and the local authorities. Additional table-top exercises would help both the health and emergency management agencies understand the different phases and steps involved in the intermediate phase. Finally, the local authorities should be more fully involved in planning and response if they are to understand how to accomplish the needed protective actions.

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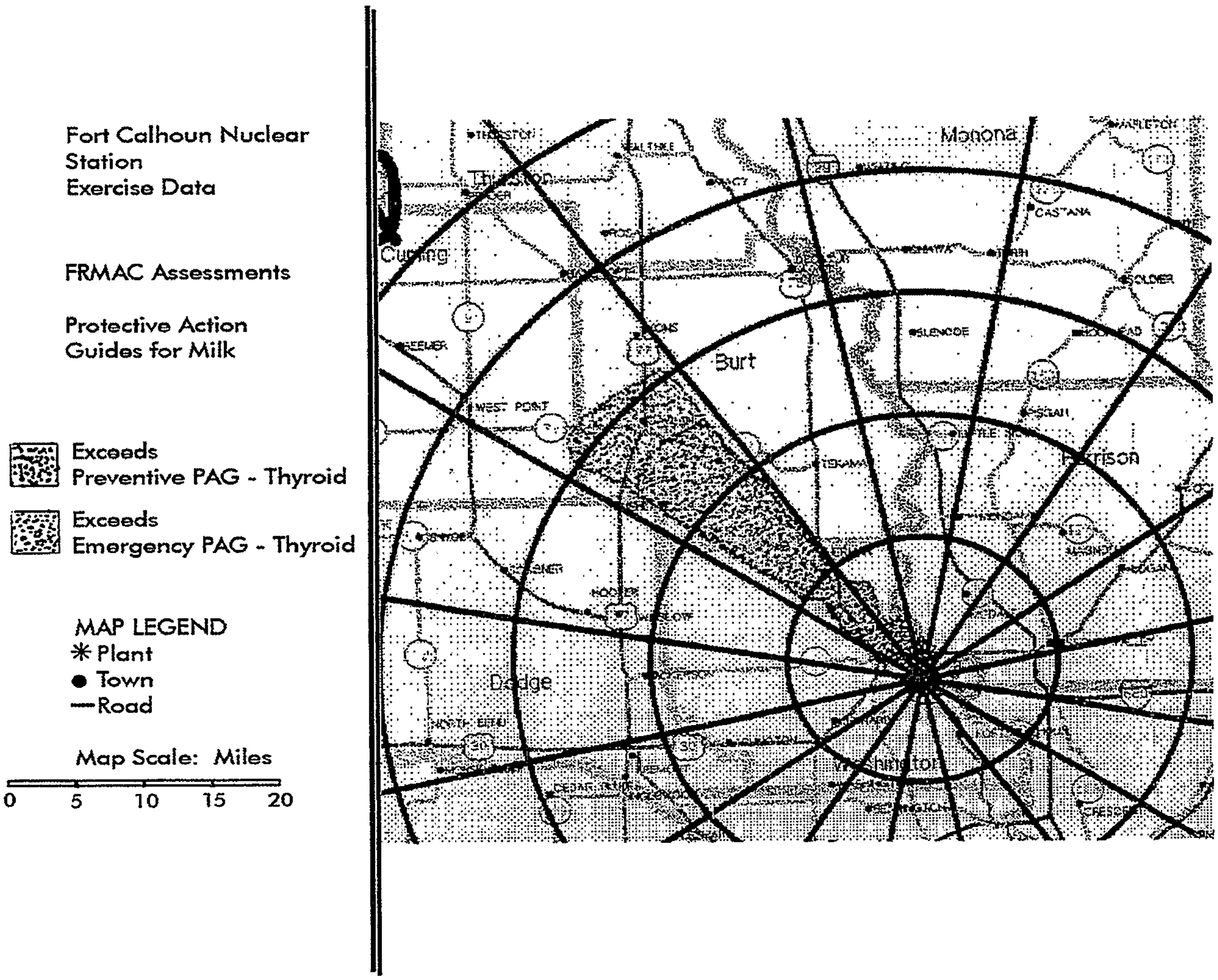

FIGURE 3 - Ingestion Zone Restrictions for Milk

Post-Emergency Planning and Exercises: Lessons Learned from CALVEX 97

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INTRODUCTION

In September and November 1997, the State of Maryland participated in a post-emergency radiological exercise with the Calvert Cliffs Nuclear Power Plant (CALVEX 97). The exercise involved 13 local jurisdictions in Maryland, 3 local jurisdictions in Virginia, the District of Columbia and numerous Maryland State agencies. The Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), the Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA) provided training assistance and participated as players during the event.

Maryland is often referred to as "the United States in miniature" because of its unique topography. This topography and diverse patterns of residential, agricultural and commercial development within 50 miles of Calvert Cliffs present many challenges to radiological post-emergency planning and operations. The Calvert Cliffs ingestion planning zone includes 13 counties in Maryland, the District of Columbia, two counties in Delaware, and 16 local jurisdictions in Virginia. The terrain includes the Chesapeake Bay, rural areas in Southern Delaware, Maryland's Eastern Shore, Virginia's Northern Neck and suburban areas around Baltimore and Washington, D.C. A wide variety of food and agricultural products are produced in the region. Seafood harvesting and poultry production are major industries; numerous food processing plants are also located throughout the area. The Chesapeake Bay and Eastern Shore are well known hunting areas for deer and migratory birds. The Eastern Shore is even home to such exotic creatures as ostriches and emu, which are raised by commercial providers. Aquaculture farms and honeybee apiaries are found throughout the area.

DISCUSSION

Maryland's last ingestion pathway exercise was held in 1990. However, very few individuals involved in the 1990 exercise were available to help plan and conduct the 1997 event. Many of the "lessons learned" from 1990 were now lost to time. Exercise planners sought to increase their knowledge by observing and participating in ingestion exercises in Delaware and Virginia in 1996. These exercises provided a wealth of useful ideas and experiences that were incorporated into the preparations for CALVEX 97. Delaware and Virginia emergency management staff generously provided advice and assistance throughout the development of CALVEX 97.

In the course of planning and preparing for CALVEX 97, a number of issues were noted. The most significant of these included the use of Federal radiological assets for exercise planning and training, the effective use of out-of sequence demonstrations, training for local ingestion pathway jurisdictions and skills training for field sampling teams and other staff.

Use of Federal radiological assets

Maryland made great use of Federal radiological assistance while planning CALVEX 97 and training exercise participants. The USDA's emergency response staff conducted a basic ingestion pathway seminar and DOE Region I staff trained ingestion sampling teams. The DOE Washington Aerial Measurements Operations office assisted in scenario development and provided simulated aerial measurement maps. Finally, the NRC held a workshop to provide an overview of Federal response activities. This workshop also stimulated many thought-provoking discussions regarding protective action decision making.

Federal assistance not only created excellent training opportunities, but also opened lines of communication between State responders and their Federal counterparts. This enhanced communication later proved to be a significant asset during the course of the exercise. It is critical, however, to request Federal assistance early in the exercise planning and training process--preferably at least a year prior to the date of the exercise.

Out-of-sequence demonstrations

Given the great complexity of an ingestion exercise, CALVEX planners decided to maximize the use of out-of-sequence demonstrations. One of the chief complaints from local officials during the 1990 ingestion exercise was that their emergency operations centers had no meaningful involvement during the exercise. It is extremely difficult to develop a scenario that simultaneously impacts every jurisdiction within 50 miles of a nuclear power facility. Therefore, the exercise planners exercised and evaluated local ingestion pathway jurisdictions two months prior to the State-level ingestion exercise.

Local evaluations were conducted using a tabletop interview format, which allowed each jurisdiction to be meaningfully evaluated. Federal evaluators visited each jurisdiction and evaluated communications, ingestion pathway protective action implementation and emergency public information activities. Local jurisdictions praised this approach, since it allowed them an opportunity to learn as well as be objectively evaluated.

Laboratory and field sampling operations were also conducted out-of-sequence to save time and not delay State-level sample planning and decision making activities. Field sampling, which included water and milk samples, occurred the day prior to the laboratory demonstration. These samples were then used during the laboratory demonstration, so that laboratory staff could realistically demonstrate the processing of samples.

Local jurisdictional training

Most of the local jurisdictions involved in CALVEX 97 had little or no ingestion pathway experience. State and utility staff offered several ingestion pathway seminars for all jurisdictions. Many jurisdictions were unable to attend these seminars due to other commitments. Ultimately, State and utility staff visited most local jurisdictions to provide individual training to emergency management, public information, agricultural and health department staff members.

Local government training was made easier through the use of a standardized training package. State and utility staff developed a computer-based presentation that was loaded on a laptop computer and taken to each jurisdiction. This ensured consistent training among all jurisdictions. The training package was continually refined and was later used in other ingestion jurisdictions in Maryland.

Skills training

Since ingestion activities are usually evaluated only every six years, exercise planners noted that participants needed practice on critical skills such as sample collection and data plotting and analysis. State and utility staff provided extensive training in the months before the exercise, with generally positive results. For future exercises, Maryland plans to train and internally evaluate ingestion-specific activities every three years instead of every six years. This will ensure a trained cadre of staff and will help maintain interest and enthusiasm for ingestion response activities.

After months of intense training and local out-of-sequence evaluations, the State-level portion of CALVEX 97 was held on November 18-20, 1997. The exercise began on the evening of November 18 with "plume phase" response activities. The exercise continued on November 19 as the State Ingestion Pathway Coordinating Committee convened to consider deposition data and develop protective actions for relocation, re-entry, ingestion and long-term recovery. Field sampling activities were also demonstrated on November 19. The State emergency operations center demonstrated implementation of protective action decisions on November 20, and laboratory operations were evaluated.

Although State officials had developed rather detailed procedures for post-accident activities, many lessons were learned through exercise play. Some of these lessons were protective actions for unconventional ingestion pathways, State and Federal interactions during protective action decision making, development and dissemination of ad hoc protective action areas and the impact of a recent environmental crisis on the decision making process.

Unconventional ingestion pathways

As previously noted, the Calvert Cliffs ingestion pathway contains a wide variety of food and agricultural activities. Maryland's decision-makers were confronted with several unusual but critical ingestion pathways. Marine life and migratory birds presented special challenges for protective action decisions and implementation.

Maryland's seafood industry is a vital part of its economy. Protective action implementation is complicated, however, by several factors. First, the Commonwealth of Virginia controls the southernmost portions of the Chesapeake Bay. Any protective action involving seafood will require close coordination between the two states. Second, it is impossible to prevent the movement of some types of marine life. Potentially contaminated fish, for example, would be difficult to conclusively sample and isolate. Crabs and oysters are more stationary and would be far easier commodities to sample and control.

Maryland's Eastern Shore also relies on migratory bird hunting as a significant part of its local economy. Migratory birds present interesting challenges. Though it is possible that birds could be directly contaminated by a radiological accident, it is more likely that these birds would ingest contaminated forage or feed in local fields. Officials then face the difficult task of sampling birds and determining exactly where they may have ingested contaminated material. If migratory bird refuge areas are determined to be radiologically contaminated, it is imperative that States all along the birds' flyway communicate the potential risk. Ingestion of migratory birds can be managed by notifying the public not to consume migratory bird meat until it has been determined to be safe. These same challenges also apply to wild game such as deer. Natural resources officials can more easily monitor potential ingestion of deer meat through existing deer checking stations.

State and Federal interactions

During the exercise, staff from the NRC, EPA, USDA and DOE participated in the evaluation of field data and the development of protective actions. This participation allowed all parties to experience the challenges of integrating Federal assets into a State's post-accident response. Although State and Federal personnel did not always agree in their assessments of data, they worked together effectively. This was largely due to the communication and working relationships established while jointly planning and training for the exercise.

Development and dissemination of ad hoc protective action areas

When protective actions are determined for areas beyond the 10 mile "plume" planning zone, they must be defined using geographic features or other boundaries. Maryland officials quickly realized that the most effective way to determine specific protective action areas was through a coordinated effort of State and local agencies. Local officials would define specific protective action areas using technical information and assistance provided by State agencies. This increased communication between State and local agencies and gave local officials a direct interest in the protective action decision process.

Dissemination of protective action areas proved to be a more daunting task. The Maryland Department of the Environment (MDE), which hosts the Ingestion Pathway Coordinating Committee, maintains a sophisticated geographic information system (GIS) which is a highly effective tool for defining protective action areas. Ideally, MDE staff could develop GIS maps that could then be transmitted electronically to emergency management customers. However, State and local emergency managers are still in the early phases of using GIS and do not generally possess compatible GIS hardware and software. During the exercise, hard copy maps were developed and delivered by courier to the State emergency operations center. Although this method is not technologically sophisticated, it was effective due to the proximity of the State emergency operations center to MDE. Maps will be transmitted electronically in future exercises as GIS equipment becomes more widely available.

The impact of the pfiesteria crisis

In the summer of 1997, Maryland experienced a significant environmental crisis when the microbe Pfiesteria piscicida caused a number of large fish kills in Chesapeake Bay tributaries. Pfiesteria also caused symptoms such as skin lesions and short-term memory loss among some humans who came in contact with waters containing the microbe. Pfiesteria soon dominated the news in the Baltimore and Washington area during August and September 1997.

Seafood sales and water recreation, so vital to Maryland's economy, dramatically declined. State agricultural officials estimate that losses by commercial fisheries, the charter boat industry, recreational fishery and tourism totaled nearly $127 million, while seafood dealers suffered an estimated $43 million loss (Baltimore Sun, June 10, 1998). These losses even though none of the individuals affected by pfiesteria came in contact with the microbe by consuming seafood. State officials made every effort to reassure the public that Maryland seafood was safe, but with only moderate success.

Maryland's key decision maker in a radiological emergency, the Secretary of the Environment, was deeply involved in the pfiesteria crisis. This pfiesteria experience was referred to frequently when discussing protective actions for foodstuffs. The public's reaction to pfiesteria seemed to serve as a clear indicator of how the public would react to the prospect of radiologically contaminated food. In light of this experience, ingestion protective action decisions during CALVEX 97 tended to focus solely on identification and embargo of contaminated food. State decision makers felt that few retailers or food processors would be willing to handle food that had been even slightly contaminated.

CONCLUSION

CALVEX 97 provided Maryland with an excellent opportunity to prepare for the many challenges of post-emergency radiological response. Plans and procedures are now being adjusted to reflect lessons learned before and during the exercise. The exercise left Maryland with renewed confidence in its ability to manage long-term radiological emergency response and helped solidify working relationships between the State and supporting Federal responders.

The Russian French Collaboration in the Radiological Post-Accidental Area

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INTRODUCTION

In 1990, the Nuclear Safety Institute from the Russian Academy of Sciences (IBRAE-RAN) and the French Institute for Nuclear Safety and Protection (IPSN) signed an agreement for promoting common technical studies dealing with the management of abnormal, or post-accidental radiological situations. Along a linked process, this Ministry EMERCOM of the Russian Federation and the French Secretariat General of the Interministerial Committee of General Nuclear Safety signed an umbrella agreement in 1993 dealing with the administrative specific issues of such situations. In such a technical and administrative framework, the implementation of large scale table top exercises has been made possible. The objectives of these exercises were mainly to test decision making processes with the associated expertise. Field exercises on the same subjects also have been organised.

DISCUSSION

The first exercise of the series took place in June 1993 in Saint Petersburg. Three one-day periods have been simulated respectively one month, one year and five years after a release.

The contaminated region of Briansk was chosen as the concrete case to be dealt with. The local public authorities were fully participating to the game with the common expertise of IBRAE and IPSN. A dedicated satellite link with the IPSN Emergency Centre in Fontenay-aux-Roses near Paris was operated. This exercise provided specifications on the necessary databases to be set up for relevant expertise as well as the computer tools to be developed for providing relevant answers to concrete questions coming from real situations.

The right way to simulate and to characterise radiological situations was clarified as well as their sanitary impact. Particular computer tools such as "Paris" code are concrete, common IBRAE/IPSN results coming from this exercise (see OECD workshop in Zurich, September 1995).

The second exercise was a bilateral contribution to the KOLA exercise organised by EMERCOM in May and June 1995, under the auspices of the Department of Humanitarian Affairs of the United Nations (UN/DHA). Three one-day periods have been also simulated respectively three days, fifteen days and one month after a major release. The Russian public authorities were again fully involved, both at the Federal level and at the blast level. A story expertise was provided by IBRAE and IPSN, including the results coming from a team of thirty experts working for the three days in the IPSN Emergency Centre. A common French Ministry of Interior/IPSN team was airborne on the site with all the necessary communication links. At the opportunity of this exercise, the lessons learned from the Saint Petersburg exercise were used and strengthened.

A third exercise was played in October 1996 around the Saclay site located in the South of Paris. This exercise lasted two full days. The emergency phase resulting from a simulated accident occurred in the research reactor Osiris was played during the first day. The second day was dedicated to the management of the accident consequences seven days after the releases. In this exercise, IBRAE prepared the main part of the scenario regarding its environmental and sanitary part. For this exercise also, a "generator" of simulated activity measurements was developed ; it was named "Enveloppe". It aimed to be used by the field monitoring teams. It was highly appreciated and showed clearly that the main problem of the radiological monitoring was not only to make the measurements but also to define what to do with them.

Based on the current results of this close collaboration, and, for IPSN, the knowledge acquisition related to the management of contaminated territories, a French process has been launched after the Becquerel exercise.

This working process aims to define and to propose concrete and operational arrangements which could be implemented during or after a nuclear accident with radiological consequences.

These arrangements are supposed to be complementary to the standard emergency countermeasures, (i.e., sheltering, evacuation and iodine prophylasis) if decided and implemented, which are not sufficient to deal with a recovery phase with taking into account all the social, economic, environmental and sanitary impacts of such accidents.

This process is structured with regular meetings of four groups. The members of these groups are mandated representatives of the different concerned ministries, of the main nuclear companies and of expertise organisations. These four groups work on the following topics:

1. Radiological characterisation of a contaminated environment. This group reviewed the current French situation (means, organisation and practices). It made recommendations along different items such as radiological units to be used, measurements and sampling procedures establishing, results transfer means. A particular issue was pointed out, as already mentioned, about the necessity to foresee a clear planning for using the results of a radiological monitoring, with emphasis on the specific problem to correct a decision

making results based only on a release prognosis with real data probably much different from the prognosis. This group has recommended a specific exercise to validate its work and its proposal, to be played in 1999.

2. Medical and sanitary policy. This group has based its work on the assessment of the dosimetric impact made with dedicated tools as ASTRAL (see again OECD meeting in Zurich, September 1995). It implements a classical risk analysis method from different typical scenarios. It made proposals concerning population typology establishing and arrangements for preparing a relevant sanitary policy based on epidemiological data to be gathered according a logical and pre-established procedure.

   One priority of this group is to study what we call "grey" situations where doses to the population are significant while remaining below international recommended intervention levels.

3. Compensation and civil liability. This group made progress establishing concrete procedures for emergency compensation and compensation during the recovery phase. Links have been foreseen between insurance company and the French public authorities to co-ordinate their respective roles in this area. A validating table top exercise is foreseen during the first part of 1999.

4. Contaminated environment recovery. This group is federating the work of the three other groups. During a first step, it established a data base of the currently available technical intervention processes for decontamination. But it is not enough. Establishing the criteria for setting up a recovery strategy taking into account the contaminated scene data, the accident data and, mainly, the local decision making becomes the basic objective. Therefore, post-accidental preparedness and planning are no more the practical aim ; but this one would be to find the right method to suggest the active management of the situation by the local population, its representatives the local authorities.

CONCLUSION

In conclusion, it could be underlined that the Russian-French collaboration in the post-accidental management area has learned, at least to the two involved countries, that the so called "recovery phase" could have chances to be dealt with successfully by considering not only the implementation of technical radiological countermeasures but also, and mainly, the definition and the implementation by the different involved social bodies of a whole strategy aiming to make the situation understandable then possibly acceptable.

Session C, Track 2: Outreach and Legal Issues

Thursday, September 10, 1998
8:00 a.m. - 9:50 a.m.

Chair: Lisa Nanko, United States Environmental Protection Agency

Uses of the Internet in Post-Emergency Response: Some Issues

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INTRODUCTION

Can the Internet be of value in post-emergency response? The answer is yes, to judge by its use following the Kobe earthquake in Japan and the ice storms in the United States and Canada last winter. This will not be a technical account of the Internet, but rather a quick look at some advantages, disadvantages, promising applications, and issues that may arise in using the Internet for post-emergency response.

The Internet and associated information technologies have already become valuable components of emergency preparedness and disaster management. So far, the Internet has probably been used most frequently in networking on a daily basis, in communicating through e-mail, and in making available general resources. Examples of these resources are the Emergency Information Infrastructure Partnership (EIIP) Website[1]; the Medical, Emergency, Rescue and Global Information Network (MERGInet)[2]; and the Natural Hazards Center Website,[3] to name a few. Some states, such as Pennsylvania, have networks that connect their counties into the State Emergency Operations Center. The amount of structured information on emergency management and disaster preparedness on the Internet is growing rapidly. Applications of the Internet in actual crisis situations have been limited, and experience with the Internet in actual post-disaster operations is even more limited. Much more can be done to utilize the Internet and related technologies, including geographic information systems and communications technologies, in coping with disasters. As access to and familiarity with the Internet increase, we anticipate that the uses of the Internet both in emergency preparedness and in dealing with actual emergencies will burgeon.

DISCUSSION

The Internet has been used during and following several disasters, and I'll talk briefly about how this experience has turned out in a few cases. Among the disasters in which appreciable Internet usage occurred and was written about are the Kobe earthquake in Japan and the 1989 Loma Prieta earthquake in California. In both cases, the Internet proved useful when other communications methods broke down (the telephone system largely went down in Kobe, and many of the radio and television stations went off the air in California during Loma Prieta).[4] The Kamsai Area Earthquake Information Web site, set up during the 1995 Kobe earthquake, is still present on the Web.[5] It provides an example of a Web site developed for use for a disaster; it includes government announcements; links to pages listing the deceased and survivors; damage information, including images; information on relief; mail services information; lists of out-of-service and usable phone numbers; information on Internet connections in the area; information on congregate care and relocation facilities; information from banks; railway service status; arrangements for money donation; information for volunteering; arrangements for pet care; information for blood donation; maps; local information; hospital information; and many other topics, including a message board.

A more recent example of Internet use during a crisis situation occurred during the January 1998 four-day ice storm in the northeastern United States and in Canada, which affected some 600,000 people for up to 14 days in northern New York State alone. With help from other State agencies, the New York State Emergency Management Office developed a Web page to assist in the disaster recovery, and the Internet also proved its worth in this disaster.[6,7] During the severe ice storm in the northeastern United States in January 1998, this Web page was posted with a range of useful information, such as what roads were opening up and which colleges were open for students. It also had information such as warnings about potential hazards of carbon monoxide from use of portable electric generators during the power outages. An interesting aspect of the use of the Ice Storm '98 Web site was that in many cases emergency workers and residents would go out during the day and struggle locally with the storm's effects, and then in the evening they would access the Web site and get the bigger picture of the status of the emergency.[7]

The Internet can provide such features as interactivity, two-way communications, and multimedia information on demand. One of its advantages is that a great deal of information can be made widely available. Access to these data can be either restricted (e.g., by password use) or open to any Internet user. The potential for dispensing information is enormous. There is also excellent potential for contacting other persons, either individually (as in e-mail) or in groups, for on-line discussions. An important aspect of the Internet is that it can provide information one-way, without permitting direct inquiries from those receiving the information. This could be an advantage for public information personnel and others responsible for information dissemination during disasters, in that they could provide information without simultaneously having to deal with a flood of direct inquiries from the media or the public.

On the other hand, the Internet does have some drawbacks. A major drawback at present is limited access. This is more of a problem world-wide than it is in the United States at present; by some estimates, about 30% of people in the United States have some form of Internet access, and this percentage is rising rapidly. To communicate or receive communications on the Internet requires literacy, knowledge of the language or languages in use, capability of using computers and software, and access to both a computer and the Internet. Also, relevant portions of the Internet must be operational: both clients and servers need to be up and not overloaded. All the communications systems that we use in emergency response, including networks, can be fragile and technically vulnerable. To compare technical vulnerabilities of the Internet with those of other communications systems, such as television, radio, telephone, cellular telephones, facsimile machines, and so on, is well beyond the scope of this paper. In crisis situations, you need redundancy; that can be accomplished by having access to many different communication channels during and after an emergency.

Another drawback of the Internet can be the presence of incorrect information. The quality of information on the Internet varies a lot, and bizarre ideas and false information have spread on the Internet in the past in other contexts. We must be prepared for this to occur during emergencies, and we will likely need some sort of rumor control operation to address rumors relating to emergencies. More generally, it would be desirable to have means to assure the integrity of information disseminated during emergencies and disasters.

While one-way electronic information dissemination may be an advantage for some applications, as just mentioned, it may also be a drawback for others. Users would have to explicitly request information that may not have been provided; they might make such requests by e-mail. (The one-way aspect of information dissemination does have the advantage that the reply can be delayed until accurate information is available.) Also, people in crisis sometimes need a direct, interactive relationship with other individuals; this need can be addressed to a limited extent by providing contact information along with the data.

The Internet has been a valuable asset in emergency management, and in the future we can expect it to become even more valuable. We can expect an increased use of computer networks during actual emergencies, for example, to support communication among emergency organizations, police, medical services, the Red Cross, and other organizations, and we can expect coordination and extension of existing State and local networks.

During a disaster, we can look forward to increased transfer of information through the Internet to and from the public and the press and among separated family, friends, and colleagues. Thus, there may be concern about traffic jams on the Internet: network traffic load. What capacity might be needed during an emergency? Could a restriction on the use of the Internet by the public be required, or even be implemented?

What about security considerations? It would appear that an increasing number of organizations may become dependent on the Internet and demand secure and efficient communications even during emergencies. Power outages can interfere with the use of computers, and Internet service providers are sometimes taken out by disasters.

Many concerns need to be addressed during the post-emergency response phase of an accident or disaster.[8] There would appear to be a potential for use of the Internet in conjunction with a significant number of the associated activities. Many command and control and surveillance tasks could be supported by the Internet both during and after emergencies. After emergencies, satellite communications, remote sensing images from space, and location data from global positioning system satellites will become critical to the success of emergency organizations, and these types of information can be integrated into Internet use. The global positioning system, together with geographic information systems, can be used to track the location of vehicles, ships, and other resources during emergencies and also to provide coordinates for sampling operations so that the location from which a sample originated will be known accurately and in a format suitable for use in databases.

In the post-emergency phase of a radiological emergency in which radioactive materials have been dispersed over a wide area, the gathering of samples and sample analysis will be very important. The Internet has turned out to be quite useful for communicating sample analysis results (e.g., by FTP [file transfer protocol]). In particular, if the number of samples is very large and they are being sent for analysis to several different laboratories, communication of results on the Internet and integration of results into databases will be highly important.

There are many other areas of potential Internet use. These range from communication and data management to public information to economic and legal aspects, medical and social needs, relocation needs, ingestion pathway considerations, and other areas. For example, Internet listings of evacuees or relocated persons and their locations could be helpful in reuniting families. An Internet site with information on financial assistance and legal issues following a particular disaster could provide accurate, detailed, and accessible information for individuals and businesses affected by the event.

CONCLUSION

To summarize, the Internet has many potential uses in the post-emergency response phase following a disaster, although various concerns are associated with this use, such as limited access. This brief paper has just scratched the surface of what can be done now. It is clear that we have not yet seen all of the potential uses of the Internet, and we can look forward to new applications of what is already an extremely useful tool for emergency management.

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Five Years' Experience in Publishing the Bulletin "Radiation and Risk"

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INTRODUCTION

Information related to radiological disasters and accidents, as well as other environmental hazards, is widely dispersed over a large list of scientific journals and other sources of published information[1]. As the consequences of such events involve different spheres of scientific, political, and socio-economic knowledge, such a dispersion is natural. The publication of technical information in specialized journals facilitates a scientist's access to developments at the frontiers of his field of activity. Unfortunately, this specialization inhibits the dissemination of a more general view of current and emerging problems between different specialties.

The importance of the 1986 Chernobyl accident in international affairs, as well as other radiological events in the former Soviet Union, made it mandatory to make all information widely available. At first, the legacy of secrecy in the former USSR made this difficult. Scientific knowledge of military significance was always excluded from the sphere of normal scientific communications. Even immediately following the Chernobyl accident, this knowledge was not used in full measure. Only recently has it become open for analysis. Nevertheless, the knowledge does not receive wide distribution, not due to official controls, but because of the relatively few people in the West who fluently speak or read the Russian language. This has hampered the dissemination of Russian research into the Western scientific communities.

It is well known that the health consequences of the large-scale radiological accidents are followed, as a rule, by misinterpretations in mass-media and mistrust of official information among the population.[3] This leads to additional aggravation of real scientific and health problems. In order to supply both researchers and journalists with a cohesive presentation of Chernobyl related issues, the Bulletin “Radiation and Risk” was launched in 1992. This paper discusses the resources provided by this publication.

DISCUSSION

The Chernobyl accident initiated a comprehensive and objective reevaluation of the radiological situation in the whole territory of the former USSR. At the time of the accident, the contribution of nuclear technologies into the defense, power generation, science, and industrial activities of the country was vastly larger than had been discussed in open scientific literature and in the mass media. Owing to the fact that the post-Chernobyl period coincided with the changes in the economic, political, and social life of the country, the information on the radiological and epidemiological situations in the different regions, on accidents in the nuclear industry, and on the consequences of nuclear and thermonuclear weapon tests gradually became available. It has become clear that the accumulated experience of the atomic epoch has been based not only on intellectual advances, but also on tragic cases as well, where the life and health of people were adversely affected by radiation.

In response to the accident, the Government of the Soviet Union established the National Radiation and Epidemiological Registry as a functional element of the Medical Radiological Research Center in Obninsk (near Moscow). The Registry was established in order to develop a uniform State system for the registration of individuals in support of needs associated with radio-epidemiology for both Chernobyl and other accidents involving radiation exposure. The Registry was used to accumulate and correlate medical and dosimetric data on various population groups, including present and former residents of the radioactively contaminated territories, emergency and recovery workers ("liquidators") and the children of members of these two populations. At present, the Registry contains personal data on more than 500,000 Russian citizens. The Registry is arranged in such a way as to permit the rapid selection of persons by cancer incidence, cause of death, thyroid pathology in persons who were children or adolescents at the moment of the accident, leukemia incidence in liquidators, and persons where a disease or death is directly linked to radiation exposure. The contents of the Registry are constantly updated and expanded due to regular examination of the registered and control populations and due to entries for people recently receiving medical surveillance. The headquarters operation in Obninsk organizes and oversees the activity of twenty regional centers of the Registry across Russia, and it is here where the initial information is collected and distributed[2]. While the large volume of data stored at the Registry does not permit transmittal in hardcopy form, interested persons and organizations may obtain data in electronic form on diskettes.

The Bulletin “Radiation and Risk” is the official periodical of the Registry and is based on its documentary data. As the accumulation of the primary ("raw") medical and dosimetric information is only the initial step of data gathering, it is prone to being misinterpreted in the hands of unqualified or inexperienced persons. Therefore, published materials from the Registry are supplemented with scientific papers and reviews discussing and substantiating the methodologies of collection and the interpretations of the results of the monitoring of radiation effects in the population. The Bulletin is intended for specialists in radiation medicine, epidemiology, radiobiology, environmental protection, dosimetry, health physics, medical statistics, and clinical practice. It is edited by Academician A.Tzyb (Director, Medical Radiological Research Center), with a distinguished Russian editorial board and a multi-national advisory council whose diverse areas of expertise reflect the interdisciplinary aspects of the Bulletin. Owing to the personal activity and support of Professor Richard Wilson from Harvard University, an English version of the Bulletin appeared in 1995. At this time, five English language versions of “Radiation and Risk” have been published. At present, work is in progress to make the Bulletin available through the Internet.

All regular and supplemental issues of "Radiation and Risk" are subject oriented. Each regular issue consists of several sections (Normative Documents, Materials of the Registry, News from the All-Russia Scientific Commission on Radiation Protection, International Cooperation, and Current Bibliography). Following the first issue in 1992, "General Description of the Registry," the following subjects have been covered:

Liquidators, Persons Involved in Recovery Operations (1992)
Radioecology (1993)
Contamination of Russian Territories with Radionuclides ^{137}Cs, ^{90}Sr, ^{239}Pu / ^{240}Pu, ^{131}I
Radiation Accident in Tomsk-7,
Health Effects of Low Doses (Kaluga Region) (1994)
The Southern Urals (1995)
Radiation Doses for Emergency Workers (1995)
Radiogenic Thyroid Cancer (1995)
Radiation Oncoepidemiology (1996)
Exposures of the Population (1996)
Radiation Risks Assessments (1996)
Normative Documents of the National Registry (1996)
Agricultural Radiology (1997)

One of the most important tasks of the Bulletin is to facilitate cooperation between the central registry institution in Obninsk and the regional units of the Registry. Several operational issues are involved: refining methods and means of data collecting and processing, managing complex medical registration forms required by the heterogeneous registry population, balancing the need for scientifically desirable data specificity and reliability against the educational and experience level of the local examination staff, and providing procedures for standardization and quality control.

The most obvious reader interest was induced by publications on risk assessments and on absorbed doses. Establishing a relationship between radiation dose and the health of the current and future generations continues to be a key area of research and discussion. Approaches to radiation risk assessment, as well as the risks from other hazardous factors, engender keen discussions.[4] For a long time, radiation risk estimates for stochastic late effects in humans were based largely on epidemiological studies of the Japanese A-bomb survivors, but such estimates do not relate directly to Chernobyl, as its exposures were from relatively lower doses, at lower dose rates, and with significant commitments of internal dose. The Bulletin has published many papers, and has devoted several issues, to this subject. It has published extensive information on the absorbed doses for the populations of Russia, for Belarus, and for liquidators. The conclusions of the authors sometimes differ, and there is great debate on the acceptable methodologies to be used for dose reconstruction. The editorial board tries to represent the entire scope of views, being concerned only with the reliability of data, and attempts to refrain from emotional or political arguments.

Issue V of the Bulletin should be of particular interest to researchers in the West. In addition to Chernobyl, significant radiological problems exist in the regions surrounding the Chelyabinsk facility. This facility was involved in the development and production of special nuclear materials for the nuclear arsenal of the USSR. The Bulletin's editorial staff pioneered the publication in the open press of declassified papers dealing with the clinical picture and later consequences of the radiological exposures from this facility. Although these works cover a number of years (1959-1990), a wide range of specialists in the field of radiation pathology and medicine are not aware of them. Specifically, a large body of information is available that deals with the transfer and distribution of ^{239}Pu in humans, including the mechanisms of its retention and elimination, the peculiarities of the clinical picture of plutonium pneumosclerosis, and the late consequences of exposure (such as carcinoma of lung and the prognosis of its development in persons involved in plutonium production). A large volume of declassified data is provided in this issue, with current reviews on the consequences of occupational exposure among the staff of plant "Majak" (a facility at Chelyabinsk), the levels of morbidity and mortality among children in Ozersk (the population center in the region), and the health effects among the population living in the contaminated territories along the River Techa. These published materials would be useful both for specialists and for the general public.

CONCLUSION

Much more information, and more precise information, about Chernobyl is available than is generally realized. The radiological experiences of the former USSR are of significant interest to the scientific community in the West. The Bulletin "Radiation and Risk" represents a new resource for this community, as well as a source of peer-reviewed scientific discussions of the issues raised by radiological accidents.

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Will the Nuclear Industry Become the Next Major Litigation Target?

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INTRODUCTION

We read almost weekly of a new lawsuit which threatens a large established corporation or even an entire industry. There is often a pattern to the development of these lawsuits which can be observed well in advance if one knows what to look for. There are also ways to avoid becoming a major litigation target.

Today's sophisticated communications technology has created a tightly knit, international society with many shared concerns. For example, the Internet contains abundant information about exposure to ionizing radiation, including reports of many specific incidents. The nuclear industry has been sued in the past for claims of injury from radiation exposure, but it has not been a major target.

This paper will address generally what factors lawyers might evaluate in deciding whether to represent plaintiffs who claim injury from ionizing radiation and what a nuclear defendant can do to minimize its litigation exposure.

DISCUSSION

What Lawyers Consider Before Pursuing an Injury Case

It normally takes a lot of lawyer time and expense to pursue a lawsuit. Major complex lawsuits may involve a several year investment for a number of lawyers and hundreds of thousands of dollars in out of pocket costs. Individuals who claim injury from a product or action of others often either don't have the money necessary to finance a lawsuit or don't wish to take the risk that they may end up owing their lawyers if they lose or recover just a small amount. As a result, lawyers in the United States generally take such cases on a contingent fee basis, which means that they only receive a fee out of any recovery they make.

To stay in business, a lawyer must accurately evaluate (1) the likelihood of proving that the defendant injured his client; (2) the amount of recoverable damages (it doesn't help to obtain a huge award against a defendant which can't pay); (3) the costs he will have to advance for filing costs, deposition costs, travel, expert witnesses (court rules generally don't allow expert witnesses to work on a contingent fee basis) and the like; (4) the time he and others will have to

This article reflects the views of the individual authors. It is not intended to reflect the views of Zelle & Larson LLP.

invest; and (5) how quickly the case can get to trial (the ideal for the plaintiff is to get to trial quickly - that keeps the plaintiff interested in the case and keeps pressure on the defendant, who will soon be before a jury.)

You may wish to familiarize yourselves with how scientifically-based claims come to the attention of plaintiffs' attorneys and end up being litigated. A Civil Action by Jonathan Harr is a very enjoyable book which describes the economic realities faced by a young lawyer who represented a number of clients suffering from leukemia against two companies who were alleged to have polluted the local water system. The book does a very credible and interesting job of describing the interface between science and law.

How a Lawyer Might Apply These Principles to a Case Involving Claims of Injury From Ionizing Radiation

To win at trial, a lawyer must prove that his client was exposed to ionizing radiation. He will also need to reliably estimate his client's dose since that impacts the type and severity of biological injury. This exercise is obviously far more challenging than proving that a defendant ran his car into the plaintiff's car. The potential damages therefore must be substantially greater than in the ordinary case to justify the added difficulty, because the added difficulty translates into increased risk and costs for the lawyer.

In rare cases, a defendant admits it generated the exposure and agrees with the plaintiff about the magnitude of his dose. However, these issues are usually hotly contested because there are innumerable variables, specific to each case. The way lawyers contest scientific issues is to hire "experts" who review the facts and arrive at opinions. An expert is someone who has unique skill or background in a particular field; however, the talent and credentials of experts can differ dramatically. It's very important to hire the best possible experts because you will likely get the most accurate answers and most thoughtful insight. Although the technical subject may be over a layperson's (and therefore, jury's) head, we believe juries can usually sense the depth of an expert's understanding and knowledge. Nevertheless, even with the brightest experts in the world, it is important to work heavily on their communication skills. An expert whose opinion is scientifically unsupported but who communicates extremely well will be a formidable foe inside the courtroom for a premier scientist who doesn't. Lawyers, experts and their clients need to continually remind themselves that juries are simply small random groups of "everyday" people who are 18 years of age or older.

These types of cases involve the issues you would expect, but with judgments made by lay people as opposed to your peers. Examples include:

- What was the exposure pathway and length of duration? (e.g. chronic radon overexposure over a number of years probably involves a more complex modeling process than modeling an acute release to workers inside a building).
- How does the body handle the internally deposited radionuclides?
- What are the risks associated with the external exposure?
- What dose did they receive?
- Are the particular plaintiffs more or less susceptible than the average person to potential radiation injury?
- How long is the latency period for injuries potentially associated with these doses?
- Is the plaintiff's response biologically plausible?

There has been a lot written in the last 5-10 years about "junk science." In the litigation context, this phrase refers to experts who espouse theories of exposure and injury which the general medical or scientific community believes are baseless. Of course, this wouldn't be news unless the junk scientists were exerting influence. In fact, many articles over this time period have focused on the ability of junk scientists to convince juries to award astronomical sums for injuries which mainstream doctors and scientists believe are nonexistent.

Judges can keep experts from testifying at trial. In most courts, the opinions of experts are supposed to be based upon generally accepted scientific methods or methods which can be tested, have been subjected to peer review and about which the error rates are known. The specific standard varies depending upon whether the case is in Federal or State court and which state's law applies. Courts have applied these standards and kept experts from testifying in a number of cases over the last five to ten years, but disqualifying an expert is still an exception.

With a case involving low dose, low LET radiation, a defendant's expert will likely point to studies which "show" that there are no adverse health effects for this type of exposure. In the absence of contrary studies, the plaintiff's attorney will likely try to dissect the defendant's studies, with the goal of showing the court that there are no comprehensive reliable studies which fit this specific fact situation and, therefore, both side's experts ought to be heard.

Once a court allows experts to testify in the courtroom, the proof is very different from what you are used to. "Proof" is simply whatever the jury decides when asked simple lay questions such as:

- Was the plaintiff exposed to radiation which came from the defendant's products or property?

  ______ Yes

  ______ No

- If so, was plaintiff injured by this exposure?

  ______ Yes

  ______ No

- If yes, what sum of money will fairly compensate the plaintiff for his injuries?

  $__________

A number of huge verdicts have resulted in part from a defendant not appreciating how scientific issues become reframed into such simple lay questions inside the courtroom.

There is always a risk that a plaintiff will prevail on issues of exposure and dose if his experts are allowed to testify before a jury because of the simpler level of proof and the influence of so many factors other than science (e.g., quality of the lawyers and experts, the jury's bias against nuclear radiation, the jury's personal fear of cancer, etc.). On the other hand, it is extremely expensive for a lawyer to get a case to that point. Experts charge high hourly or daily rates, and in a complicated case they must do a lot of work to develop support for their opinions and help the plaintiff's lawyer understand and show the fallacies in the defendant's positions. As a result, the potential damages must be large or no plaintiff's lawyer will reasonably go down that road absent some non-economic reason for pursuing the case (but even then, someone has to pay all of the costs referred to above or the case will go nowhere and will eventually be dismissed by the court).

Absent a very straightforward accident with concededly excessive levels of radiation exposure, lawyers generally must represent a sizable number of plaintiffs to have potential damages which justify the investment of time and money. The plaintiffs' lawyer's job is clearly easier if the plaintiffs have already developed symptoms of the type one would expect from exposure to the nature and level of radiation claimed. However, in many cases, the exposed plaintiffs may be asymptomatic when they sue. In these situations, plaintiffs may try to seek damages for fear of injury, medical monitoring or increased risk of future injury. The courts in different states vary significantly regarding whether they will allow plaintiffs to sue for these claims. However, since nearly everyone is afraid of radiation and cancer, the damages can be significant if a jury is allowed to make those awards. The nuclear defendant can and should do a great deal proactively to reasonably limit such situations.

We have only talked about exposure to radiation and resulting injury. We haven't talked about the conduct of the defendants responsible for the exposure. Were they blameless, negligent, reckless . . .? While a plaintiff generally doesn't have to prove that the defendant did something wrong which caused the radiation exposure, a plaintiff will often focus on the defendant's conduct to try to show recklessness or a willful indifference in order to seek extra damages which are permitted in some states pursuant to a particular state's laws or to "punish" the defendant and deter future bad conduct.

While a defendant may feel comfortable that it has done nothing wrong, one has to realize that documents or testimony can be taken out of context to portray a very different image. Therefore, good conduct does become a major theme in defending these cases. Of course, one can plan in advance by considering what a plaintiff is likely to legitimately criticize and then proactively develop procedures to assure the type of conduct you'd like to present in the courtroom.

What Can the Nuclear Industry Do to Lessen Its Litigation Risks?

The nuclear industry conducts numerous simulations of possible emergencies to assure the best preparation and response. They should also consider how they might become a major litigation target and consciously plan how to prevent that from occurring. The industry can take a number of steps to lessen the likelihood of becoming a target. The following are some examples:

- Have the appropriate instrumentation, procedures and controls in place. It's easier to defend when you have the most accurate data on any releases, exposures and doses, as opposed to leaving lawyers and their experts to argue about what they might have been or why these numbers are unavailable.

- Fight the cases where science is absolutely solid, but be flexible and creative about resolving cases where liability is likely or possible under the best science. Cost effective resolution is achievable. Some of the worst corporate and industry litigation disasters have resulted from an attitude that benefit accrues from fighting every case, even arguably legitimate ones. That can work for a while if the plaintiffs have limited funds to pursue litigation and a defendant devotes considerable resources to its defense, but eventually well funded, talented plaintiffs' lawyers will end up with good cases. If the claims are legitimate, plaintiffs will win and possibly win big if the company's or industry's records or testimony make it appear that they were hiding the "truth."

- Communicate quickly and clearly to individuals who may have been exposed. Often people will not consult a lawyer if they feel they are being treated properly and being kept fully informed.

- If the plaintiffs already have a lawyer, don't immediately hunker down into a litigation mind set. As this discussion indicates, plaintiffs' lawyers are often looking for efficient, economical and fair ways to resolve legitimate cases and will often settle for many orders of magnitude less than they will likely ask a jury for if they are forced to trial.

- If people need to be assessed medically, help arrange it. People will understand that you have their best interests in mind and will look to you for help. One of the strongest defense themes is that you made the welfare of those potentially exposed your top priority.

- Consider how to handle a situation where different agencies are involved which have different regulations and guidelines for appropriate exposure. The plaintiff's lawyer will capitalize on these differences. The jury will likely gravitate toward the safest exposure or possibly a lower one, if effectively communicated by the plaintiff's expert who will say that he is bringing clarity to the "agencies' confusion."

- Consider what people (and lawyers) will criticize you for if things don't go well. Continue to diligently plan for emergency situations and update your responses as science develops. It is easier to defend if you remain flexible in an emergency and don't limit actions to what the minimum regulations call for, if more can be done.

CONCLUSION

A number of factors have to come together before a radiation case will appear attractive to a plaintiff's lawyer. The nuclear industry can do a great deal now to protect itself from such cases and from becoming a major litigation target in the future. This paper briefly discusses some of the proactive steps which can and should be taken by both licensees and regulators within the nuclear community.

Session D, Track 1:
Agriculture, Forestry and Land Use Issues

Thursday, September 10, 1998
10:10 a.m. - 12:40 p.m.

Chair: Jack Patterson, United States Department of Agriculture

Problems of Agroindustrial Production on Contaminated Territories and Principles of Their Rehabilitation

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INTRODUCTION

In radiation accidents that are accompanied by radioactive contamination of the environment, the intake of radionuclides with farm products becomes a very important source of irradiation of the population. Therefore, the implementation of a system of countermeasures on affected agricultural lands is a vital element in mitigating consequences of accidents. Thus, following the accident in the South Urals in 1957, the presence in the radionuclide mixture on the East Urals radioactive trace of the long-lived β-emitter ^{90}Sr (2.7% in the total composition of radionuclide mixture) predetermined a long-term biological threat to humans because of the formation of the internal irradiation source (of principal importance was the consumption of milk, vegetables and bread). In the Chernobyl accident in 1986, the presence in the mixture of ^{131}I in the early stage (intake through the milk chain "fodder-milk") has resulted in the development of thyroid cancer, one of the major epidemiological consequences of the accident. A long-term hazard of the Chernobyl accident is associated with the release of ^{137}Cs, the main dose-forming radionuclide (in relatively small area ^{90}Sr was of great significance as well). Analysis of the 12-year radioecological studies in the ChNPP accidental zone has shown that in both acute (about one year) and distant periods the ratio of internal and external doses is close to unity. For some regions affected by this accident the contribution from internal irradiation to the overall dose burden amounted to 70-90% [1-5]. In the Sellafield accident in the UK in 1957, an essential role was played by ^{131}I release and its associated transfer via the milk chain.

Following the nuclear weapons tests and their induced global biospheric contamination, the importance of internal irradiation (i.e. consumption of radionuclide containing foodstuffs) has considerably increased.

It should be noted that limiting the overall dose burden from radioactive contamination of the environment by means of reducing the internal irradiation component can be an economically and ecologically more effective way than decreasing dose burdens from external irradiation. The control of radionuclide flux in agricultural chains in the system soil-farm crops - farm animals - human diet by means of applying special measures (countermeasures) reduces concentrations of radionuclides in foodstuffs.

The type and scales of countermeasures in agroindustrial production depend on the time elapsed after the contamination. In the early period (several weeks to one year) prohibitive countermeasures prevail (a ban on the use of critical in terms of dose formation foodstuffs, on animal pasturing, etc.). In the medium and long terms after the accident, dominant are countermeasures that restrict concentration of radionuclides in farm products and reduce the collective dose of irradiation.

DISCUSSION

In the early period of an accidental contamination of the environment, a zonal principle of agricultural production is realized. In this case countermeasures and farm specialization (meat, milk, vegetable production) depend on the contamination density (for critical radionuclides). In the medium and long-term periods, a zonal principle of agroindustrial production is replaced by a dose one (according to ICRP and national recommendations this dose is currently 1 mSv/year). This principle suggests that the dose above the background irradiation from all the sources (i.e. internal and external) should not exceed 1 mSv/year.

The countermeasure effectiveness in agricultural production is assessed by a number of criteria: radioecological (reduction factors of radionuclide content in foodstuffs after countermeasure implementation), radiological (value of the averted dose due to countermeasure application, man.Sv), radiologo-economic (cost of unit of collective dose saved as a result of countermeasure application, cost of dose decrease per man. Sv, thousands US $).

The experience gained in liquidating the consequences of the South Urals (1957) and Chernobyl NPP (1986) accidents testifies that the most effective countermeasures for restricting transfer of the most important long-lived radionuclides via agricultural chains are as follows (in brackets reduction factors of radionuclide transfer are indicated):

1. In restricting ^{90}Sr transfer to foodstuffs:

   a) in plant production - liming of acid soils (2), application of mineral fertilisers (2-3), deep ploughing to remove the contaminated layer into lower horizons (1.5), selection of crop species and varieties with minimum accumulation of ^{90}Sr (3-5), radical amelioration of meadows (by a factor of 3-4 for milk);

   b) in animal production - Ca enrichment of animal rations deficient in this element (2), organization of a pre-slaughter feeding (2);

   c) in processing industries (processing milk to cheese and butter (2-5).

2. In restricting ^{137}Cs transfer to foodstuffs:

   a) in plant production - application of mineral fertilisers at increased K doses (2-2.5), liming of acid soils (1.5), deep ploughing to remove the contaminated layer into lower horizons

(1.5), selection of species and varieties with minimum ^{137}Cs accumulation (5-7), radical meadow amelioration (8-10);

b) in animal production - use of ^{137}Cs binders (for milk - 3-7, for meat 3-5), pre-slaughter feeding;

c) in processing industry - processing milk to cheese and butter (3-6).

CONCLUSION

As stated above, the effectiveness of countermeasures for mitigating the consequences of accidents in the agricultural sphere depends on a number of factors, among which are time after radiation fallout, specific features of agricultural production and natural conditions (primarily soil type). As an example let us consider results from the studies in one of the Chernobyl affected regions of Russia where countermeasures have been applied [6]. Milk is a critical foodstuff in dose formation. Therefore, the effectiveness of countermeasures is assessed by this product. Depending on soil properties, special features of agricultural production and countermeasures dose from the consumption of milk containing ^{137}Cs can vary by a factor of 50 and more (Table). In this case, doses to the population from milk can be considerably (from 20% on heavy loamy and clay to 45% on peaty soils) reduced through the use of countermeasures. For peaty soils, the contribution of milk to the overall dose even with countermeasure application remains greater than that of external irradiation even for the staff who a great deal of time are working outdoors. For sandy soils, the contribution to the overall dose from internal irradiation connected with milk consumption and external irradiation are comparable and in the event of countermeasure application it does not exceed 50% of the dose of external irradiation.

The cost of the unit of saved dose in man.Sv for the region considered increases monotonically: from 0.8 in 1987 with countermeasure application to U.S. $ 3,000 in 1997 with countermeasure application; these values are U.S. $ 6 to 18,000 and U.S. $ 24 to 80,000 for sandy and heavy loamy soils, respectively (Figure). A precise estimation of the "red line"of the warranted cost of dose decrease per 1 man.-Sv (in particular in the existing economic situation) is an extremely complicated task which is unlikely to have purely scientific substantiation. Therefore, the figures suggested in the ICRP Publication 37 (U.S. $ 10 to 20,000) are used in assessments of countermeasure justification.

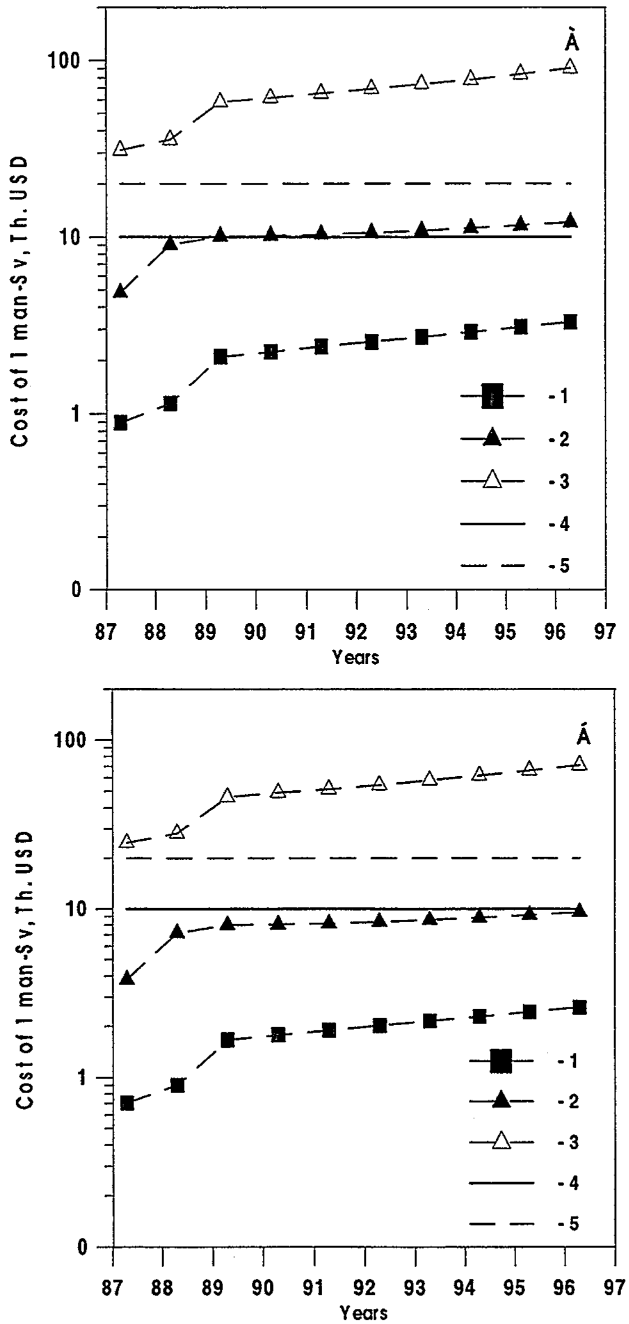

Figure 1. Dynamics of changes in the cost of dose decrease of 1 man. Sv as a result of radical improvement in collective sector. Density of ^{137}Cs fallout is 740 kBq m^{-2}.
Soils: 1 - peaty; 2 - sandy and sandy loam; 3 - heavy loam and clay; 4 and 5 - costs of dose decrease of 1 man. Sv for which countermeasure application was considered justified (10(4) and 20 (5) thousands US $). A - collective sector, B - private sector

Table 1. Individual effective doses from milk consumption received over the first 10-year period after ^{137}Cs fallout (ignoring the acute period) depending on the agricultural practice details ($\mu Sv/kBq\ m^{-2}$)

Treatment	Soil type			
	Sandy	Loamy	Clay	Peaty
Private sector, without countermeasures	18.6 (0.77-1.0)*	5.1 (0.21-0.27)	2.7 (0.11-0.15)	66.7 (2.8-3.6)
Private sector, intensive countermeasures	8.5 (0.35-0.46)	2.8 (0.12-0.15)	1.1 (0.05-0.06)	18.0 (0.75-0.97)
Collective sector, without countermeasures	15.9 (0.66-0.86)	4.5 (0.19-0.24)	2.3 (0.10-0.12)	55.9 (2.3-3.0)
Collective sector, intensive countermeasures	10,1 (0.42-0,54)	3,2 (0,16-0,20)	1,3 (0,05-0,07)	25,8 (1,6-2,1)
Real dynamics of counter-measure implementation	12,9 (0,53-0,70)	3,8 (0,16-0,20)	1,8 (0,07-0,10)	39,6 (1,6-2,1)

* In brackets is the ratio of internal and external irradiation

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Integrated Long-term Management of Radioactively Contaminated Land: the Ceser Project

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INTRODUCTION

Accidents at nuclear installations can cause widespread long-term contamination of soils. On land used for agriculture this may necessitate countermeasures to reduce the transfer of radionuclides into the human food chain. A wide range of countermeasures have been evaluated in European countries in the aftermath of the Chernobyl accident.[1] The main aim of this evaluation has been to identify the most effective and practical techniques for reducing the radiation dose to humans. In comparison, little attention has been paid to the potential long-term impacts of these measures on the functioning of agro-ecosystems and their economic value. It is conceivable that environmental and economic costs due to these impacts may equal or even outweigh the benefits of dose reduction. Thus any changes in the economic and ecological values of resources should be considered as part of a comprehensive remediation strategy. It is the objective of the work presented here to develop and test an impact assessment methodology which permits decision makers to choose an ecologically and economically balanced long-term remediation strategy for severely contaminated areas. This research is part of an EU funded project under the Nuclear Fission Safety Programme entitled: Countermeasures: Environmental and Socio-Economic Responses (CESER) and involves partners in Austria, Finland, Germany, Norway and the UK.

The approach shown in Fig. 1 is being adopted to assess ecological and economic impacts of countermeasures. The various steps included in Fig. 1 are characterized in the following.

DISCUSSION

Identification

Initially a comprehensive list of potential countermeasures intended to reduce radiation doses from radioactive cesium and strontium was compiled. Countermeasures reviewed include interventions both at the soil-plant level and at the animal level. Criteria adopted for countermeasure selection included radiological effectiveness, applicability, cost and acceptability to farmers. Based on these criteria, deep ploughing to bury contamination, soil application of fertilisers that compete with radionuclides in the soil solution, use of binding agents in soils or livestock, changes in livestock management or in land use (e.g. afforestation) were included in the study. For these countermeasures, a literature review identified potential impacts on the quality of soil, water and air; the health of plants, animals and humans; the quality and quantity of the products; and the diversity of landscapes and organisms. Examples are:

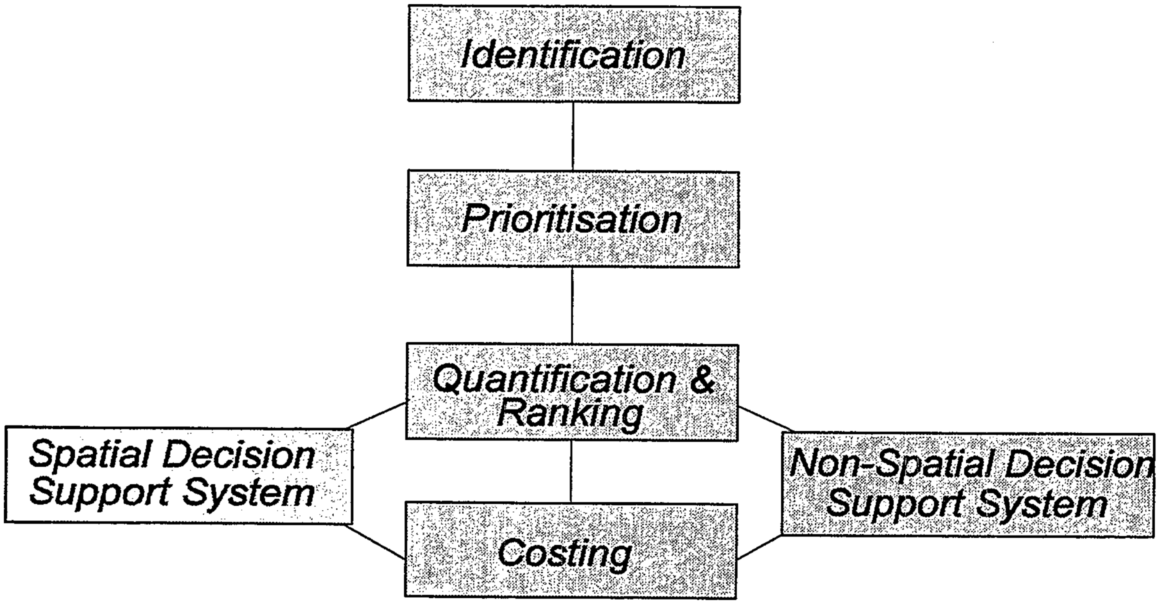

Fig. 1: Approach adopted for the integrated impact assessment of countermeasures.

At the soil-plant level, ploughing may enhance mineralisation of organic soils and increase erosion. At the animal level, movement of animals to less contaminated areas result in a shift of grazing pressure and may increase manure application which consequently may affect water quality and increase the potential for eutrophication. Both positive effects (e.g. growth stimulation of plants due to fertilizer application, higher milk yield) and negative effects (e.g. lower food quality, reduced animal health) were included.

Emphasis was given to identifying the basic physical and chemical mechanisms of the selected countermeasures and their potential non-radiological impacts, since their understanding is essential for quantification of site-specific effects by modelling.

For some potentially important non-radiological impacts of selected countermeasures, however, the information available in the literature was found to be inadequate for quantifying these effects. Thus laboratory experiments were initiated: Soil column experiments have been set up to study the environmental fate and identify potential degradation products of ammonium-ferric(III)-hexacyanoferrate(II) (AFCF) which is used as a cesium binding agent in livestock feeding. Diffusion experiments[2] have been designed to investigate the potential of mobile organic matter degradation products (fulvic acids) for transport of trace nutrients and toxic trace substances.

Prioritisation

The potential countermeasures identified were then prioritised for case study areas in Finland and Scotland on the basis of four radioactive deposition scenarios and existing agricultural production systems taking into account crop and animal production. The four radiological scenarios included contamination levels ranging from depositions characteristic for greater distances from a damaged nuclear plant to levels to be expected near to the accident location.

Quantification and Ranking

The impacts selected are either quantified through calculations and simulation modelling or qualitatively assessed on the basis of expert knowledge. The models ICECREAM [3], OPUS [4] and PHREEQC [5] were chosen to simulate environmental changes due to countermeasures. ICECREAM and OPUS are used to simulate soil erosion and transport of water and solutes via surface runoff and percolation in the soil column in a watershed taking into account a variety of agricultural management practices (e.g. ploughing, fertilisation, manure application). Since both study areas include soils rich in organic matter, the OPUS code was modified to include a recently proposed hydrological model based on the Vereecken [6,7] pedo-transfer function which is applicable for both mineral and organic soils. PHREEQC is applied to simulate effects of changes of fertiliser addition on soil chemistry and availability of major and trace nutrients and of toxic trace substances taking into account a variety of chemical reactions (e.g. exchange reactions, precipitation).

For the selected countermeasures, the simulations will provide matrices of erosion, nutrient losses, changes in the availability of toxic trace substances and chemical changes in soil solution for the most common soil types, climates, slopes, land use categories and land management practices within the selected geographic areas. Within a geographical information system (GIS), the model output matrices are linked to spatial data sets covering topography, soil types and land uses. This enables the mapping of impacts for different countermeasures.

Costing

Environmental cost-benefit analysis is used to estimate off-site costs such as loss of fisheries or amenity value and benefits such as reduced radiation risk arising from the application of countermeasures. Costs will be derived by combining the environmental modelling results with valuations from the literature. Selected impacts such as landscape changes are being valued through an original 'willingness to pay' survey. The direct monetary costs of countermeasures will be included in the final analysis.

Decision Support Systems

Multicriteria Decision Making (MCDM) [8] has been chosen as the methodology for integrating the assessments of impacts and costs resulting from countermeasures. This methodology will provide the decision-maker with a set of countermeasure suitability rankings or suitability maps based on the quantitative and qualitative impacts.

The MCDM approach will be embedded into two types of decision support system. The first will be a non-spatial assessment for a single area, built as a piece of stand alone software using Visual Basic. "Wizards" will take the user down a series of decision trees regarding the type of agriculture and the deposition scenario. Based on this information the user is presented with a selectable list of countermeasures. Once the user has made the selection, he/she is asked to provide additional information on site properties which might limit the application of the countermeasures. The impacts, costs and benefits of the countermeasures are then assessed qualitatively and quantitatively using the MCDM methodology.

The second system will be a more generic suitability assessment of a larger, heterogeneous area using a GIS. A suitability assessment will be performed using spatial data within the GIS. Thematic maps depicting site suitability for a single countermeasure or showing the overall "most suitable" countermeasure can be created. By being custom built for this project, both Decision Support Systems should prove to provide greater flexibility, specificity and user-friendliness compared to commercially available software packages.

CONCLUSION

As final product, this methodology will provide decision-makers with a set of countermeasure suitability rankings or suitability maps based on an integrated assessment of their quantitative and qualitative radiological, ecological and economic impacts.

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Remediation Options for Agricultural Land: Evaluation and Strategy Development

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INTRODUCTION

Since the Chernobyl accident considerable research effort throughout Europe has focused on understanding the behaviour of radionuclides in agricultural systems. The ultimate aim of this work has been to identify strategies by which the radiological impact of large-scale accidents like Chernobyl can be minimized. Over the last 2 years the focus of research has shifted to one of evaluation of past research findings and compilation of the information into practical, user-friendly decision support systems for remediation of radioactively contaminated land. A number of international projects are presently under way all with this basic objective. These projects test different approaches to aspects of decision making such as (a) the different end-users of the system - whether it be a farm adviser or a local authority; (b) the use of computer models to predict effectiveness and impact; and (c) the geographical scale over which intervention is assessed.

This paper is based on a review of the available literature describing the current state of European research into remediation strategies for agricultural land. Also presented are preliminary observations on the difficulties of compiling this research into a meaningful and practical tool for use in real-life, post-nuclear accident situations.

Table 1 lists the agricultural countermeasure options which are discussed in the literature. This table is drawn from a 1994 IAEA publication[1] in which guidelines for agricultural countermeasures are reviewed. In the few years since its publication, the list of available options has not changed significantly but a few of the options have been found to be impractical due to poor availability of equipment and raw materials.

Table 1: Agricultural countermeasures as reviewed by IAEA[1]

Counter-measure type	Specific Application	Effectiveness[a]	Availability[b]
Soil Based - mechanical	Normal ploughing	High with mouldboard ploughs	A/B
	Deep ploughing	RF[c] of up to 10	C
	Skim and burial ploughing	RF of at least 10	C
	Remove 5-10cm top-soil	Removes up to 95% of radioactivity	C
	Soil stabilisation	Variable with material used	C
Soil based - additives	Lime addition	High on acid soils, RF up to 10 for ^{90}Sr, up to 3 for ^{137}Cs	A
	Potassium addition	High when soil soln K conc <20μM. RF up to 5 for ^{137}Cs	B
	Apply Sapropell	High, RF up to 6 for ^{137}Cs, up to 5 for ^{90}Sr	B
	Apply Aluminosilicates	Limited, RF up to 2 for ^{137}Cs	B/D
	Apply organic fertilisers/manure	High, RF up to 5 for ^{90}Sr	A
	Apply soluble phosphate	High, RF up to 10 for ^{90}Sr	A
Production management	Select lower- uptake varieties	Variable but can achieve RF up to 5	A/B
	Select similar but lower-uptake crops	Variable but can achieve RF up to 3	A/B
	Select different, lower-uptake crops	Variable but can achieve RF up to 8	A/B
	Select crops from which processing removes contamination	Variable but can achieve RF of up to 10 in final product	A/B
	Select non-food crops	Not applicable	A/B
	Harvest crops for disposal	High, up to 80% removal	A/B
	Replace sheep/goats with cattle	Variable, RF up to 5	B
	Change from arable crops to cattle	Variable, RF of up to 100	B
	Change to forestry production	Not applicable	A/B
Animal based	Provide uncontaminated feed	High, up to 100%	A/B
	Grow forage with lower uptake rate	Switch from grasses to cereals, tubers and root-crops. RF 5-10	A/B
	Use land for non-dairy animals or those not yet for slaughter	Variable	B
	Raise cutting height of fodder grasses	Variable – reported RF of 3 for ^{137}Cs and 9 for ^{131}I. [2]	A
	Delay slaughter time to period of reduced uptake	Variable	A/B
	Provide prussian blue (AFCF)	Variable – 2 to 5 fold reduction in ^{137}Cs content of milk and meat	A/B/C
	Add clays to diet	Variable – 5 fold reduction in in ^{137}Cs content of milk and meat is possible	B
	Increase Ca in diet	Increase of 2-4 times Ca in diet reduces ^{90}Sr in milk by factor of 1.5-3.0	A

[a]Effectiveness as described in IAEA (1994)

[b] IAEA (1994) rating : A, Widely applicable; B, Effective but resources might not be available; C, Technically effective but requiring specialised equipment that is not widely available; D, Not recommended (either inadequately tested or proven to be of little or no value).

[c] Reduction Factor = Radioactivity or dose before treatment/ Radioactivity or dose after treatment

DISCUSSION

Strategy development

In developing a strategy for managing radioactively contaminated agricultural land, the intervention must be justified , in the sense that the action taken should achieve more good than harm. The levels at which the intervention is introduced and at which it is later withdrawn should be optimized, so that the protective measures will produce maximum net benefit[1]. The conventional approach[3,4] has been to compare the different actions in terms of reduction of dose to man and the associated cost factors according to the following relationship:

Collective Averted Dose versus Costs (manpower + consumables + equipment costs)

But in practical terms what does this really mean to the farmer? The aim of dose reduction dictates that if the radiation dose to man from the contaminated agricultural situation is unacceptably high then some restriction must be applied to the use of the land or produce. However, to minimize the cost of this intervention a parallel aim of the remediation strategy must be the restoration of the economic use of the land. Except in the case of low-level contamination it is probably unrealistic to hope that the remediation will achieve complete restoration of the land to what it was prior to contamination. It is more reasonable to aim to restore economic viability to the agricultural situation or to shorten the time interval over which the land use is restricted. In this approach, the effectiveness of the action is compared only with limited economic factors. Other authors[1,5] have suggested that social and environmental factors also warrant consideration. Recent experience in evaluating remediation strategies confirms this suggestion and indicates several other, less obvious but equally important, factors as outlined in Table 2.

Each of the factors listed in Table 2 will be considered at some stage in every countermeasure evaluation process, but depending on the option being considered each will take on greater or lesser importance. Lost production and lost product value refer to situations in which production is restricted or where the crop attains a lower market value due to its contamination. In this case the farmer may expect compensation for lost earnings and so this factor becomes a real cost of the remediation option. Applicability involves factors such as the slope of the land and the stoniness of the soil, as well as the availability of equipment or raw materials. In the final analysis these factors may exclude even the most effective or most economical remediation option.

Benefit		Costs	
Collective Averted Dose	vs	Direct monetary Costs	Application costs (Manpower, Consumables, Equipment, Waste disposal) Lost production or lost product value
		Applicability	Suitability to for example, topography, soil, production system etc.
		Acceptability	to farmer, consumer, local residents
		Secondary impacts	Environmental, Ecological, Social, Economic

Table 2: Cost-benefit analysis parameters for agricultural remediation options

Acceptability to the farmer is related to applicability and production losses and may ultimately depend on compensation arrangements. Acceptability to the consumer is a much more complex factor; it would be unwise to assume that a food product that is grown on decontaminated land, or produced using some method of dose reduction, will be acceptable to the consumer. This factor greatly influences costs in an agricultural context and represents the greatest challenge to the restoration of economic viability of agriculture after a nuclear accident.

Acceptability to local residents and secondary impacts refer to the fact that agricultural land is not only a food production system but has many functions in the wider natural, social and economic environment. For example, agricultural land is a feature of the landscape, a habitat for wildlife and a source of raw materials for industry. The integrity of the natural landscape has implications for the sense of well-being of the population.

These wider scale secondary impacts raise a very important question in the development of any remediation strategy: on what geographical scale should the evaluation be made? It is clear that there will be economic consequences for those whose livelihood comes from farming contaminated land. In addition to these costs however, there will be knock-on effects in for example, the local sales of seed and fertilizer. Evaluation on a regional level may require consideration of the impact on food processing industries, transport companies and export trade.

It is essential therefore, that prior to developing a strategy for management of radioactively contaminated land, a decision is taken about the geographical level to which the assessment of the remediation options will be made.

Scenario analysis

A comparative analysis of the remediation options for a given agricultural scenario requires that the effectiveness and the value of each of the above cost factors is known and that the change in these cost values due to the remediation can be predicted. The experience attained in Europe is that this is where the greatest difficulties in restoration strategy development lie.

Evaluation of remediation effectiveness and costs as applied to real situations requires detailed knowledge of the environmental, economic and social parameters which influence these factors. Consider for example the site information needed to evaluate the application of potassium to agricultural soil as a countermeasure against radiocaesium transfer to vegetation. This countermeasure works by providing excess K ions which compete with and effectively dilute the available Cs ions. The effectiveness of K as a countermeasure is strongly dependent on the level of exchangeable K in the soil.[6] In order to evaluate the benefit of this countermeasure the decision maker requires knowledge of the K status of the soils to be treated. The K status of soil is a commonly measured parameter in normal agricultural practice but even so, our experience is that these data are not sufficiently available to facilitate a reliable evaluation of the effectiveness of this countermeasure on a wide geographical scale.

In the case of liming as a countermeasure against strontium transfer to vegetation, the key effectiveness parameter is soil exchangeable calcium. Ca is not a soil parameter which is commonly recorded for agricultural soils in Europe, therefore compared to K, these data are very scarce. Other remediation options present similar difficulties of poor availability of data essential for prediction of effectiveness, applicability, acceptability, costs and secondary impacts.

Many of these effectiveness parameters are spatially variable such that within even a single field, different areas will require different levels of treatment to achieve a uniform effectiveness of the countermeasure. In many cases, much of the information required is available on a very local level. Most farmers have a detailed knowledge of the peculiarities of their own land and how any change will affect the crop. It is therefore a useful strategy to avail of this wealth of experience in the analysis of remediation options. It may seem impractical to gather such detailed information, but on the other hand, we must conclude that the larger the unit of land upon which the strategy is assessed the lower will be the reliability of the analysis.

A practical approach may be to combine the local and the regional data and identify which stages in the decision-making process are best achieved at a local level and which can best be solved regionally. In this way the process maximizes the use of available information at each stage. An example of this combined approach is presented in Figure 1. Here the general, broad-scale applicability of countermeasure options can be assessed based on regional crop data, soil maps, topographical, demographic and climatic data etc. This step will eliminate all countermeasure options which are not applicable. The resulting list of appropriate remediation options can be evaluated regionally with respect to application costs but local assessment is required to evaluate these options in terms of effectiveness, small scale applicability and production losses. The resulting short-list of remediation options will require further local-level assessment with respect to acceptability and secondary impacts before a final decision on the best remediation strategy can be reached. If secondary environmental, economic and social impacts are to be evaluated on a wider scale then an additional step may be required prior to reaching a final decision.

CONCLUSION

A wide range of potentially useful agricultural countermeasures are reported in the scientific literature. The following points are indicated as being important to the development of a strategy for remediation of agricultural land following a nuclear accident:

- Cost-benefit analysis of remediation strategies should include consideration of production losses, applicability, acceptability and social and environmental costs
- The geographical scale of strategy evaluation should be established
- Consumer acceptability of products is a significant challenge to the restoration of economic viability to contaminated land

Extensive data are required to properly assess the costs and benefits of remediation. Experience in Europe is that these data are not always available in central databases but may be obtained directly from local farm personnel.

It is suggested that an approach to strategy evaluation which incorporates local assessment stages will maximise the use of the available data.

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Countermeasures in Forest Ecosystems: a Preliminary Classification in Term of Dose Reduction and Ecological Quality

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INTRODUCTION

Overall in Europe, forests account for about 28% of the total land area.[1,2] It is interesting to note that in contrast to other parts of the world, recent trends in land use in Europe have shown a general decline in arable/cropland and an increase in forests.

In the aftermath of the accident at Chernobyl, it was difficult to define the contribution to the dose to man from forests and to adopt well-justified countermeasures, because there was very little information relating to the impact to man of radioactive fallout on forests. After the fallout from atmospheric nuclear weapons testing, in the 1960's, considerable attention was paid to the effect of fallout on agricultural products, drinking water, etc. but only the lichen-caribou-man and lichen-reindeer-man food chain was studied for natural and semi-natural environments.[3,4] The few observations in semi-natural environments in the 1960's and the studies carried out after the Kystym accident (in which mainly Sr-90 was released) showed that in these environments, radionuclides remain available for a longer time than in agricultural systems.[5]

In the wake of the Chernobyl accident, it became apparent that forest ecosystems are very important sources of dose to man which demand careful management. Nine years after the Chernobyl event, the ^{137}Cs concentrations in plants grown in forests and in meadows had not declined significantly.[6] Meat and milk from animals grazing on clearings as well as mushrooms, wild berries and game, contribute a significant dose to man.[7] Restrictions in the use of food products coming from semi-natural ecosystems are still necessary in some heavily contaminated areas of Belarus.[7] At present, the intake of radiocaesium and radiostrontium through food from semi-natural systems is, in some areas, the greatest contribution to the dose to man. Additionally, external doses may be received by forestry workers and groups of population using timber for furniture or building material. Wood industries, like pulp mills, consuming large amounts of wood, concentrate radionuclides in their waste products. In highly contaminated areas these wastes can be a source of external dose to workers in wood industries. Furthermore, in the heavily contaminated areas of CIS countries, forests are a potential reservoir of secondary contamination and forest fires represent a resuspension risk. In the long-term, the contribution to the dose to man from forests may be, for some groups of population, more important than that from agricultural and urban areas.[7]

Countermeasures aim to minimise the radiological impact to man of nuclear contamination of an environment. Their effectiveness is generally expressed in terms of dose reduction. The design of a post-nuclear accident management strategy involves appraisal of the benefits of dose reduction versus the cost of implementation. The cost of implementation is generally calculated as a function of manpower, equipment, consumables and in some cases waste disposal. Experience since the Chernobyl accident has demonstrated that additional factors relating to practicality and side effects must be considered during the evaluation of countermeasure options.

The aim of this paper is to evaluate the state of knowledge in Europe with respect to countermeasures in forest ecosystems and to suggest a preliminary classification in terms of dose reduction and ecological quality.

DISCUSSION

A Preliminary Classification of Countermeasures in Forest

In the last 12 years, considerable research has been carried out in Europe aimed at devising countermeasures for reducing the radiological impact of land contaminated by the Chernobyl fallout. Table 1 presents a summary of the countermeasures evaluated so far which have potential for use in forests. Little research has been targeted specifically at forest ecosystems. The majority of the countermeasure research is related to agriculture and application to forests has by and large not been tested. The research also focused mainly on the effectiveness of the countermeasure whereas practicality of application and potential secondary impacts of the countermeasures were seldom reported. Because of the lack of direct forest research in many cases it was necessary to extrapolate conclusions based on agricultural systems to the forest ecosystem.

A first classification of the countermeasures reported in Table 1 has been carried out considering their applicability, the timing of countermeasure application, the time period over which the countermeasures is effective and their impact on ecological quality.

Table 1. Forest Countermeasures

Counter-measure Type	Action taken/ Application	Practicality/Suitability	Secondary Ecological Effects
Soil Based chemical/ additive	• Clay minerals • Potassium • Liming	• Most effective on organic soils • Application and adequate mixing in forest soils is impractical due to presence of roots and understory vegetation	• Change in floral composition recorded on upland organic pastures treated with bentonite and lime. • May alter availability of fungi and forest fruits • K may enhance understorey biomass but the effect will be short lived • K may limit bioavailability of micronutrients • Excessive lime treatment may reduce the fine root biomass of conifers • Liming can reduce the bioavailability of essential nutrients especially P
Soil Based physical	• Ploughing • Soil surface removal	• Impractical due to physical heterogeneity of the forest floor and poor equipment access.	• Damage to roots and geophytic plants • Destruction of understorey vegetation • Ploughing displaces contamination to deeper in the soil profile • Potential contamination of ground water • Erosion risk • Loss or dilution of nutrient pool in surface soil layers • Organic soil removal generates 5-100t/ha of contaminated waste • Each additional 1cm removal of mineral soil generates 100-150t/ha of contaminated waste • Loss of forest grazing • Alternative fodder required • Loss of forest fruits and fungi • Loss of game/hunting • Alternative foods required • Reduction of amenity value
	• Litter removal	• Over a small area (urban park) litter removal may be done manually • To be effective, timing is critical	• Damage to understorey vegetation • Minor loss of nutrients • Generation of contaminated waste

Table 1. Forest Countermeasures (continued)

Counter-measure Type	Action taken/ Application	Practicality/Suitability	Secondary Ecological Effects
Forest Management	• Restrict human access to forest	• Difficult to enforce • Education required • Forest maintenance and fire prevention must be continued	• Loss of forest grazing • Loss of forest fruits and fungi • Loss of hunting • Alternative foods required • Reduced control over game population • Loss of amenity value • Loss of fire-wood • Negative psychological impact
	• Restrict access by grazing animals	• Difficult to enforce • Education required	• No ecological effects • Alternative fodder required • Negative psychological impact
	• Restrict consumption of forest foods	• Difficult to enforce • Education required	• Loss of forest fruits and fungi • Loss of hunting • Alternative foods required • Reduced control over game population • Loss of amenity value • Negative psychological impact
	• Change game hunting season	• Difficult to enforce • Education required	• Reduced game weights • Game may be more difficult to locate • Change in traditional practices
	• Delay forest felling	• Forest maintenance and fire prevention must be continued	• Enhanced risk of timber loss through disease and wind fall • Possible loss of timber quality • Loss of employment • Prolonged amenity value

Counter-measure Type	Action taken/ Application	Practicality/Suitability	Secondary Ecological Effects
	• Change to nursery production	• Staff retraining required • Equipment requirement • Market required	• Disposal of clearfelled trees • Change of landscape • Change of forest ecology • Loss of understorey vegetation • Loss of forest fruits and fungi • Loss of hunting • Alternative foods required • Loss of amenity value • High fertilizer demand • Altered hydrology • Soil erosion risk • Possible contamination of water bodies • Migration of game to alternative habitats • Change in employment pattern • Loss of timber processing industry • Spread of contamination via saplings
Tree Based Chemical	• Defoliation and removal of leaves/ needles	• Timing is critical • More applicable to deciduous trees	• Leaf loss will damage trees severely • Defoliant may have toxic effect on flora and fauna • Possible contamination of water bodies • Access by humans and domestic animals may be restricted • Hunting and wild food collection may be suspended • Alternative foods and fodder required • Minor loss of nutrients • Generation of contaminated waste • Alteration of landscape • Negative psychological impact

Applicability

The application of countermeasures can be optimised on the basis of knowledge about the effects of soil type on transfer of radionuclides to forest biomass. Depending on soil characteristics particular forests may require restrictions applicable to a more (or less) contaminated zone. For example, forests on hydromorfic soils (with a well developed holorganic layer) have a high transfer of contamination to wood so require restrictions applicable to a more contaminated zone (one class more severe). Less strict limitations (one contamination class) are required on soils with heavy texture (clay and loamy soils). Soil type may also be used to prioritise the application of countermeasures.

Timing of Application

The evaluation of the benefit in terms of dose reduction by some countermeasures depends on time elapsed from the deposition and on the characteristics of the forests. Litter removal for example would be more effective for deciduous trees if contamination occurs just before autumn. If the contamination occurs at other periods for deciduous trees and for coniferous trees in general this method could be effective from six months to one year after the accident. In the case of the Chernobyl accident, litter removal carried out in autumn 1986 could have removed between 10 to 20% of the total radiocaesium deposit.[8] Similarly, tree defoliation is only effective while the canopy retains the contamination. Data from Chernobyl show that 80-90% of total forest contamination could be removed by defoliation within the first 6 months of the accident.[8] In the analysis of the cost computation of this remediation action it is necessary to consider the cost of the transport and the treatment of a large volume of radioactive waste. The relatively slow migration of radionuclides in the forest soil[4] means that timing is not so critical for soil based or forest management countermeasures.

Duration of Effect

Information on the persistence of radionuclides in the forest compartments and knowledge of the dynamics of radionuclides in these ecosystems are required to determine the duration of effect of the different countermeasures. The duration of effect is a major component of the calculation of averted dose. Data collected in the wake of the Chernobyl accident have shown that tree wood will become increasingly contaminated and the ^{137}Cs concentration will reach a maximum between the years 1998 and 2010.[9] Data on mushrooms show that for some species there is no significant decrease with time.[8] These data indicate, therefore, that remediation measures taken soon after contamination will have a long term dose saving effect.

Defoliation and litter removal have long term benefits in that they reduce the contamination source in the forest - but the waste produced by these actions present long-term disposal problems.

Restriction of access to forests and use of forest products results in an instantaneous dose reduction but this action must be sustained over many years to be continually effective. These measures require the population to change traditional practices which involves the loss, for extended periods, of foodstuffs traditionally collected in the forest. The economic effect may be significant and the cultural change can cause a strong negative psychological impact on the population.

Ecological Effects

Secondary impacts on the forest as a result of countermeasure application are important considerations in countermeasure evaluation because very often the direct economic costs associated with the action (for example, loss of timber value) are less important than the impact on other forest functions. Forests have many functions in the environment (e.g., a production system for wood for industry and fuel, a habitat, a grazing place for domestic animals, a source of food, a territory for game, a recreation ground for man, a feature of the landscape). The forest gives stability to soil, intercepts precipitation and forms an attractive barrier to sound, unpleasant views and airborne contaminants. The more functions, either economic, social or environmental that a forest has, the greater its value and the more precious its ecology.

A classification of forest countermeasures in terms of their impact on the forest ecology must consider both the severity of the secondary effects as well as the range of functions which will be put at risk by this secondary effect. Table 1 indicates the potential secondary impacts of the listed countermeasures. It is clear that some have more potential effects than others.

The majority of research effort has targeted soil-based countermeasures which are most effective in agricultural situations. The important role of soil in the bio- and geo-sphere means that there is potentially a very wide range of secondary effects associated with any interference in soil. The radiological literature which propose soil based countermeasures do not do justice to the important role of soil in the environment.

Table 1 lists both physical and chemical soil amendments as countermeasures and indicates that chemical applications to soil are less ecologically damaging than the physical. Any of the impacts listed will be magnified if a large forested area are to be treated. Changes to the forest soil will affect the availability of forest fruits and the use of the forest for grazing. In small forested areas such as in an urban parkland, these measures may be justified on the basis of the large social benefit to be derived from the preservation of a parkland. In this case, any secondary effects of the countermeasure which risked the health of the forest would defeat the purpose of remediation.

Chemical defoliation is a frequently suggested action but the loss of all leaves is a severe shock to the physiology of a tree, especially to coniferous trees. In addition to this effect, there are significant potential ecological hazards associated with the defoliant. The defoliant is likely to affect all of the forest flora with knock-on effects in the forest fauna. There is also a risk that the defoliant could spread to water bodies. As with the soil based countermeasures the potential secondary effects associated with defoliation may be acceptable for small area treatments where understorey vegetation has not got a food role.

CONCLUSION

With forest management measures there are few direct losses of ecological quality. However, the restriction of forest use by the public reduces the value of the forest to the local community which in turn can negatively impact the public perception of the wider environment and of their quality of life. This indicates again the important role of public education programs in such forest management based countermeasures. Listed under forest management is the option to change forestry production to one of nursery production. This management option preserves commercial activity but it is dependent on the availability of markets and it would require a shift in the labour patterns. This action also has the most severe ecological consequences because it involves the loss of the forest itself and every function which it performed in the community and the environment.

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Phytoextraction and Phytostabilization of Radionuclides in Contaminated Soils

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INTRODUCTION

Remediation of soils contaminated with radionuclides has historically been removal and replacement of the soil. New approaches to remediate the risk of soil radionuclides by phytoremediation (phytoextraction or phytostabilization) are being developed. In phytoextraction, plant species which accumulate unusually high concentrations (have very high bioconcentration factors) compared to crop plants are being grown as a "hay" crop. The hay is grown using management practices to maximize yield and accumulation of the contaminant, dried in the field, baled, and the biomass burned or pyrolyzed to produce a concentrated ash which is a significant part of the total soil contaminant in a small mass. This reduces the cost of appropriate disposal of the contaminants, and retains soil fertility. During the remediation period, cropping limits wind or water erosion of the contaminated soil, and evapotranspiration reduces potential for leaching.

DISCUSSION

Phytostabilization uses application of chemicals or soil amendments which reduce the bioavailability of the contaminant in soil. Plants may play a direct role by oxidation of xenobiotics, or by accumulating an element needed to inactivate a contaminant (such as accumulating phosphate which improves the rate of formation of chloropyromorphite, a crystalline Pb solid which has very low bioavailability). Application of adsorbents such as hydrous Fe and Mn oxides can increase adsorption or precipitation of a contaminant, or favor occlusion within the more crystalline solids formed over time. If bioavailability is persistently reduced such that environmental risk is reduced to required levels of protection, phytostabilization can be a practical remediation. Demonstration of the persistence of the reduction in bioavailability is a necessary to win acceptance of phytostabilization.

Technologies are under development for phytoremediation/phytoextraction of the elements Zn, Cd, Ni, Co, and Se using hyperaccumulator plants, and for Hg and Se using phytovolatilization. Soil and crop management practices are being optimized to maximize annual removals. Evidence has been reported that some radionuclides (Cs, Sr, Co) can be effectively phytoextracted, and more radionuclides are being studied. Addition of chelating agents can increase uptake of some metals or radionuclides, but leaching would need to be controlled if this approach were applied in the field.

Application of phytoextraction to specific radionuclides using specific plants. We have completed a Critical Review of the literature on Phytoremediation of Soil Radionuclides to identify both promising plant species for specific radionuclides, and appropriate methods for evaluation of phytoextraction, and a Report is being prepared.

Response Criteria

Response Actions are limited reactions to releases of hazardous substances into the environment to minimize hazard or dispersal. Phytostabilization could be an Emergency Response wherein cover crops which have reduced uptake of radionuclides of concern are grown on the site. An effective vegetative cover can be achieved on nearly any site if soil analysis is conducted to identify deficient nutrients or toxic elements, and existing pH and adsorption ability of the soil. Inexpensive locally available byproducts may provide needed changes in soil nutrients and toxic element phytoavailability so that desired plants can be grown; plant species which exclude radionuclides from food-chain plant tissues could be sown and maintained using conventional agricultural practices.

CONCLUSION

Phytoextraction as a Response Technology?

Thus the Agency has begun to gather information about phytoremediation and its possible application as a cleanup technology. Bioremediation and Phytoremediation have some similarities in their application to contaminated soils, and present similar issues to On Scene Coordinators considering use following a release event. We believe that research and demonstration of radionuclide phytoextraction will show the ability of this technology to achieve practical remediation of soil radionuclides, and provide the information needed for public decisions on use of phytoextraction of contaminated sites.

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Session D, Track 2:
Public Health Issues I

Thursday, September 10, 1998
10:10 a.m. - 12:40 p.m.

Chair: Jim Rabb, Centers for Disease Control and Prevention

Operation *Chernobyl Challenge*: The Public Health Response by US Military Forces in Europe

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INTRODUCTION

News of the Chernobyl Nuclear Power Station accident and its widespread environmental radioactive contamination became public knowledge on April 28, 1986. At that time, more than 500,000 US military members, US government civilian employees and their families were working and living in Europe. For information on health threats and for guidance on precautions to take, these American citizens looked to their own government, rather than the governments of the countries in which they resided. To coordinate the public information and health response actions, the United States European Command (USEUCOM) organized a Chernobyl Task Force in the Office of the Command Surgeon. Cooperating with US State Department and local host nation authorities, the Chernobyl Task Force responded through a variety of actions to evaluate the hazard and to ensure the safety of US personnel.

The USEUCOM is the Department of Defense element exercising operational command of US Forces in Europe. In 1986, the USEUCOM area of responsibility covered 13 million square miles, from the North Cape of Norway through the Mediterranean, most of Africa and parts of the Middle East. Although planning for an NATO conflict was first priority at USEUCOM, consideration also was given to contingency planning for humanitarian relief in the event of natural disaster or terrorist activity. Tactical US military units in Europe with nuclear monitoring capability were organized for wartime responsibilities with detection equipment optimized for evaluating relatively intense radioactivity in a nuclear exchange environment. The military medical units in Europe did have sufficient radiological evaluation equipment to support their peacetime missions of medical treatment, occupational health and environmental hygiene. However, military units did not have the mission of routine monitoring for environmental radioactivity in a peacetime or garrison situation.

Following early reports of the accident, USEUCOM established a crisis management team to address the situation as it developed. The initial team meeting on April 29, 1986 brought together US Army medical staff consultants in public health, preventive medicine, radiological hygiene, veterinary medicine/food sanitation, nuclear medicine, medical operations and medical logistics. In subsequent meetings the team was augmented with representatives from public affairs and members representing Navy and Air Force Commands, and was designated as the USEUCOM Chernobyl Task Force (CTF). Under the direction of an Army Medical Corps physician, the CTF accumulated radiological data, evaluated information and planned public health responses to minimize the radiological impact of the accident on US personnel in Europe.

DISCUSSION

Public Affairs

The main crisis management function of the CTF evolved to be information management: obtaining information, interpreting data, developing guidance and disseminating public instructions. In this context, environmental radioactivity data played the major role. Initially, sources of radiological data were the newspapers, the US Embassy in Bonn, the Federal German Interior Ministry Crisis Action Center in Bonn, the German Weather Service and German military liaison officers with German State governments. Later, environmental monitoring data by US military forces were routed to the task force to support their deliberations.

Although organized as a crisis management team and working from an emergency operations center, the most significant determination by the Task Force was that the situation in Western Europe was neither a "crisis" nor an "emergency." The situation was certainly not normal, but based on the operations and evaluations discussed below, the CTF concluded that individuals taking reasonable precautions following public health directives need not be exposed to other than a negligible individual risk. The CTF developed recommendations covering food, milk and water, and precautions for children and pregnant women using existing Federal guidance documents[1,2] and distributed its guidance and information through several available information channels. Environmental situation analyses were provided to military services for their use. Military hospital commanders were encouraged to contact the CTF daily for updated information. Public announcements were provided in press releases, published in English language newspapers ("*The Stars & Stripes*") and broadcast on the US Armed Forces Network radio and television stations. The CTF directed several operations by military personnel to monitor radioactivity in people, milk, foodstuffs, equipment and the environment. These results gave the CTF first-hand knowledge of conditions, lending credence to public announcements on the environmental situation.[3]

Protocol for Screening Tourists

When the accident occurred at the Chernobyl power station, there happened to be two groups of U.S. military personnel family members on commercial tours inside the USSR. The unknown situation within the USSR following the accident led USEUCOM officials to concerns for radiation exposures to the individual tour members and for contaminated items they might bring back to the West. Planning for the reception of these groups built on operational procedures used previously when USEUCOM medical units had received American hostages returning from Middle East locations. However, in this situation several differences complicated the execution:

since the time of the accident was not certain, it was unclear whether the groups had departed Kiev before or after the release of radioactivity from Chernobyl; the tour groups were arriving at commercial rather than military airports; and the tour groups were traveling on commercial airlines rather than military aircraft.

Army units met one tour group upon its arrival at Frankfurt, Germany, while Air Force units met the other tour group in Luxembourg. Both screening operations included monitoring individuals and their baggage for external contamination, obtaining individual itineraries and medical histories, performing thyroid counts and obtaining bioassay samples to assess internal contamination, and incorporating all analyses and interpretations into the individual's medical record. Radioactivity above background was not detected on any luggage nor in the thyroids, nasal swabs or fingernail scrapings of the 88 group members.

Food Supply Monitoring

Fresh foods for consumption by US personnel were obtained from many outlets throughout the European theater. Following the Chernobyl radioactivity release, health agencies in each nation began monitoring food distribution points and enforced national standards for radiologically contaminated items. Food inspectors from USEUCOM veterinary service units traveled to wholesale markets, bulk issue points, and US commissary distribution warehouses to monitor the food supplies destined for American tables in Europe. Inspectors also obtained representative food and dairy product samples for analysis in the Army medical laboratory. Other samples were sent to the US for analysis by the Food and Drug Administration. Information on this surveillance and knowledge of these efforts reassured the American population in Europe of the safety of their food supply.[4]

Monitoring Mission to Moscow

Following the news of the reactor accident, personnel at the American embassy in Moscow were presented with a dilemma of unknown proportions. While the Western press was reporting widespread radioactive contamination and fallout in countries surrounding the USSR, the Soviet government would not discuss the radiation situation inside the country. At the request of the US State Department, USEUCOM dispatched a Radiation Advisory Medical Team (RAMT) to Moscow to advise the US Ambassador on the radiation status and to evaluate any hazards to the community of Americans in the USSR. The team of Army officers (three health physicists, a food sanitation veterinarian, and a nuclear medicine physician) arrived in Moscow on May 3, 1986, only five days following the first public knowledge of radioactivity fallout.

While in the USSR, the RAMT surveyed the US embassy in Moscow, the US Consulate mission in Leningrad, and the living quarters of US families in both cities. Without an opportunity to interact with Soviet government officials, the Team established its own environmental monitoring program to support the US Ambassador's need for information. The radiation monitoring activities conducted at these locations included surveys of external radiation exposure and surface fallout contamination, individual body scans and thyroid counts, daily air samples for radioactive particulates and radioiodine, screening of foods, and sample collection for definitive analysis in the USA. All monitoring results were discussed with Embassy staff and were forwarded to the US Federal Chernobyl Interagency Task Force in Washington, D.C., providing a basis for the determination that there was not a radiological health risk in remaining in Leningrad or Moscow.[5] The RAMT departed Moscow for return to Germany on 13 May 1986, following the Soviet announcement that the reactor fire had been extinguished.

Environmental Radioactivity Monitoring

Local environmental radioactivity data was available to the CTF from US State Department and host-nation authorities. However, the information was often delayed due to multiple bureaucratic channels, sometimes confusing due to the radiological units reported, and even unavailable for some geographic locations in which US populations were domiciled. Limited environmental data from impromptu monitoring by military units was also available.

Health physicists at the US Army 10th Medical Laboratory, Landstuhl, Germany had begun sampling on 29 April. Landstuhl is in southwest Germany, adjacent to the major logistics centers of the US Air Force base at Ramstein and the Army depots at Kaiserslautern, and it is more than 1,600 km (1,000 miles) due west of Chernobyl. Around Landstuhl in the Kaiserslautern vicinity lived and worked almost 60,000 Americans, at that time comprising the largest American community outside the US. Environmental sampling included airborne particulate radioactivity, airborne iodine/gaseous radioactivity and radioactivity in rainfall. Preventive Medicine units of the US Air Force also collected air and soil samples from air bases in eight countries throughout western Europe. Sufficient samples were collected and analyzed to give a picture of the radioactivity situation as the fallout cloud passed through the area in early May 1986. A spectrum of gamma energy from the May 1, 1986 air sample filter revealed gamma rays characteristic of the presence of the fission products Ru-103, I-131, I-132, Te-132, Cs-134 and Cs-137.

On May 12, 1986 the CTF began a theater-wide sampling program using Army 7th MEDCOM Preventive Medicine personnel and equipment assets. Besides obtaining environmental data, the CTF intended the program be used to evaluate analytical system constraints and capabilities, and to identify equipment needs for future use of the sampling program by other military services. The program involved environmental monitoring at 18 sites, 15 locations in West Germany, and individual sites in West Berlin, Belgium and Italy. These sites coincided with or were adjacent to communities and training sites with large populations of US personnel. Media sampled included air particulates and air gases daily, while drinking water, surface soil and rain water were sampled twice per week. Samples were sent daily to the Army Medical Laboratory in Landstuhl for analysis.

By May 30, 1986, after the collection and analysis of more than 350 samples, it was evident that radioactivity levels had returned to baseline levels. On June 1, 1986 the monitoring intensity was reduced to weekly air samples and monthly samples of soil and drinking water. This monitoring level was continued for 11 months to allow baseline radiation characterization of the various US communities, while analyzing system constraints and procedures. In early May 1987, the environmental monitoring system moved into a maintenance mode of semiannual samples.

Evaluation of Hazards to Troop Exercises

A remaining concern following the Soviet announcement that the accident situation had stabilized was whether the fallout in local areas would have any impacts on military training operations. As tanks and tactical vehicles maneuver in the training areas, significant amounts of surface dust become resuspended in the local atmosphere. If significant fallout radioactivity were present in the soil, breathing this resuspended activity could present a health hazard to troops engaged in tactical exercises and training. In late May 1986 the CTF initiated an evaluation of surface soil radioactivity at Grafenwoehr and Hohenfels Training Areas in Southern Germany that had reported higher levels of airborne radioactivity continuing into mid-May.

Surface soil samples, shallow soil plugs and deep soil core samples were collected adjacent to tank trails and samples of road dust were also collected from the tank trail. All samples were analyzed for total alpha and total beta activity; surface dust samples were further analyzed for gamma activity. Abnormal levels of radioactivity were not observed in any of the soil samples, although sample-to-sample variations were noted. Soil core samples showed little variation in radioactivity from the surface down to a six-inch depth, showing that significant fallout had not accumulated on the ground surface. Gamma radiation spectroscopic analysis of the road dust samples indicated the radioactivity was consistent with naturally occurring radioactive Thorium, and the spectrum did not show the presence of reactor-produced gamma-emitting nuclides such as Cs-137.

The absence of abnormal levels of environmental radioactivity in the soils at the Training Areas indicated that short or long term radiological health hazards from exposure to resuspended road dusts and surface soils were not present during training activities. This finding confirmed that the Army training to support the NATO mission could continue without distraction by undue health concerns.

CONCLUSION

Through these diverse public health response activities following the Chernobyl Nuclear Power Station accident, the USEUCOM assured the safety of American military and family members in Europe. The operations directed by the USEUCOM Chernobyl Task Force provided data and evaluations to support an extensive public information effort to address the concerns of the community of Americans far from familiar information sources. The activities of the military forces' Chernobyl Task Force during and after the radioactivity release provided credible information that dispelled public uncertainty and enabled continued military operations and diplomatic functions.

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Application of Environmental Dose Reconstruction to Post-Emergency Response Public Health Issues

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INTRODUCTION

The Centers for Disease Control and Prevention (CDC) is currently responsible for environmental dose-reconstruction activities at four different nuclear weapons production sites in the United States under a Memorandum of Understanding between the Department of Energy and the Department of Health and Human Services. An environmental dose reconstruction is a comprehensive analysis of the exposure received by people living in the vicinity of facilities that have released contaminants into the environment. One goal of a dose reconstruction is to estimate exposures and doses as realistically as possible for a given site. The results of CDC-conducted dose reconstructions are being used as the basis for performing risk analyses and deciding what other public health activities should be undertaken around these sites.[2] In addition, the results of dose reconstruction can be used in other site-specific risk assessment activities, such as those associated with environmental restoration and radioactive waste management.[3]

During a post-emergency response following a major release of radionuclides to the environment, public health will be of utmost concern to persons affected by the event. While State and local officials have primary responsibility for the health and safety of their citizens,[3] all people involved in the post-emergency response will be involved to some extent in providing information to the public on the possible health consequences resulting from their exposure to radionuclides. Providing this information will require knowledge of the radiological doses received during the event. Such doses will likely need to be reconstructed from environmental and other types of measurements made during and after the emergency event.

DISCUSSION

CDC is currently using a phased approach in conducting the technical aspects of environmental dose reconstructions.[3] These phases are summarized in Table 1. However, CDC has learned that there is more to a credible dose reconstruction project than technical work. Public involvement is critical to this process.[1] A meaningful public involvement program not only provides a forum to allow community members to voice their concerns so they can be considered by the project, but it also builds credibility in the community for the technical work that is being done. Such a program also ensures that the government agency responsible for the dose reconstruction is accountable to the community. Indeed, the success of any dose reconstruction depends as much on public involvement in the project as on the scientific and technical credibility of the methods used to estimate doses and exposures.[3]

Table 1. Technical phases of an environmental dose reconstruction project.

Phase	Activity
I	Locate and catalog all records applicable to the dose reconstruction project
II	Estimate a source term for the site (i.e., a listing of what toxicants were released, what amounts of each were released, the point(s) on site where they were released, how and when they were released, and the physical and chemical form of the release)
III	Perform screening calculations to help determine which contaminants at a site are of most or least concern to human or environmental health and which environmental media and pathways of exposure or sections of the site require additional study
IV	Develop more detailed assessment models that use as much site-specific data as available and incorporate a quantitative uncertainty analysis in the assessment results
V	Using the models and data gathered in previous phases, perform as realistic a dose and risk analysis as possible

Public involvement will be an important aspect of any post-emergency public health response, too. One of the first steps that responders must take is to identify potential local stakeholders. This will certainly include State and local elected and public health officials, but it will also include members of the general public. It is not only important to assess the radiological dose and risk to the public resulting from the emergency event, it is also critical to assess the public's concern about the event. This can only be done effectively by involving them directly in the assessment process.

It is important that all phases of the radiological dose and risk assessment be conducted in as open and public a manner as possible. For example, the compilation of all records related to the emergency event must be an open process. Copies of all records must be readily available for public review even as they are being examined by scientists and engineers charged with evaluating the event. Members of the public must be strongly encouraged to participate in the record collection process, providing any information that they feel may be of importance, including personal observations of activities that occurred during the emergency event.

However, this process must be sensitive to the need to protect personal identification data related to the information.

As responders begin using the compiled records to reconstruct the source term for the event, care must be taken to insure that the public is involved in this process, too. Depending upon the exact nature of the radiological emergency, source term reconstruction can be very technical. However, responders must make the time and effort to help the public understand what is being done and why. This will require that the scientists and engineers doing the work interact with the public. CDC has learned through its dose reconstructions that scientists, not just public information specialists, must be available to answer questions from the public if those answers are going to have maximum credibility. Also, any reconstructed source term will have some level of uncertainty associated with it. This uncertainty must be quantified and then discussed with the public in an open manner. The public knows that science is uncertain, and they appreciate it when scientists are open about it.

Once the source term has been reconstructed, screening analyses can be performed to identify the most significant radionuclides and pathways of exposure for the event. Members of the public can be most helpful in performing this work. Are there any special or unusual populations in the exposed area? Are there any special or unusual pathways of exposure in the area? And just what is the area of concern for the event? From a purely technical point of view identifying the exact area around the event where exposures to people and/or ground contamination has occurred or could occur in the future is of utmost importance. For the public, however, clearly and convincingly delineating the area where exposures or contamination is NOT present may be of equal or greater importance. The screening process is a way to begin judging community concerns and selecting programs, such as environmental monitoring and health education, to address those concerns.

The results of the screening process can be used to select the necessary mathematical models and procedures to use in reconstructing the potential doses to people from the emergency event. Providing people with these doses is not the end of the public health process, however. The first thing people will ask is "but what does the dose estimate really mean to me; what is my risk from this event." These questions must be addressed with care and sensitivity by the responders. One aspect of the answer will be a program of health education both for members of the public and local physicians. CDC has found that members of the public consider their personal physician a primary source for information of this nature. As a result, it is important that local physicians understand the dose and risk information associated with the emergency event. Another aspect of the response to people's concern will be the design and implementation of a highly visible and effective environmental monitoring program. This program should be designed to provide a high level of assurance to people that their health and safety is of utmost importance to responders. As always, this program should have significant public involvement when it is being designed.

CONCLUSION

There are no definitive guide books on how to implement an effective post-emergency response public health program. All responses will, of necessity, be site-specific in nature. The key consideration is that all responders must be flexible and be responsive to the needs and concerns of the public. Again, the success of any post-emergency response will depend as much on public involvement in the project as on the scientific and technical credibility of the methods used to estimate doses and risks from the radiological release.

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A Discussion of Public Health Issues From a Severe Nuclear Reactor Accident

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INTRODUCTION

Any strategy for implementation of protective actions for the general public following a nuclear power reactor accident must be based on justification and optimization of the imposed actions to produce a maximum benefit by reducing the total harm. This paper discusses the influence of some of the factors affecting the analysis of risk and assignment of priorities in the creation of a rational and flexible strategy for post-emergency periods. The issues discussed include: radiation-induced risks, the impact of protective actions, and psychologically induced illnesses.

DISCUSSION

Radiation-Induced Risks

The risks induced by exposure to radiation have been catalogued, analyzed, and quantified by national and international agencies.[1] Procedures for emergency preparedness for response to the emergency phase of a nuclear reactor accident have been fully documented.[2] The levels of radiation-induced risk have been correlated with both rates and duration of exposure.[3] The radiation risks during the post-emergency periods are principally from chronic irradiation due to inhalation of contaminated airborne radionuclides, ingestion of contaminated food and water, and external exposure to the contaminated ground. The principal radiation-induced effects are somatic late effects, which include stochastic effects such as leukemia, sarcoma, and carcinoma. Each one of these late effects has a period of latency, which is the time period between irradiation and manifestation of the cancers. The latency period may be from several years to decades long.

A particular protective action may decrease the radiation dose, but the long-term decrease in somatic effects of the exposure may not be uniformly distributed for all age cohorts in the demographic distribution. This non-uniformity in protective effect is a consequence of a non-linear age-dose-response distribution. For example, for older adults whose remaining life span is less than the latency period for induction of a somatic effect, the effect of the radiation-induced risk may not be realized.[3]

The Impact of Protective Actions

Among the most common emergency and intermediate protective actions are evacuation, relocation, and restriction of the intake of contaminated food and water. All have associated impacts and risks, as described below.

Some actions, such as evacuation and administration of potassium iodide (KI), could be intrusive and may induce unintended harm. Evacuation under adverse climatological conditions, such as a severe winter storm, could prove far riskier than the dose to be avoided. Evacuation of medical facilities can pose high risks to the elderly or critically ill. Adverse reactions to KI resulting from hypersensitivity to iodide, although uncommon, are not unknown.

Furthermore, while local emergency plans thoroughly address the use and implementation of early protective actions like evacuation and sheltering, they commonly fail to address the consequences of later actions; i.e., those involving potentially contaminated food, water, animals, etc. Evacuation decisions will likely be based on science (reactor stability, accident sequences, dose assessments), while food chain decisions will more likely bow to public perception. For example, following the Chernobyl accident, some foodstuffs grown in the Ukraine were sampled, analyzed, and found to contain minimal amounts of radioactive contamination, far below cut-off levels. Although science verified the safety of such products, the public perception of risk was skewed, and these items were driven from the market. The economic consequences were considerable.

Likewise, long-term actions for environmental cleanup can have drawbacks. One long-term protective action for a contaminated area is the option of "no action," permitting natural removal of the radioactivity by surface runoff and by mechanical mixing of the contamination into deeper soil matrices by wind and precipitation.[4] Another option is surface stabilization using surface active chemicals to reduce resuspension. This may also reduce relocation of the radioactivity by surface wash off. Finally, deep tilling of the moist, agricultural land can be performed to reduce resuspension of the radioactivity. All of these options reduce availability of the land for an extended period of time and would increase the potential for plant uptake and leaching of radionuclides into the groundwater.

Psychologically Induced Illnesses

Psychologically induced illnesses include both psychosomatic illnesses and the induction of anxiety, depression, and helplessness. Some of the induced psychological effects are created by overestimating the magnitude of the risks beyond the reality of the potential hazards. An apprehension about risks of unknown events and lack of control, fed by misinformation and poor comprehension of reality, increases the anxiety and its consequences.

The psychological effects of major accidents, such as car, train, and airplane crashes, or natural disasters, such as floods, tornadoes, and earthquakes, have been studied and understood better than nuclear accidents. The public has become aware of the dangers and consequences of natural disasters on the affected individuals and the environment; thus the public has developed a reasonable comprehension of risks and realities. In contrast, our experience with nuclear reactor accidents is embedded in the Hiroshima and Nagasaki bombings. The consequences of the atomic bombs have created an unrealistic apprehension about non-military sources of radiation. The horror of events in unscientific fiction and movies about monstrous genetic mutations are etched into our memories. Radiation phobia (or radiophobia) is an expression for an exaggerated perception of radiation risks. This phobia has been nurtured by decades of misinformation while the real and significant risks in our daily life are downplayed. Although we are all affected by any event that deviates from the daily routine--coping[5] with evacuation or food restrictions would be stressful enough--the prospect of additional actions such as whole body counting and decontamination could induce even more anxiety and stress.

These psychological effects are physically real and are usually disproportionate to the magnitude of the radiation exposure. These syndromes are classified as post-traumatic stress disorder (PTSD)[6] and chronic stress disorder (CSD). A major difference between these two disorders is the duration of the stress itself. Whereas the duration of the stress may be brief for the onset of PTSD, lasting up to several days, the stress would be chronic for CSD. In Chernobyl, the continuity of the stress among the population created CSD, similar to that found among victims of war and prolonged occupation. A review of the Three Mile Island[7] (TMI) and Chernobyl[8] accidents indicates that the PTSD and CSD contribution to the total risk is significant. The impact of induced psychological risks on the public health is difficult to analyze and quantify using standard risk analysis techniques. Because these effects are hard to quantify, they often are not included in the traditional methods of risk analysis. This is a serious omission.

A major objective following a severe nuclear reactor accident is allocation of regional and national resources to reduce any potential public health risks. These allocations should be cost-effective and based on realistic objectives for reduction of total harm. Unfortunately, this is difficult in practice because of multiple factors affecting the decision process.

An optimum risk management structure would include elimination of interference among several parallel imposed actions. Not all of the parameters for the evaluation are amenable to digitalization (assignment of cost to a particular risk factor). In addition, some of the risk parameters are subjective and many carry a large uncertainty in their value.[9] These include biotic uptake coefficients, resuspension coefficients, and the accuracy of measured radiation concentrations in the environment. Nevertheless, expert evaluation of these risks, including some attempt at quantization, may permit the creation of scales for trade-off among several risks. In contrast to the emergency and early post-emergency periods, a more systematic evaluation of each of the input parameters could permit a more accurate estimation of the accident's psychological, social, and economical impacts upon the society, and thus assist in the development of longer-term strategies.

The trade-off among several risk factors has to be weighed against the long-term benefits and cost-effectiveness of the actions to be taken. Assigning an economic weight to each risk increment is fraught with difficulty, because it is non-linear in functional structure. For example, the cost of the reduction of a particular risk from 50% to 10% may be economically worthwhile; however, the corresponding cost of reductions from 10% to 1% may not be cost-effective. Cost analysis relative to the associated baselines (no protective action) for different risks may not be additive.

Risks may also be shared unequally across a population. The psychological and economic consequences of some protective actions may affect the members of older cohorts in the population more than younger ones. A uniform imposition of actions for all ages may be robust and practicable; however, the consequences of the action may be non-uniform. Segregation based solely on age for any protective action would impose its own psychological effects, adding anxiety and stress particularly to young families.

Any analysis of risks based solely on reduction of the radiation risks could easily underestimate the total risk and cause more harm than good. History bears this out: protective actions following the Chernobyl accident were a brute exercise in relocation. The second wave of evacuation, in 1990 and 1991, did reduce radiation exposure, while exacerbating and extending the chronic environmental disorder. What were the merits of the evacuation in terms of reduction of total impacts on public health? In some cases, especially when the whole body radiation doses were less than 10 rem, the psychological and social consequences of evacuation on those older than 60 years of age may have exceeded the potential radiation-induced biological effects. An evaluation of an optimum procedure for the management of risks must, by necessity, be flexible and based on inputs from multiple disciplines: radiation protection, agriculture, conservation, economics, psychology, sociology, and political science. The analysis should draw from each discipline using techniques such as multi-attribute utility analysis.[10] The perception of risk would be the dominant force affecting the process.

CONCLUSION

Finally, good public information and education are essential for effective risk reduction. Systematic programs to educate the public through participation and interaction must be initiated before any severe nuclear reactor accident. Negative public reactions following an accident should be expected and planned for. Emergency planners must integrate the effect of psychological factors into the response planning and training in order to optimize the benefits of public protective actions.

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Separating of Radionuclides Component in Technogenous Ecological Influence on Health of the Population

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INTRODUCTION

It has become one of the lessons of the Chernobyl disaster that the small levels of radioactive contamination which was treated as not dangerous for the population had imposed over the old non-radiation contamination that led to outbreak of nonspecific morbidity. A new term "Chernobyl syndrome" has appeared which consists of a lot of symptoms suffered by a frequently sick child [1, 2]. This is a new term, used for describing the state of children's health, suffering from frequent diseases on the territory that was contaminated as a result of the Chernobyl accident. "Chernobyl syndrome" is characterised most often by a high level of respiratory diseases in spite of the lack of connection of these pathologies with the direct radioactive influence. It's worth mentioning that frequent respiratory diseases are characteristic for the child population living in the territories with a high level of chemical contamination [3]. That is why this class of morbidity can be used as an indicator of unfavourable ecological conditions.

In present methodical documents the comparison with the morbidity in the analogous inhabited territory or with the morbidity of the unexposed group of population is the decisive argument about the dominating influence factor on the level of morbidity. It is supposed that all the other conditions are equal. Unfortunately to collect such pairs for comparison is practically impossible nowadays. As an example, the choice of control territory of Chernobyl influence can be illustrated by the choice of Poltava and Sumi regions where there is no radioactive contamination. But as the continued research of the Institute of Geography demonstrated conclusively, these regions were admitted with the highest level of oncological morbidity in that period in Ukraine [4]. The results of comparing oncological morbidity levels can be underestimated greatly under these conditions. In addition, analyzing the simultaneous influence of several factors can be done in 2 ways: 1) sorting out of isolated factors or 2) with the help of an estimating system.

Not to mention the little attention paid to the analysis of the territorial distribution of morbidity and contamination at the investigated territory.

DISCUSSION

The development of natural particularities on contaminated territories to a great extent and its landscape geochemical peculiarities for forming of doses of irradiation became the other important lesson of the Chernobyl emergency. Under the same density of radiocesium contamination of soil (Kiev region for example), its contents in milk may differ as much as 2-10 times [5]. This means that different natural geochemical conditions have levels and kinds of technological contamination (industrial wastes, transport of waste, radionuclides, pesticides, mineral fertilizers) from ecological unfavourable zones on Ukrainian territory which are characterized by the increasing of substances of natural and technological nature.

Selection of ecologically unfavourable zones in the condition of combined pollution of radioactive and chemical substances of environment demands considerable time and finance which is not realistic for Ukraine nowadays.

Taking into account that the modern human is under the influence of a great number of ecological agents and that is why it's sometimes almost impossible to discover the reason for changes in human health. To pinpoint this or that factor, it's necessary to use a new methodical approach.

For this purpose, during 1991-1995, a group of specialists of different profiles and different institutions (NAS Ukraine, Russia and Belorussia, Ukraine State Committee of Geology and Agrochemical Service), under the leadership of Academician V. Shestopalov held the detailed polygon investigation of the northern part of the Kiev region, attached to the zone of the Chernobyl accident, and also screening research of the territory of "west trace".

The new-found information allowed scientists to formulate and publish "Methodical recommendations on radioecological assessment of territories by mapping", (all the participants were co-authors) in 1995 [6]. They include the following suggestions:

- Account and analysis of territorial distribution of all possible unfavourable ecological factors of population health, which is under state monitoring.
- The mathematical analysis of factor-dependent conditions and modeling of risk morbidity for definition of the contribution of each investigated factor;
- Zoning of territory in accordance with the risk from each studied factor.

In these recommendations, our presentation of ecological risk was introduced as a combined criteria action of all pathological ecological factors including radioactivity as an integral part of common ecological risk. "Ecological risk" means the quantity of the undesirable declining in the population's health which was calculated with the definite probability and the level for this territory, caused by the influence of investigated factors of morbidity per 10,000. The child population morbidity (from 0 to 14 years of age) is the most vulnerable under the influence of unfavourable factors [7] and that is why it was used as an indicator of the territory state. Because it has a sufficient number for receiving true statistical marks studied on the territory of the former

USSR, using only one method for many years, it allows the comparison of different territories for different periods, and they are available for each person.

Taking into account the detailed investigation, including the registration of morbidity on the level of countryside, medical district (some inhabited districts) and an insufficient number of children, who were living in these territories for receiving representative data in "Methodical recommendations". We offer to hold analysis only on the base of indexes of general and respiratory morbidity. In addition, it's necessary to analyze the level of medical care provided to the district by doctors in the investigated territories. This will permit analysis of the influence of medical service among all the investigated factors. For example: the production of radioactive factors contribution characterizes the radioecological risk.

The level of ecological risk and the contribution of each factor out of the investigated complex is defined with a help of multi-factor regressive models. The choice of models is created after the analysis of outcome information, which reflects the real interrelation of "factors" and "states" of organisms in a concrete ecological system (in this case - contamination of the environment and morbidity of children's population and morbidity of children's population living on this territory).

We define a "state" as the numerical characteristics of the biological bodies peculiar to anthropogenosis and biogeocenosis over a given area (in our case it is the local population morbidity). We define "factors" as the numerical characteristics that show the contents of artificial and natural components over a given area. We consider the spacial distribution of a risk parameter marked on a basic map (administrative, landscape-geochemical, etc.) of correspondent scale, as a ecological risk map.

Zones of high ecological risk (over the average for a given area) are shown by red and yellow colors (the "traffic light principle"); green and blue are the colors for zones where the risk is below the average. Let us consider, as an example, the research that has been carried out in the territory of the Kiev region in Ukraine, bordering on the alienated Chernobyl zone in the North. The research allowed estimations of the degree of influence of the complex environmental factors of radioactive and non-radioactive nature on somatic morbidity of the child population.

The investigation of the territorial distribution and the degree of influence of the complex environmental factors of radiating and nonradiating nature on somatic morbidity of the child population have been carried out in the territory of the Kiev area in Ukraine, bordering on the Chernobyl alienated zone in the North. The following factors of environmental contamination were studied: pollution of soil by radiocesium and by strontium - 90, of milk (from individual farms), the annual summary of equivalent effective radiation dose, as cumulated pesticide load, chloro-organic pesticide load and others, nitrogen, phosphoric and potassium fertilizer load, loading in soil of heavy metals and microelements Pb, Ni, Cu, Cr, Cd, Co, Ba, Mn, Sn, Zn, Zr, V for 1989-1994. Twenty-seven factors were investigated and landscape-geochemical characteristics on investigated territory.

The mathematical analysis has shown that influence of all investigated factors achieved 30-40%, variation in different zones of supervision. The influence of radioactive factors in the Northern part of Kiev test site is six times more than the risk caused by heavy metals and agrochemical pollution, taken together. The greatest influence of heavy metals was found in the centre of the Kiev region. The result of mapping analysis gave the evidence, that the zones of maximum influence of each investigated factors coincide in some cases.

The zones of maximum radioecological risk were marked, which exceeds the average level for investigated territories as follows: 1) by 3-10 times, 2) by 3 times; and areas where the radioactive risk is on average 10 times less than the average. It was concluded that the mathematical probability of this influence was insufficient, which is why research was conducted towards improvement of the mathematical risk model.

Taking into account the presence of trend and nonlinearity, different nonlinear dependencies were investigated with the help of the software package STATISTICA for Windows. The square law model turned out to be the most optimum (on a criterion of multiple regression R=0.65 against R=0.52), the most reliable (the significant majority of regression coefficients has a generally accepted confidence interval not less than 95%), and the most adequate, after the analysis of residual remainder. During the process of model construction, the procedure of reducing a nonlinear model in linear was used, due to which the implementation of the model has become possible, as above mentioned linear. It can be considered as one more lesson of the Chernobyl accident.

CONCLUSION

Thus, it can be stated that as the lessons of the Chernobyl accident that are necessary to be considered under other ecological accidents, we have:

- A splash of somatic morbidity of the child population, particularly the respiratory diseases. That is why this class of morbidity can be used as an indicator of unfavourable ecological conditions;

- The considerable influence of natural particularities of contaminated territories, its landscape geochemical characteristics on the level of pollution entering into the human organism. That is why it's necessary to take them into account for assessment of accident consequences for humans.

- The action of ecological factors in small doses on the contaminated territories displayed not only directly, but as interacting with other factors. Thus, in making analysis of ecological accident consequences it's necessary to take into account the complexity of environmental factors.

- The method scheme for the assessment of ecological risk is recommended for a complex analysis of the factor influence and separating radioecological component in technogenic and ecological influence on population health [6].

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Rehabilitation of a Chernobyl Affected Population Using a Detoxification Method

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INTRODUCTION

The Chernobyl disaster resulted not only in the acute exposure of hundreds of thousands of people to various radionuclides, but also in a situation where a significant part of the population now lives permanently in radioactively contaminated territories. Many residents of the areas suffer from chronic stress and radiophobia.[1,2] The situation is exacerbated by relatively high levels of environmental chemical contamination. Despite this, the present health care in the affected areas is aimed mainly at the medical examination of persons and the diagnosis of diseases. Some programs dealing with specific aspects of the problem have been suggested and implemented, with inconclusive results.

Recently, a treatment modality has been examined which appears to offer the broad-spectrum approach necessary to address the range of problems resulting from the Chernobyl incident. The use of the detoxification method developed by L. Ron Hubbard has been described in the literature as a safe and effective means for removal from the body of specific toxic substances accumulated in the process of work activity. Detoxification procedures have been demonstrated to remove various xenobiotics, mainly with lipophilic properties,[3,4] and to remove chlororganic compounds.[5] A number of case histories[6] exist where the detoxification method produced a remission of physical and mental complaints that attending physicians have associated with the relative high radiation doses received by individuals ("liquidators") involved in cleanup work at the Chernobyl site.

In a cooperative effort between the Medical Radiological Research Center of the Russian Academy of Medical Sciences (MRRC RAMS) and Human Detoxification Services International (HDSI) of Great Britain, a group of twenty-four males aged 20 to 40 years old underwent detoxification using the Hubbard protocol. Participants were long-term residents of contaminated areas. The purpose of this work was to perform a broad examination of the effects of the human detoxification program as it applies to the removal of toxic substances, xenobiotics, and radioactive Cesium-137 (Cs-137) from the human body. In addition, an assay of the effects of the method on the physical processes of the body was performed.

DISCUSSION

The Hubbard detoxification program includes a daily regimen of one-half hour of moderate physical exercise (jogging), followed by up to four and a half hours of intermittent thermal procedures (i.e., moderate temperature sauna with periodic cool down). The detoxification regimen includes specific criteria by which the optimum rate of progress of each individual can be monitored and assured. Vitamin and mineral supplementation is administered based upon a standardized dosage scale modified by daily medical supervision and patient reporting of symptoms and perception of general health.

The use of psychodiagnostic testing and daily written debriefs enables the program administrator to establish the rate of progress of the patient and to determine the endpoint of the program more precisely. A typical course of treatment takes approximately two to three weeks.[7]

In this study, twenty-four males aged 20 to 40 years old from the Klimovsk District of the Bryansk Region participated. All of the participants were long-term residents of radioactively contaminated areas. The participants were randomly selected from the registry database of individuals with confirmed body burdens exceeding levels of 5,000 kilobecquerel (kBq) of radioactive cesium. For better uniformity of the group, the individuals were selected from a settlement with similar socio-economic levels.

Because of the requirements for relatively robust physical activity during the detoxification procedure, participants received preliminary examinations to ensure that they did not have physical or mental conditions that contraindicated participation in the procedure (e.g., oncological diseases, acute infections, mental disorders, decompensated somatic diseases, etc.). Three potential participants were excluded from the program, as they could not meet the above requirements.

In addition to standard physical examinations and clinical tests, special examinations were conducted in order to determine various physical responses to the program (i.e., extended biochemical blood tests; cellular and humoral immunity status evaluations, assay of thyroid hormone levels, estimation of antioxidant activity in the blood serum, and evaluation of the functional activity of neutrophils). Diagnostic psychological evaluations (including both objective and subjective evaluations of self-perception, activity, moods, and emotional reactions) were also conducted. When indicated on an individual basis, the participants were provided additionally with echocardiography, ultrasound, dopplerography, rheovasography, fibroscopy, x-ray imaging, caprologic examination, etc. A series of tests reflecting a functional state of the heart, liver, kidneys, and pancreas was conducted. In addition, lipid exchange and microelement metabolism were monitored. In all, twenty-two biochemical parameters of the blood were evaluated. In most cases, the parameters observed varied within accepted normal ranges. The most notable fluctuations were an increase of conjugated bilirubin in blood serum, the decrease of glucose and triglycerides, and the reduction of glutamiltransaminase activity.

The functional status of each patient's immune system was estimated from the level of immunoglobulins in serum (normal antibodies to rat erythrocytes detected by hemaglutination reaction) and from the determination of the functional state of the thymus gland through the use of a proprietary immunodeficiency analyzer ("Helper"). During the course of detoxification, each patient displayed a pronounced elevation of the intensity of spontaneous chemoluminescence of polymorphonuclear lymphocytes of the blood and increased antioxidant activity in the blood serum. These reactions are considered to be the response to elevated levels of toxins, free radicals, and peroxides in the blood. The most typical effects were such improvements as a decrease in heterophylic antibody titers and the normalization of thymic function. In addition, the positive changes in the immune parameters in patients were confirmed to still be present one year after the rehabilitation treatment.

No significant negative impacts on the immune system were noted. At the end of the detoxification program, the level of integral antioxidant activity returned to the initial activity in almost all the patients. A year after the completion of the program, the level of antioxidant activity was found to have increased 2-3 fold over the pre-detoxification levels. This finding suggests that detoxification may have rehabilitated the immune system, and that these levels reflect the body's now more successful resistance to the chemically and radiologically contaminated environment.

The thyroid system was studied on the basis of measurements of thyroid hormones (FT3, FT4, TSH). Starting from the initial days of the program, the thyroid system was shown to respond by the enhanced secretion of thyroid hormone hypophysis into the blood stream and, respectively, the decrease of free triiodothyronine level and, to a lesser degree, of thyronine. Two explanations of these observations exist. On the one hand, these results may be considered as the development of an acute phase of subclinical hypothyrosis in response to the physical challenges of the program (i.e., exercises, sauna, and high doses of vitamins) with the concurrent release of xenobiotics and other catabolic products into blood. On the other hand, hypothyrosis may also be explained by the extensive "spending" of thyroid hormones in response to the above-mentioned factors.

We believe that the thyroid gland responded adequately to the systemic stresses induced by detoxification. This view is supported by the fact that the thyroid function had re-normalized three weeks after the end of the program, and that long-term examinations performed nine and twelve months after the rehabilitation demonstrated that the level of thyroid hormones were within the limits of a normal physiological range.

A series of *in vivo* measurements of radioactive Cesium-137 were performed on all participants prior to and during the program. Rates computed from these measurements were compared to elimination rates expected from routine physical processes. While Cesium-137 was reliably detected in the sweat of all the patients, an evident acceleration of Cesium-137 elimination was not found. However, an earlier study involving a group of 14 children exposed as a result of Chernobyl did find significant acceleration of elimination. We suspect that this discrepancy may be attributable to metabolic differences between children and adults, especially with regard to the metabolism of potassium (the pathway which cesium follows in the body.) This would be a fruitful area for further research.

This consultation of the patient's feelings and observations about how he is progressing on the program is a standard feature of the program. During this trial, additional objective testing methods were also utilized. The results of the evaluation of the participant's psychosocial states were particularly interesting. Analysis of data reveals a significant ($p<0.05$) positive change in the psychoemotional status of the program participants. Anxiety decreased from 23.48% to 9.09%, activity and "ability to work" increased from 40.9% to 46.96% and from 60.24% to 80.36%, respectively. This correlates with changes in individual status, levels, and ways of adaptation according to SMIL tests and SOC method. Such conditions are interpreted as a reduction of unproductive hypochondriac symptomatics, decrease of anxiety, increase of spontaneity and activity, increased self-confidence, renewed motivation for achievement, an increased "searching activity" and self-sufficiency. Results of the diagnostics of self estimation level showed that in most of the patients, positive changes occurred not only in the objective characteristics of psychological adaptation, but also in the subjective sense estimation of the individual as a person. No negative manifestations in mental status or organism comfort were noted. No decompensated disorders of major regulatory and life maintaining systems were revealed during the course of detoxification.

Follow-up examinations of the participants conducted at one and nine months after the completion of the program indicated that chronic diseases present at the start of the detoxification study were in lengthy remission, and an improvement in resistance to acute respiratory diseases was noted in a number of patients.

CONCLUSION

There is evidence suggesting that the program revitalizes the immune system and improves the general physical condition of the participant. In spite of its robust regimen, there is an absence of negative health effects. While out of normal range fluctuations of several key biochemical parameters were noted during the process, the deviated parameters renormalized upon completion of the course of treatment.

In addition, the detoxification program devised by Hubbard possesses a powerful psychotherapeutic potential that has been associated with significant improvement in the general health of the participant. Increases in physical and mental endurance, activity level, and resistance against stress can be expected. The specific physical processes induced by the detoxification method have not been fully examined at this time. Further research into these areas would be valuable. Nevertheless, it is our opinion that the detoxification method holds great promise as a general treatment for a number of non-specific symptoms associated with living in the contaminated areas of the Chernobyl disaster.

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Session E, Track 1:
Monitoring, Measurement, and Modeling II

Thursday, September 10, 1998
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Chair: Peter Stang, United States Department of Energy

Aquatic Countermeasures in the Chernobyl Zone: Decision Support Based on Field Studies and Mathematical Modelling

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INTRODUCTION

The water protection is one of the significant direction of post-Chernobyl accident countermeasure activities in Ukraine. Chernobyl Nuclear Power Plant (NPP) stays near the bank of the Pripyat River at 30 km from its outflow to the Kiev Reservoir of the Dnieper River (Fig.1). The floodplain territory near Chernobyl NPP and surrounding watersheds are heavily contaminated by ^{137}Cs and ^{90}Sr. The spots of ^{137}Cs are in the upper Dnieper watershed in Russian and Belorussian territory and on the entire Pripyat watershed. The surface contamination leads to the permanent influx of ^{137}Cs and ^{90}Sr into the Kiev Reservoir (the capacity is 3.7 cub.km) that is an upper one in the cascade of six Dnieper reservoirs. The Dnieper River transports radionuclides through this cascade at 900 km to the Black sea. The aquatic pathway is considered in post-accidental period as a main one for the radionuclide dispersion from the Chernobyl zone after the early accidental phase [1,2].

The main objective of water remedial activities that have been implemented since 1986 was to prevent significant secondary contamination of the surface water bodies that are hydraulically linked with the areas of heavy fallout and to mitigate expansion of expected ground water contamination. The choice and design of the countermeasures was supported by the modelling of radionuclide transport in the aquatic system and by the field and laboratory studies of these processes [3-6]. The presentation summarizes an experience of the research and developments to support the water protection countermeasures in the Chernobyl area.

DISCUSSION

Field Studies

During the initial accidental release period after April 26, 1986, the surface water bodies around the Chernobyl NPP (Fig.1) were directly contaminated by atmospheric fallout. Surface water contamination was characterized with a high level of radiation over a wide spectrum of short-lived radionuclides. The total beta-contamination of the open water bodies near the

Chernobyl NPP reached approximately 10^{-6} Ci/L (1Ci=37 GBq, 1Liter= 10^{-3} m^3) . The beta-activity of the Pripyat River water downflow Chernobyl NPP in early May 1986 exceeded 10^{-8} Ci/L. The range of radioactivity in Dnieper River water near the main water intake of Kiev City (at 130 km downflow from the Chernobyl NPP) was from 10^{-10} to 10^{-8} Ci/L in May and June 1986. The largest contribution to water contamination in first months after the acident was from ^{131}I. Since 1987, the radionuclides ^{137}Cs and ^{90}Sr had the largest influence on the water contamination. The special regular water sampling program was organised in the Chernobyl Exclusion Zone to control the radionuclide dispersion from this territory via the Pripyat River. The detailed studies of the watershed pollution demonstrates that the most contaminated areas that could be flooded is the part of left-bank floodplain of the Pripyat River upstream the Chernobyl NPP (Fig.1). It was estimated the deposition of at 8000 Ci of ^{90}Sr on this rather small territory at 10 km along the river channel. The parameters of the radionuclide washing out from the floodplain soil was studied within the special laboratory experiments. The monitoring program for studies of the radionuclide concentrations in the water, suspended sediments and bottom deposition was implemented since 1986 for the whole Dnieper basin.

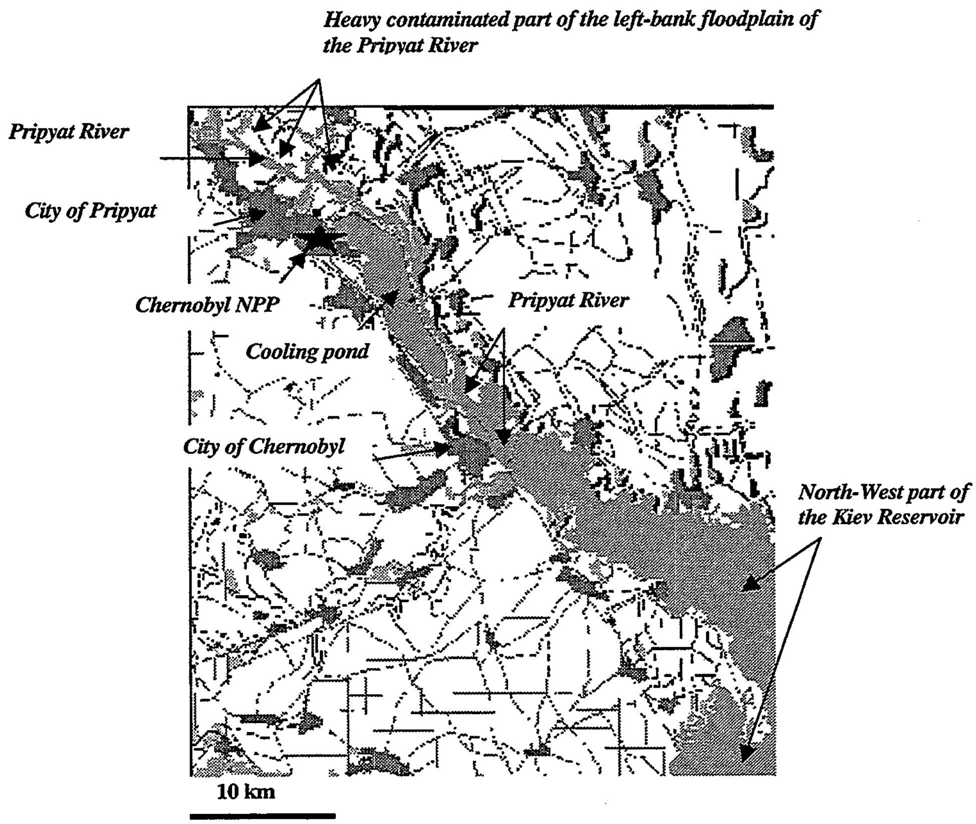

Figure 1. Scheme of water bodies surrounding Chernobyl Nuclear Power Plant

The main feature of the radionuclide release from the contaminated watersheds to the Kiev reservoir within 12 years after the accident is the significant diminishing of the ^{137}Cs influx to the reservoir, however, ^{90}Sr washing out to river net continued to be on a rather high level. Since 1992, the rate of ^{90}Sr release to Pripyat River was reduced due to the water protection measures (dike construction) on the floodplain near Chernobyl NPP. Annual total influx of ^{137}Cs and ^{90}Sr into the Kiev Reservoir from Pripyat River and Upper Dnieper changes after the accident as follows: 2620 Ci and 1030 Ci respectively in 1986; 365 Ci and 320 Ci in 1989; 130 Ci and 510 Ci in 1991, 45 Ci and 90 Ci in 1997. The difference in the behavior of the radionuclides appears also in the phenomenon that a large part of ^{137}Cs, as well as some other radionuclides, are associated in water with suspended particles. The experimental studies of the Chernobyl radionuclide fate in water bodies were an important part of the background for the water protection activities in the Chernobyl area.

Models

The simulation of the efficiency of countermeasures was done based on a set of models, describing radionuclide transport in rivers and reservoirs in different scales of resolution [3-5]. Wide range of scales is achieved by combining the box model WATOX, describing radionuclide concentration averaged over compartments (whole reservoir or its large part), one-dimensional river channel model RIVTOX (the variables are averaged over the channel cross-section), two-dimensional lateral-longitudinal model COASTOX (the variables are averaged over the flow depth), two-dimensional vertical model VERTOX (the variables are averaged over the flow width), THREETOX- 3-D hydrodynamics and radionuclide transport model. Each model at its specific level of resolution simulates the flow dynamics, suspended sediment transport, radionuclide transport in dilute and on suspended sediments, radionuclides fate in the bottom deposition. The models developed by Y.Onishi in the Pacific Northwest National Laboratories also were used for the simulations in the area [6]

The predictions of $_{137}Cs$ and $_{90}Sr$ concentration in the Dnieper reservoirs during spring flood were prepared in February-March each year since the accident. The predictions also were developed during the high rainstorm flood and other emergency events at Pripyat River watershed. The seasonal and short term predictions are in reasonable agreement with the measured data for the spring floods, rainstorm floods, consequences of the radionuclide releases from the Pripyat floodplain as results of the ice jams in winter 1991 and 1993 [4,5].

The models of radionuclide transport that were tuned and validated on the basis of the monitoring data gave a tool to simulate the efficiency of the designed water protection measures to diminish the radionuclide concentration in the water. This data was used to simulate deminishing of the collective dose as the result of the countermeasure implementation [1,2].

Water Protection Measures

The specifics of radionuclide transport defines the strategies of aquatic countermeasures. A lot of remedial strategies that have been proposed and implemented in the Chernobyl area and may be classified as follows:

A. Measures in drainage area
   a) Removal of contaminated soil;
   b) Alternations in the catchment area to minimize the run-off of radionuclides from land to water, e.g. , planting of trees, digging of channels/ditches, or adding the chemicals to bind the radioisotopes (e.g., lime, potash or dolomite);
   c) Prevention of flooding most contaminated territories attached to a water body (e.g., floodplain dikes);
   d) Construction to prevent radionuclide transport to surface water bodies by ground water flow (e.g. contra-seepage wall in soil).

B. Measures in water bodies
   a) Constructions to increase the sedimentation of contaminated suspended materials in rivers (e.g., a quarry - a bottom trap for contaminated sediments, dams, ditches and spurs).
   b) Construction to separate most contaminated parts of the water bodies from a main stream (e.g., dikes and dams dividing the water bodies);
   c) Dredging of contaminated deposits;
   d) Change in mode of the Dnieper reservoir management to optimize it on the minimum of the radionuclide concentration.
   e) Change in drinking water intakes (e.g., recommendation to switch on other water supply sources).

The computerized system was used to evaluate the efficiency of the countermeasures proposed to diminish the radionuclide concentrations in the Dnieper reservoirs. The demonstration of low efficiency of the large scale hydraulics projects for Kiev Reservoir, e.g., the construction of the new dam through the reservoir and submerged dike near Hydropower Plant, was background to stop these expensive projects. It was simulated and demonstrated low efficiency of the bottom traps designed for settling down of contaminated sediments in the Pripyat River channel.

CONCLUSION

The modelling results demonstrated the efficiency of the construction of the special dike around the contaminated floodplain area on the left bank of the Pripyat river at the Chernobyl [3,4] that was used as the background of the decision to construct the dam. The modeling predictions were confirmed by the data measured during the flooding of this area due to the ice jam in the Pripyat River in January 1991 [5,6]. The dike was constructed in 1992 and it is estimated now as the most efficient water protection measure in the Chernobyl zone. This dike prevented the remobilization of radionuclides, especially $_{90}Sr$ from the highly contaminated floodplain into the river, thus lowering the collective dose by 600 to 700 menSv. The construction of a dike along the right riverbank could further reduce the collective dose by 300 to 400 menSv.

Further action in the Chernobyl exclusive zone should be focused on the construction of the right riverbank dike upstream the NPP and on the decontamination or rehabilitation of the bottom sediment of the cooling pond after planned shutdown the Chernobyl NPP.

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Dose Refinement: ARAC's Role

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INTRODUCTION

The Atmospheric Release Advisory Capability (ARAC), located at the Lawrence Livermore National Laboratory, since the late 1970's has been involved in assessing consequences from nuclear and other hazardous material releases into the atmosphere. ARAC's primary role has been emergency response. However, after the emergency phase, there is still a significant role for dispersion modeling. This work usually involves refining the source term and, hence, the dose to the populations affected as additional information becomes available in the form of source term estimates—release rates, mix of material, and release geometry—and any measurements from passage of the plume and deposition on the ground.

Many of the ARAC responses have been documented elsewhere.[1] Some of the more notable radiological releases that ARAC has participated in the post-emergency phase have been the 1979 Three Mile Island nuclear power plant (NPP) accident outside Harrisburg, PA, the 1986 Chernobyl NPP accident in the Ukraine, and the 1996 Japan Tokai nuclear processing plant explosion. ARAC has also done post-emergency phase analyses for the 1978 Russian satellite COSMOS 954 reentry and subsequent partial burn up of its on board nuclear reactor depositing radioactive materials on the ground in Canada, the 1986 uranium hexafluoride spill in Gore, OK, the 1993 Russian Tomsk-7 nuclear waste tank explosion, and lesser releases of mostly tritium. In addition, ARAC has performed a key role in the contingency planning for possible accidental releases during the launch of spacecraft with radioisotope thermoelectric generators (RTGs) on board (i.e. Galileo, Ulysses, Mars-Pathfinder, and Cassini), and routinely exercises with the Federal Radiological Monitoring and Assessment Center (FRMAC) in preparation for offsite consequences of radiological releases from NPPs and nuclear weapon accidents or incidents.

Several accident post-emergency phase assessments are discussed in this paper in order to illustrate ARAC's role in dose refinement. A brief description of the tools (the models) then and now, is presented followed by a description of how these models have been applied during the post-emergency phase to various events.

DISCUSSION

The ARAC Models

The ARAC wind flow model is a combination of two codes: MEDIC[2] interpolates meteorological observed winds to three-dimensional girded space; MATHEW[2] mass adjusts the winds in the presence of terrain using atmospheric stability to affect this adjustment so that mass is conserved in the three-dimensional space. The dispersion model ADPIC[3] is a Lagrangian particle model with random displacement diffusion and has the flexibility for specifying various source characteristics with full decay and ingrowth of daughter products during transport and after ground deposition. In addition to these models, ARAC has a computer code that matches radionuclide air and ground deposition measurements in time and space with the model-generated air concentrations and ground deposition concentrations.

Over the past four years, ARAC has been developing new models to replace the older ones. ADAPT[4] is the interpolation and mass adjustment flow model and LODI[5] is the dispersion model. Since these models are under development, the present versions have only limited capability and are not yet part of the ARAC production environment. Major improvements in the new models are continuous terrain representation rather than the block terrain of the older models, and variable and graded resolution in both the horizontal and vertical dimensions. Other attributes in these models will be horizontally varying turbulence and boundary layer depths.

Post-accident Responses

A FRMAC would most likely be formed for offsite consequences from a significant radiological release within or impacting the US and its territories. The FRMAC works with the State, local government and tribal authorities to determine the consequences and to mitigate the consequences to the extent possible from a radiological release to the environment. ARAC works with the FRMAC both from the ARAC Center in Livermore and by deploying staff members to the field.

Based on both a real need and considerable experience, the ARAC program has developed a methodology to derive the amount of radioactivity released by a matching procedure applied to model calculations and representative measurements. This is an iterative process of improving the source term estimate as more measurements are taken. The resulting refinement to the source term allows the dispersion model to better define the deposition boundaries and greatly adds to defining the airborne plume concentrations, which most likely will not be measured well during most accidental releases particularly during the earliest phase. ARAC may then answer with greater confidence who was exposed and at what dose. As a part of FRMAC exercises, ARAC routinely uses simulated measurements of ground deposition to re-scale the source term, and hence the computer generated air concentrations and ground deposition concentrations.

Chernobyl Accident

During the first few weeks following the 1986 Chernobyl accident, ARAC derived the first estimates of the total inventory released into the atmosphere using measurements that were then obtained from various European countries.[6] Calculations of projected air movement and radioactive air concentrations were matched with measurements from up to 20 sites throughout the Northern Hemisphere. Through an iterative process involving adjusting the source term geometry and release rates, ARAC was able to refine estimates of how the radioactivity released varied with time and how the radioactivity was initially distributed in the air. ARAC is presently working with Russian scientists (SPA Typhoon) to acquire additional meteorological data in the region surrounding the reactor in order to calculate a refined reconstruction of the dispersion. The refined plume may lead to improved dose reconstruction in the region. Since the Chernobyl accident, the available meteorological data sets, and improved ARAC models and tools permit better iterative plume and source term reconstructions.

General Chemical Accident

For several months after a 1993 major rail tank car spill of sulfur trioxide (oleum) in Richmond, California, ARAC participated in an intensive effort to assess the source release rates and total exposure to the population from the released sulfuric acid cloud.[7] Even though this event was not a radiological release, it did provide additional insight for plume reconstruction. Using just the standard reporting meteorological station data that were available through the World Meteorological Organization's global distribution system, the ARAC initial calculated plume did not follow the path that staff meteorologists believed it should have. The staff meteorologists had knowledge of non-reporting meteorological tower data in the vicinity of the plume. After rerunning the ARAC models with this additional data, the plume was judged to be in the right place. Later runs of a prognostic mesoscale forecast model[8] confirmed this flow pattern.

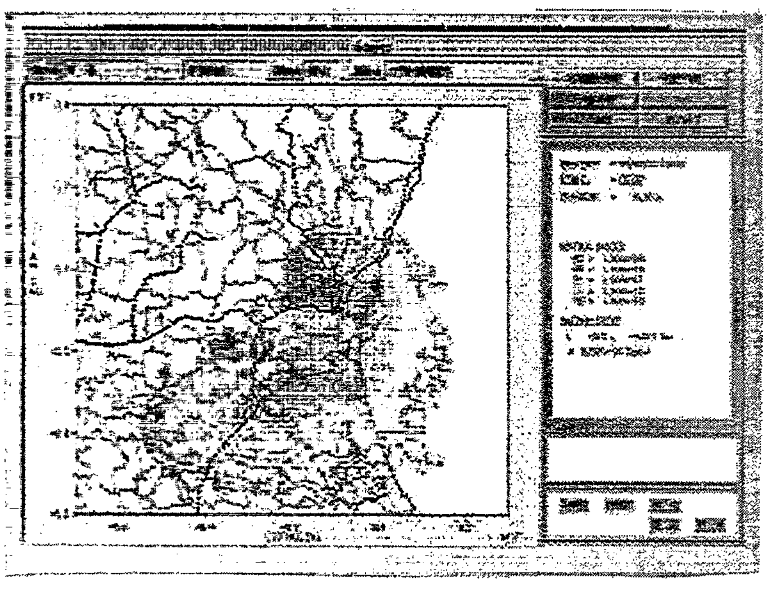
Over the next several months, the quantity of material released from the rail tank car was determined along with estimates of the release rates over a four-hour duration. ARAC and a private firm both recalculated the plume based on this new source term. Apart from one sampler that measured concentrations in the passing plume, the only source of information on exposure to the population from the cloud was the plume calculation. Litigation proceeded using plume calculations. This event serves as an example for what could occur for an unmonitored remote radiological release, particularly where the release is composed of mostly non-depositing noble gases and short lived radioactive iodines.

Tokai Accident

In March of 1997, PNC-Tokai corporation of Japan, located on the JAERI facility, experienced a fire and subsequent explosion in a fuels reprocessing facility. ARAC and JAERI were (and still are) collaborating on the development and evaluation of a nuclear accident assessment information Internet-based communication protocol, incorporating televideo, whiteboards and web pages.

During the Tokai accident and shortly thereafter, ARAC and JAERI were able to view each system's model assessment plots, discuss differences, locate measurements sites and values, discuss differences due to differences/deficiencies in meteorological data and then recompare and discuss results when comparable data were used in both systems. The dialogue with whiteboard interaction proved highly effective in communicating mutual understanding as well as unique insights. Shortly after assuring that both had the same meteorological data, JAERI received preliminary radiological measurement data and rapidly, using the graphical web pages on whiteboard, identified the locations and preliminary readings at three locations.

The shortfall of not having full live video was evident but not-detrimental. The results accomplished over a two-week period in a cooperative response to an actual event would have been impossible to achieve using conventional exchanges via phone, e-mail and telefax. The combination of the web pages and the teleconferences yielded a collaborative effort which could only have been otherwise achieved by actual face-to-face meetings. In fact, this prototype system even provides an advantage over the face-to-face exchange, as each participant is acting from their own institutional environments, where all local data and even colleagues are readily accessible, whereas travelers must reduce their tools and information to fit in a suitcase.



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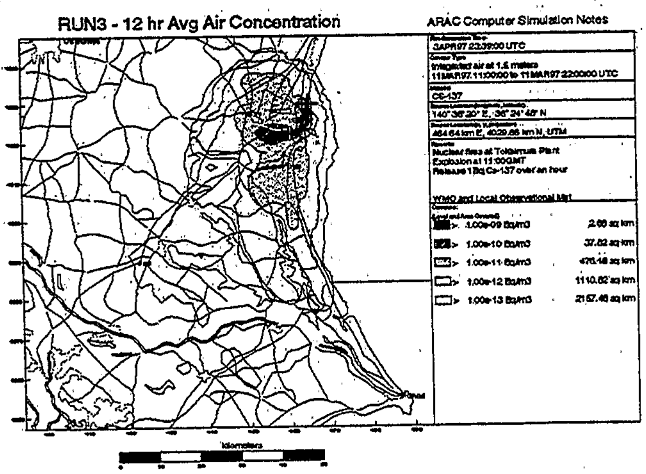

ARAC

Since the ARAC and SPEEDI transport and dispersion models provided similar results including estimates of the release magnitude within ±15% after using the same input data, both centers judged the interactive refinement process to be useful for the estimation of source term coupling with monitoring.

This work fits within the context of the Global Emergency Management Information Network Infrastructure (GEMINI) and is an example of the benefits of exploiting cyber technology for timely and enhanced accident assessment. We intend to offer this as a start toward an international "mutual aid" structure.

CONCLUSION

Examples of post-emergency phase assessments by ARAC for three real hazardous releases to the atmosphere were presented. The 20 years or more of ARAC experience in training for and responding to emergency releases of hazardous materials into the atmosphere has demonstrated the need for post-emergency assessment transport and dispersion model calculations for most major events until the exposure to the population has been fully determined. This is an iterative refinement process as source term estimates and air and surface concentrations measurements of the released material become available.

ACKNOWLEDGMENTS

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Post-Accident Inhalation Exposure And Experience with Plutonium

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INTRODUCTION

This paper addresses the issue of inhalation exposure immediately afterward and for a long time following a nuclear accident. For the cases where either a nuclear weapon burns or explodes prior to nuclear fission, or at locations close to a nuclear reactor accident containing fission products, a major concern is the inhalation of aerosolized plutonium (Pu) particles producing alpha-radiation. We have conducted field studies of Pu-contaminated real and simulated accident sites at Bikini, Johnston Atoll, Tonopah (Nevada), Palomares (Spain), Chernobyl, and Maralinga (Australia).

DISCUSSION

It has long been recognized that the most significant pathway for human exposure to Pu is the inhalation of aerosolized-Pu attached to soil, and methods have been developed to estimate human exposure by this pathway.[1] From the perspective of health risk assessment there are two physical processes that should be predicted: the first-order process that produces the "respirable" Pu-concentration in air, and the second-order process that causes a Pu flux into the air (rate of Pu-aerosol emissions) for subsequent redistribution. The term "respirable" is defined here as particles having less than 10 μm aerodynamic diameter. Resuspended Pu particles normally have a peak in the size-distribution at 2 to 5 μm, and are approximately log-normally distributed with a geometric standard deviation from 3 to 5. The Pu is found as plutonium oxide aggregated in soil particles.

Observations of normalized radionuclide concentrations in air following an accident show a remarkable agreement, since at all sites the concentrations decrease by 5 orders of magnitude in the first 20 to 30 days. This should guide decisions on reentry into an accident site. Our hypothesis is that (1) this occurs because fallout particles initially adhere to any available surface, but are transferred to sites of greater and greater adhesion with time and (2) the process is much more rapid than migration into the soil. But eventually, fallout radionuclides find their way to the soil surface. Our time dependent empirical model is too conservative and overpredicts Pu-concentrations in air[1]. There are several time-dependent models in current literature, and none seem to be completely accurate even though they are physically-based. More work needs to be done in this area.

A simple model for predicting the Pu concentration in air is the *resuspension factor* approach. In this concept, the Pu concentration in air is integrated over a period of at least several days to eliminate the variations due to wind and weather conditions, and these Pu concentrations are normalized by dividing the observed concentrations in air (C, Bq/m3) by the local soil-Pu inventory from deposition (D, Bq/m2). This method has proven useful around the world because once S_f is estimated, then the concentration can be predicted from the deposition, D, that is, $C = S_f D$. The resuspension factor values, S_f, tend to a long-term limit between 10^{-10} m^{-1} and 10^{-9} m^{-1}.

Enhancement Factor and Effects of Disturbance

This "steady-state" can be interrupted, however, by disturbances such as construction, traffic, etc. Another model, the *mass loading* approach, tries to deal with this problem by predicting the Pu-aerosol activity (A, Bq/g) and the total suspended particulate mass loading (M, g/m^3). The activity, A, would be predicted from an enhancement factor, E_f, and the average surface soil activity to a depth of 0.05 m,S_o (Bq/g), that is, $A = E_f\ S_o$. In this model, the concentration can then be predicted by the product combination, $C = E_f\ S_o\ M$. Both S_o and M are easily measured. But both E_f and M can be expected to increase during disturbances, and in undisturbed soil, both have seasonal variations. That E_f would increase with disturbance indicates that the Pu bindings with soil aggregates are somewhat fragile. In some cases M is predictable from dust emission factor models for various types of construction and agricultural activity. In studies performed over a wide number of sites, Shinn[2] found that values of E_f were usually less than unity, typically 0.7, for the non-fissioning types of accidents and at large distances from fission events (Bikini, Palomares, Tonopah, Maralinga). For disturbances such as traffic, bulldozer blading, wildfire, and freezing-thawing cycles, Shinn reported that E_f values temporarily increased to between 2.5 and 6.5. In the case of a nuclear fission event at ground level, much of the soil Pu within a kilometer of the "ground zero" is found in small glass beads that are too large to be resuspended. So for nuclear fission accidents, these E_f values were found to be about 0.01 and the resuspension factors, S_f, decrease to a lower long-term limit between 10^{-13} m^{-1} and 10^{-11} m^{-1}.

Particle Emission Rates

The second-order problem, predicting the Pu-aerosol emission rates, is determined by solving the flux equation $F = K\ (dC/dz)$, where K is conventionally measured as the turbulent diffusivity for sensible heat, and the vertical gradient dC/dz is measured from vertically-spaced air samplers. We simplified this even further by the approximation $dC/dz = p\ C/z$ where p is the power-law parameter determined as the constant slope from the log C versus log z measurements.[1]

The parameter p is a measure of the surface conditions and for suspended particulate mass loading has typical values of -0.2 with a range between -0.05 and -0.6. The negative sign indicates that suspended mass is decreasing with height in the air above the soil. The values of p vary through the season and depend upon the degree of surface cover. The turbulent diffusivity K can be easily measured and varies directly with wind speed and height above ground. To determine the resuspension rate, R, the flux F (Bq/m^2 sec) is divided by the local soil

Pu-inventory from deposition (D, Bq/m^2), that is R = F/D. This gives the fraction of the contamination being resuspended per second. Typical values[3] for R are 10^{-11} s^{-1} to 10^{-12} s^{-1}. But in some cases soils have a higher R, i.e. more erodible, sandy soil or disturbed soils that have R greater than 3 x 10^{-11} s^{-1}; then local redistribution of Pu is a problem[4].

Considerations in Environmental Cleanup

Environmental cleanup decisions for Pu should be based on the potential risk to human health. Since plutonium oxide is insoluble, doesn't transfer through the intestine, is not transferred into food chains, and does not produce a significant external dose (barely detectable gamma radiation), the decisions will be largely based on inhalation exposure estimates. It is important to average soil measurements over an area, because at typical inhalation heights, the trajectories of particles come from an upwind range characterized[5] as 90% within a distance of 150 m.

A first consideration is the removal of fragments and radioactive debris. This requires locating and removing fragments that are visible, and a vacuum cleaner method worked well with a 60% removal efficiency for each pass.[4] Locating Pu fragments must be done with a special instrument (high purity germanium crystal) optimized for detecting a weak gamma emission from a daughter radionuclide, ^{241}Am. At Johnston Atoll, a mining technique of sifting soil on a moving belt was used successfully to remove the fragments but did not reduce the activity in the inhalation size range.[6] At Maralinga, residual Pu fragments were mapped after the contaminated surface soil was scraped off, and the fragments were either removed by hand or by vacuum cleaning.

Consideration of potential land use, and cultural practices for habitation has led to different cleanup criteria[7] as appropriate. Experiences in cleanup at Enewetak Atoll, Maralinga, and Tonopah led to slightly different cleanup criteria and averaging areas for integrating sampled soil Pu; Table 1. Cleanup criteria for Pu in these cases were between 1.5 and 15 Bq/g (40 to 400 pCi/g). For comparison purposes, the calculated Pu-concentrations in air using the upper limit steady state resuspension factor of 10^{-9} m^{-1} could be estimated from the contamination depth of 0.05 m and a soil bulk density of 1500 Kg m^{-3} to be between 112.5 and 1125 μBq/m.[3]

Table 1. Risk-Based Plutonium Cleanup Criteria for Cleaned Sites.

SITE	POTENTIAL LAND USE	CLEANUP CRITERIA $^{239,240}Pu$
Enewetak Atoll	residential island agricultural island food gathering	1.5 Bq/g over 0.25 Ha 3.0 Bq/g over 0.5 Ha 6.0 Bq/g over 0.5 Ha
Maralinga, Australia	hunting and gathering	9-15 Bq/g (0.7-2.2 Bq/g 241Am)
Tonopah, Nevada	cattle grazing	7.4 Bq/g over 1 Ha

CONCLUSION

Post-accident inhalation exposure is an important determinant entering decisions about re-entry and possible risk management schemes, because of the alpha contamination from Pu. Our experience in field studies at Pu-contaminated sites provides some insights about risk estimation and risk management. Since Pu-concentrations decrease by 5 orders of magnitude in the first 20-30 days, it would be advisable to postpone re-entry until after that time. Furthermore, because of the importance of inhalation exposure and the possible local effects on the enhancement factor (ratio of aerosol activity, Bq/g, to surface soil activity, Bq/g) it would be advisable to monitor the air concentration and the total suspended particulate mass loading and to predict future resuspension factors from these observations rather than to estimate them from empirical means. We expect nevertheless that when steady state is reached, the resuspension factor will have a long-term limit between 10^{-10} m^{-1} and 10^{-9} m^{-1}. Typical risk-based cleanup criteria will be between 1.5 and 15 Bq/g in soil and this will result in Pu-concentrations in air less than the range 112.5 to 1125 $\mu Bq/m^3$. The soils will have a resuspension rate of 10^{-11} s^{-1} to 10^{-12} s^{-1} unless they are highly erodible and then redistribution of Pu is a problem if the rate exceeds 3 x 10^{-11} s^{-1}.

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Post-Accident Cleanup Analysis for Transportation of Radioactive Materials*

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INTRODUCTION

Approximately 5 to 10 million packages of radioactive material and wastes are shipped annually in the United States.[1] Most of these shipments consist of small quantities of medical and research isotopes. However, larger quantities of radioactive wastes are shipped by the U.S. Department of Energy (DOE) via commercial truck or rail service. The number of shipments of radioactive waste is expected to increase over the next several years as efforts to dispose of waste stored and generated at DOE sites progress.[2] The potential for a severe accident involving these anticipated waste shipments is small, but not insignificant. The probability of a severe accident resulting in the largest credible release of material has been estimated to range from approximately 0.01 to 0.1 over the 20-year time period considered for permanent disposal of each of the low-level, transuranic, and high-level radioactive waste types (LLW, TRUW, and HLW).[2] The potential radiological consequences of the most severe credible accident involving each of these waste types could adversely affect the community in which it occurred. These consequences are considered below. Accidents involving spent nuclear fuel (SNF) shipments are of concern to the public and are also considered.

Exposure of individuals to radionuclides can occur through many exposure pathways if an accident results in a radioactive release to the environment. The Federal Radiological Emergency Response Plan establishes a coordinated response by Federal agencies when requested by State, tribal, or local government officials during a peacetime radiological emergency.[1] In case of such an emergency, DOE has primary responsibility for providing assistance unless the radioactive source is unknown, unidentified, or from a foreign country, then the U.S. Environmental Protection Agency (EPA) becomes the primary coordinating Federal agency. The EPA has issued a set of protective action guides[3] (PAGs) to aid public officials in responding to an accident involving radioactive materials. Under emergency conditions, maximum individual dose limits are suggested when practicable. Limits are set for the early phase of an accident, lasting up to four days from the time of the initial radioactive release, and for the intermediate phase of an accident, taken to represent up to one year after the accident.

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In this paper, a pathway analysis code, the RISKIND computer program,[4] has been used as a screening tool to help develop an example action plan for both the early and intermediate phases of an accident involving the release of radioactive materials. RISKIND was developed for the analysis of radiological consequences and health risks to individuals and the collective population from exposures associated with the transport of SNF or other radioactive materials. RISKIND was developed by Argonne National Laboratory under the support of the DOE Office of Civilian Radioactive Waste Management.

Projection of individual doses at the start of the early phase following an accident is difficult because quantitative data on contamination levels in the vicinity of a transportation accident are not immediately available to response officials. However, RISKIND can be used to estimate potential doses to members of the public in specific locations downwind of the accident. The following discussions illustrate the application of RISKIND to the most severe, credible transportation accidents involving the different radioactive waste types.

DISCUSSION

Transportation Accidents

The primary regulatory approach used to ensure safety during transport of radioactive materials is to specify standards for the proper packaging of such materials. Primary regulatory authority is provided by the U.S. Department of Transportation (DOT), as set forth in 49 CFR Part 173 ("Shippers — General Requirements for Shipments and Packaging"). Packaging for transporting radioactive materials must be designed, constructed, and maintained to ensure that it will contain and shield the contents during normal transportation. Type A packaging provides such protection for less radioactive material, such as low-level waste (LLW). Type B packaging is required for more highly radioactive material, such as high-level waste (HLW), transuranic waste (TRUW), and SNF. Type B packaging is designed to contain and shield its contents in all but the most severe accidents.

In general, accident severity is characterized by the potential release fraction of the shipment contents. That is, for the same type of packaging, more severe events result in a larger quantity of material released.[5,6] The more severe cases, however, are associated with lower probabilities of occurrence. In its recent programmatic environmental impact statements, DOE has evaluated various options for managing its radioactive wastes and SNF. Because of the large number of DOE shipments and total estimated mileage, transportation accidents leading to the highest potential releases have been estimated to have overall probabilities that range from 1 in 10 to 1 in 100 for all waste types (i.e., HLW, LLW, and TRUW). Possible SNF accidents within this probability range are not the most severe but could result in a potential release. In this study, only three waste types are included (and the cases are so designated): LLW, TRUW, and SNF. No analysis is performed for HLW because of the low release in its vitrified form. Because of the large variability of accident release fractions, the study also includes a very improbable event, a second SNF case involving the highest potential release. Such accidents have a probability of about 3 in 100,000 (case designated as SNF1).

Early Phase

Doses to individuals downwind during the early phase of an accident are primarily from inhalation during the passing of the contaminated plume. In the case of a transportation accident, protective actions such as sheltering or evacuation to mitigate exposure may not be feasible in the near vicinity of the accident because there may be only a matter of minutes or less before the plume arrives. Figure 1 shows the relative time-integrated ground-level air concentrations within the first 1 km downwind of an accident as determined by RISKIND. The results are based on a ground-level release under neutral weather conditions. It can be seen that the ground-level air concentrations are highest near the accident for this ground-level release. Working downwind from the area with the highest concentration, every second isopleth in Figure 1 represents a factor of 10 decrease in concentration. In an accident involving fire, which can be modeled with RISKIND, the highest concentrations would be at the downwind location where the buoyant plume descends back to the ground.

If projected doses are expected to be near the PAG values, protective actions should be taken to mitigate exposure, providing the risk involved in implementing the protective actions is not comparable to or greater than the risk posed by the accidental release itself. Protective actions include such measures as sheltering and evacuation in the early phase following an accident if the projected dose is expected to exceed 1 rem. As estimated by using RISKIND, individual doses could reach 6.6, 32, 1.9, or 2.1 rem from the LLW, TRUW, SNF, and SNF1 accidents, respectively. If the release occurs over a short period (seconds), there may not be time for protective actions. However, if the release occurs over a longer period (minutes or hours), such as in a transportation accident involving a fire, there might be time to implement sheltering or evacuation to mitigate dose.

RISKIND can be used to estimate the area that might require protective actions in the early phase of an accident. Figure 2 shows the total area near the accident in which RISKIND projects the 1-rem PAG to be exceeded for each waste type accident. Although the accident conditions used in the RISKIND calculations were the same for each waste type (except for the SNF1 accident, which involves fire), areas of different sizes are affected because of the different radioactive isotope mixes typically found in each waste type.

Intermediate Phase

For the intermediate phase of an accident, RISKIND can estimate both the need for protective actions and the amount of cleanup necessary to achieve proposed dose limits. Intermediate-phase exposures occur through inhalation of resuspended contamination and external exposure to contaminated surfaces and resuspended contamination. RISKIND estimates contaminated ground concentration isopleths similar to those calculated for contaminant air concentrations.

These contours match those for air concentrations under most conditions. The exposure time and dose limit can be input independently. The doses estimated for this illustration take into account the average daily indoor/outdoor activity patterns of people and the shielding normally afforded by different types of structures.

The PAGs suggest relocation as a protective action if the first-year dose to a single individual would exceed 2 rem. Figure 2 shows the amount of contaminated area where this PAG is projected by RISKIND to be exceeded. Without mitigation, a person might be expected to receive a dose in the first year as high as 70, 13, 7, and 3.5 rem from accidents involving LLW, TRUW, SNF, and SNF1, respectively.

For doses expected to be less than 2 rem, the PAGs suggest that surface contamination be reduced to levels as low as reasonably achievable and recommend initial efforts to be concentrated in areas where the projected doses are expected to exceed 0.5 rem in the first year. Again, Figure 2 displays the amount of area in each case where this PAG would be exceeded.

Longer-Term Objectives

The stated objective of the PAGs regarding deposited radioactivity for the intermediate phase is that doses to an individual in any single year after the first year not exceed 0.5 rem and that the cumulative dose over 50 years (including the first and second years) not exceed 5 rem. RISKIND shows (Figure 2) that in the case of the LLW, SNF, and SNF1 accidents, the 50-year 5-rem value is more limiting than the first-year guide of 2 rem. Without cleanup, an individual might receive up to 416, 13, 71, and 54 rem from a LLW, TRUW, SNF, or SNF1 accident, respectively, over a 50-year period following the accident. (Note that the LLW, TRUW, and SNF1 examples have different limiting PAG values, as shown in Figure 2).

CONCLUSION

RISKIND has been shown to be a useful emergency response planning tool for shipment of radioactive waste and spent nuclear fuel. The code has been used to project individual and population doses for the early and intermediate phases following an accident involving the release of radioactive material. In the process, the decontamination factors for deposited radioactivity to achieve a specific PAG, as input to RISKIND, were provided on an isopleth-by-isopleth basis downwind of the accident. RISKIND can also be used to determine the most restrictive PAG, in large part on the basis of the type of radioactive material released, as demonstrated in the examples provided. However, the quantity of material involved can also be a major factor. For example, severe accidents involving LLW shipped in Type A packaging can have consequences similar to or worse than those from TRUW, SNF, and HLW accidents involving material shipped in Type B packaging, because more radioactive material is released.

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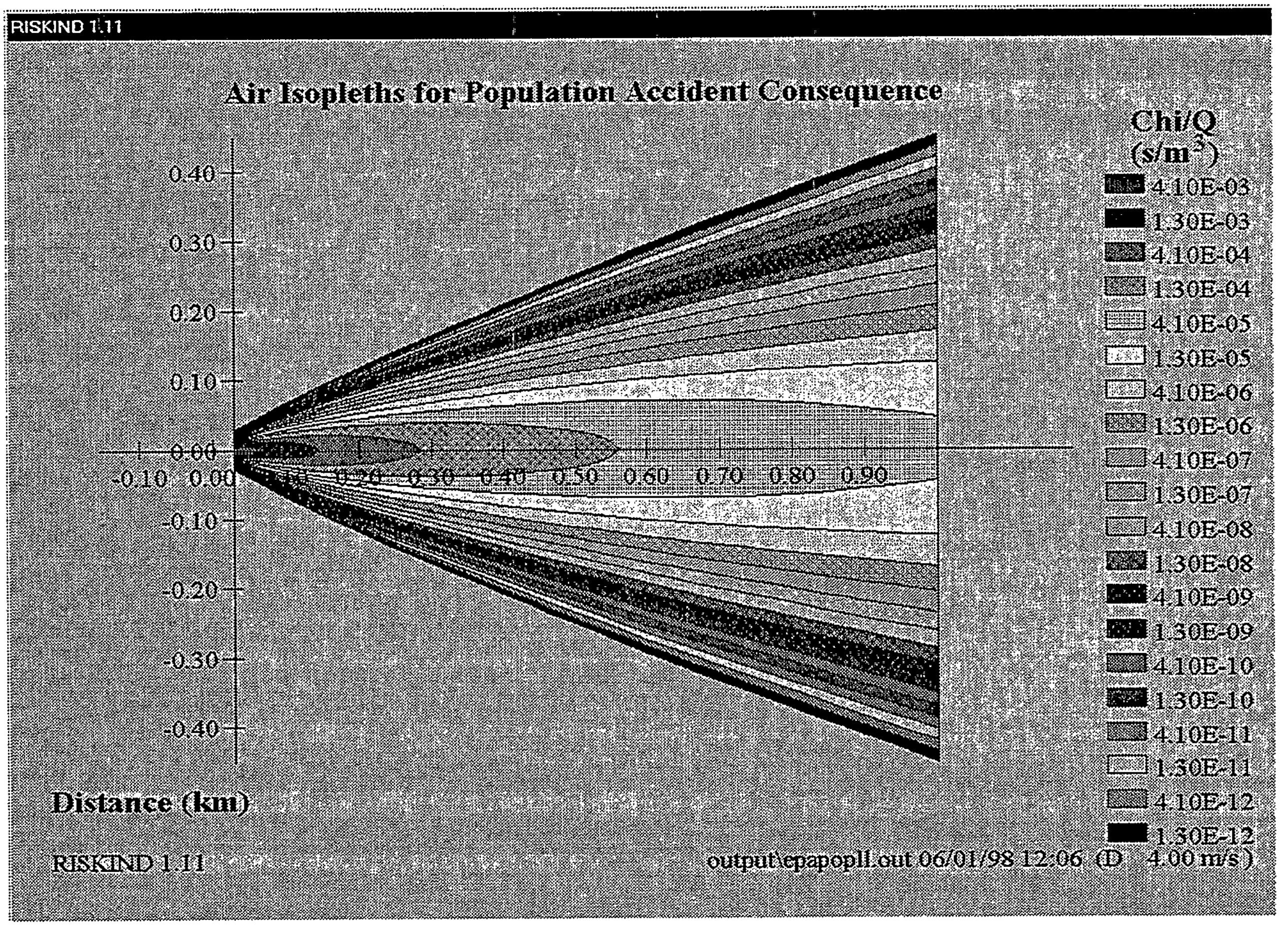

Figure 1. Isopleths of time-integrated air concentrations following an accidental release of radioactive material under neutral stability weather conditions (ground-level release, Pasquill stability class D, 4 m/s windspeed).

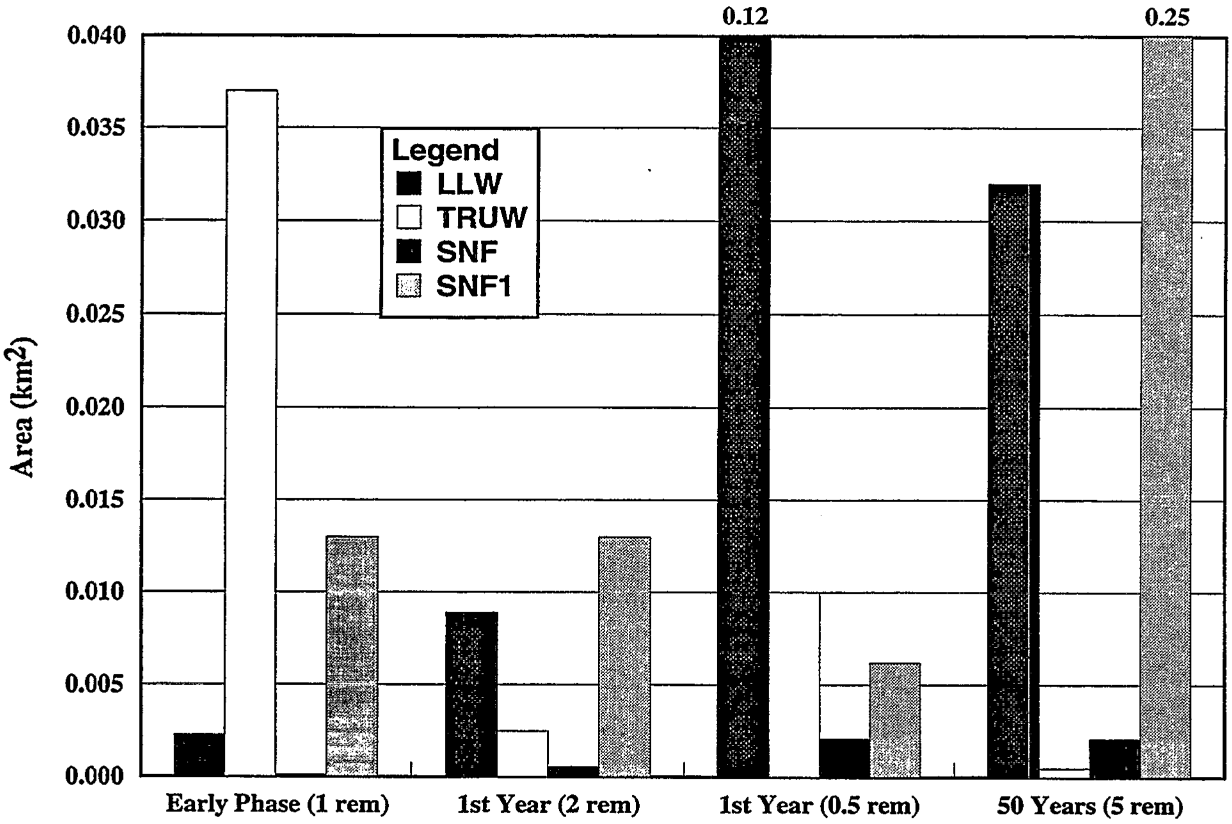

Figure 2. Amount of area affected by early-phase and intermediate-phase PAG values

Using Chernobyl Experience to Develop Methods and Procedures of Post Accident Radiomonitoring

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INTRODUCTION

The Three Mile Island, Goiania and Chernobyl accidents have resulted in the re-examination of many emergency planning principles and practices.

A nuclear, or radiation emergency response planning is based on expected avertible doses for short (4 hours, 2 days, 1 week) and long (50 or 70 years) periods of time. Therefore, in emergency planning one has to differentiate the following three periods in evaluating accident exposure: the acute (at and 4-6 hours after a radioactive discharge), the short-term (duration of the acute period plus 48 hours) and the long-term (50-70 years).

The primary task of radiation protection in the acute period is to forecast the area distribution of radionuclide contamination in order to prevent deterministic effects as the effective doses can exceed 1Sv from the moment of release to the following 4-6 hours. The principal protective measures are evacuation, sheltering, and iodine prophylactics. The acute period evaluation is based on the state of the reactor core and that of the area of 3-5 km around the NPP.

The main task of the short-time period evaluation is to forecast territories, where doses could exceed 1 Sv in the following month. The forecast is made on the basis of accident radiomonitoring with a due account of protective measures undertaken.

The long-term evaluation is designed to forecast territories where doses for 50-70 years can exceed permissible levels. The forecast is made on the basis of comprehensive radiomonitoring, soil characteristics, and expected soil-plant transfer coefficients, as well as the economic possibilities to carry out the corresponding countermeasures and the analysis of socio-psychological situation.

To develop a comprehensive integrated system for emergency response, it is necessary to elaborate on the methods and procedures for post-accident radiomonitoring, which would provide countries with uniform techniques and procedures for accident radiation measurement and appropriate dose assessment, and could be integrated as a part of the decision support system.

International study and analysis of consequences of the Chernobyl accident set up a unique basis for using the Chernobyl experience in the areas of environmental radiomonitoring techniques, dose assessment, and decision making. The contaminated area is the largest out-door laboratory for testing developed methods and procedures.

The two stages in emergency response require techniques and procedures for accident radiation measurement and appropriate dose assessment, i.e. the short-term and the long-term periods of assessment. The main components of exposure, which need to be assessed during the short-term period are external and internal exposures from the released radioactive cloud, external exposure from the radioactive fallout, and internal exposure from the contaminated food and water.

DISCUSSION

In an emergency situation the contamination can cover large areas and have unpredictable spot structure due to meteorological conditions and other factors. Since for most nuclear accident scenarios the highest part of the dose is external exposure, the first priority is to have a measurement of the external dose. In this case, the first step of the monitoring should be to use integrated methods, like aerial monitoring, which have high productivity and provide opportunity to have a generic structure of contamination on the large area during a short time. But this survey does not have a sufficient accuracy for ambient dose assessment and requires knowledge of the ground dose rate measurement. This measurement details the contamination structure but does not provide information on composition of the fallouts for evaluation of the avertible dose. Unfortunately, the radionuclides composition in the release and fallout can significantly vary depending on the processes in the reactor core and the mechanism of precipitation. The in-situ gamma-spectrometry is commonly used for measurement of the radionuclides composition. It provides information about radionuclides mixture integrated for an area of about 30-50 sq.m The main problems of the accident in-situ gamma-spectrometry are high dose and complicated spectrum. Currently existing devices and techniques are completely acceptable in real reactor accident situations.

The information about radionuclides composition can be made more precise by soil sampling. The local soil contamination varies significantly (up to 3-5 times within a few sq.meters) due to a complex mechanism of deposition. Fig. 1 presents an example of frequency distribution (FD) of the activity soil samples collected within 5 m radius. This FD in theory follows a log normal distribution. The geometric mean of activities of as minimum as 10 samples collected within a few square meters should be used as an estimator of the real density of the contamination.[1]

For internal exposure assessment, samples of air, water, vegetables, milk, and other ingestion stuff are collected. The main goal of such activity is to assess collective and individual doses for the public. Thus, the air samples should be collected in the settlements near the accident source immediately after the early warning signal about the accident occurs.

The water, vegetables, milk, and other ingestion stuff samples should be collected at the same time as the soil samples. The activity of these samples also can vary significantly, and for assessment of the real contamination one should use a geometric mean of activities on a minimum of 5 samples. It is also necessary to take into account that for the emergency personal collection of the samples is the most difficult and expensive step of the monitoring. Thus, you should have a guarantee that collected amounts of samples are sufficient for real radiological assessment.

The Chernobyl experience has demonstrated that in case of a nuclear reactor accident only two radionuclides ^{137}Cs and ^{90}Sr have the highest contribution to the long-term exposure. These radionuclides have half-lives (~ 30 years) close to the human life, high ratio in the reactor core inventory and release, as well as similar chemical characteristics to elements as potassium (for Cs) and calcium (for Sr) with such importance for human beings.

More than 99% of the Chernobyl accident collective effective dose (CED) is due to ^{137}Cs (90-95%) and ^{90}Sr (0.5±4%). The internal exposure produced about 70% of the total CED. The main part of this dose (90-95%) was produced by ^{137}Cs. The food stuff contributed the most (97-98%) to the internal dose. In Ukraine 70-90% of the 137Cs intake is due to milk. The contamination of milk depends on radionuclide migration within a chain soil-plant-milk.[2]

One of the main parameters used for radiological status forecast is the root-layer clearance half-time. The ^{137}Cs effective clearance half-time for the 0-10 cm soil layer, taking into account radioactive decay, typically varies from 10 to 25 years. The soil layer clearance was slower in the upper layer (24-27 years for the 0-5 cm layer) than in the deeper layer (10-17 years). Typically, the processes of soil clearance of ^{90}Sr are up to 3 times faster than those of ^{137}Cs. The clearance half-time for ^{90}Sr is typically 7 to 12 years. Three years after the accident, a stabilisation of the transfer factor between soil and plant has been observed. The variability in observed soil-plant transfer is due to the varying chemical and physical properties of different soil types.

The level of contamination of agricultural products depends on several factors, including the level of soil contamination, the soil properties, and the biological characteristics of the plants. The transfer coefficients of radionuclides into the plants growing on soddy-podzolic loamy soils are 1-3 times lower than the same coefficients for soddy-podzolic sandstone soils. Thus the treatment of soddy-podzolic soils through the complex use of organic fertilizers, liming and high doses of potassium and phosphorus fertilizers, makes it possible to reduce the ^{137}Cs contamination of agricultural crops by up to 4 times when accompanied by water regime improvement, i.e. increased irrigation and drainage by up to 10 times.[3]

CONCLUSION

As a result, for the long-term period of the radiological assessment of the consequences of an accident, the type of the soil of the contaminated area should be measured and the transfer coefficient, be evaluated. Everybody hopes that we will never have to face another nuclear accident, but the emergency response plans should be prepared, and all the details of the monitoring and modeling procedures be taken into account and tested in a real contaminated area.

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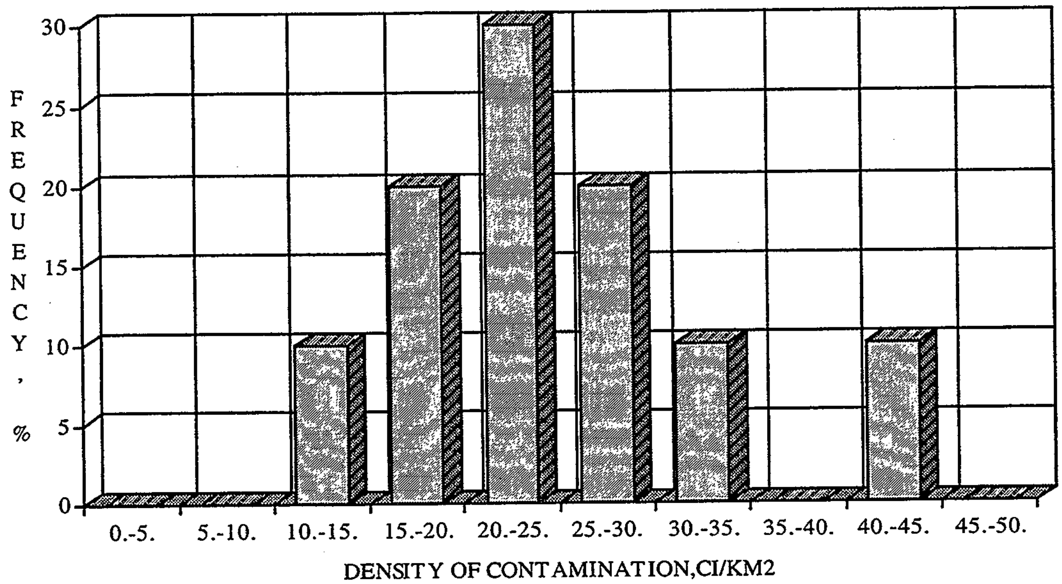

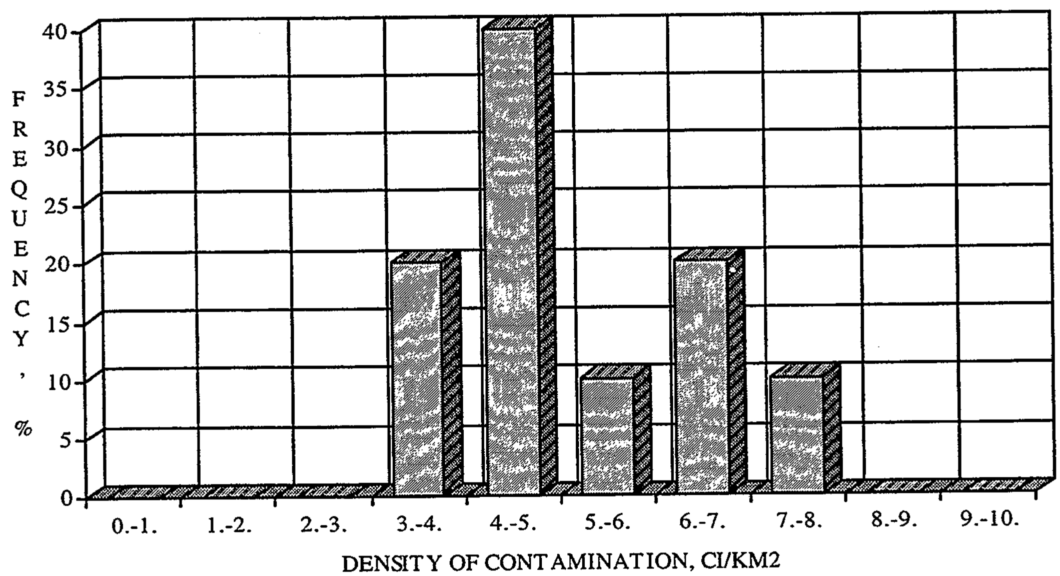

Figure 1. Frequency distribution of the soil sample activities collected within 5m radius

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Session E, Track 2:
Public Health Issues II
Thyroid Disorder as a Result of Chernobyl and Other Health Issues

Thursday, September 10, 1998
2:15 p.m. - 4:40 p.m.

Chair: Andrea Pepper, State of Illinois, Department of Nuclear Safety

A Model Explaining Thyroid Cancer Induction from Chernobyl Radioactivity

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INTRODUCTION

The high level of the incidence of thyroid diseases in children and adolescents born from 1968 to 1986 is the most especially dramatic health consequence of the Chernobyl nuclear catastrophe[1,4]. The number of thyroid cancers in the radioactively contaminated territories of the Russian Federation, as well as in Belarus and Ukraine, has significantly exceeded the preliminary prognostic estimates made by national and international experts.

At present, in the most heavily contaminated territories of the Russian Federation (the Bryansk, Kaluga, Orel, and Tula regions), more than 250 cases of thyroid cancer in children and adolescents have been registered. The ages of these patients, at the time of the accident, ranged from newborn to 18 years. Based upon known ratios between Cesium-137 (^{137}Cs) and Iodine-131 (^{131}I) in fallout, no apparent correlation exists between the incidence of thyroid cancer and the mean levels of radioactive contamination of ^{131}I and ^{137}Cs in the contaminated areas.

Based upon ten years experience with this problem, we propose a process model for the development of thyroid pathology in the post-Chernobyl period.

DISCUSSION

In spite of numerous publications on the thyroid problem, many questions remain because of the lack of factual material, or because of the absence of adequate explanations for the occurrence and mechanism of causation for such an increased incidence. At this writing, the following questions remain unresolved:

1. The role of short-lived radioisotopes of iodine in the radiation exposure of the thyroid;
2. The interdependencies among the exchange of stable and radioactive iodine, the physiological state of the thyroid itself, and differences of exposure dynamics as a dependency on the maturity or physiological condition of the individual (i.e., in utero, neonate, prepubertal and postpubertal, pregnant and lactating, menopausal, etc.);
3. The dynamics and relationships between the intake and delivery of the internally absorbed dose;
4. The epidemiology of thyroid disease for patients living in areas with iodine deficiency;

5. The difference in disease latency periods in children affected by uptakes of radio-iodine into the thyroid and then afterwards either remaining in radioactively contaminated zones or living in clean territories of Russia following evacuation;
6. The role of isotopic transport factors in active radionuclide transfer in the first hours and days after the accident and its contribution to thyroid exposure doses;
7. The effect provided by life-style differences between urban and rural populations in the affected territories; and,
8. Reactions of immune, endocrine and other systemic responses due to chronic exposures from low dose rates of external and internal irradiation.

As can be seen, the assessment of the aftermath of thyroid radiation exposure after the Chernobyl accident reveals a very complex medical problem. After extensive study of post-Chernobyl thyroid pathology, we believe that we have developed a model describing the mechanism of induction of radiogenic thyroid cancer. This process model consists of the following features:

1. In Russia, a definite dependence between the cancer incidence and the proximity of children living near major roads and railways was discovered[5]. This fact is inconsistent with the commonly held assumption that all exposure resulted from an airborne plume of activity from the damaged reactor. We conclude that in the first hours and days after the accident, trains and automobiles served as passive transport pathways for significant quantities of short-lived iodine radionuclides. These radionuclides were inhaled and ingested by children living near transportation arteries. These intakes resulted in significant doses to the thyroid of these children.

2. The highest frequency of the thyroid cancer is registered in children who were between 0 - 4 years of age at the moment of the accident. This is of great significance for several reasons. First, thyroid gland function in infants and young children differs markedly from that in adults. In young children, one notes higher proliferation of thyreocites and elements of stroma, a non-competent immune system, etc. Second, in children under one year of age, the frequency of breathing is 2-2,5 times greater than in adults, and this, in turn, could enhance the intensity of radionuclide inhalation. Third, the mass of the thyroid, at these ages, is much smaller than that of an adult. Thus, it can be demonstrated that in terms of specific dose (i.e., mSv/gram), the exposure levels to the thyroid of small children results in a dose nearly 8 times that received by an adult for a similar intake of activity. Because of this higher specific dose, the effectiveness of the radiation is higher, and cancer incidence is more prevalent. These factors all combine to effectively concentrate the effect of iodine intake in very young children and multiply the potential damage of the resulting thyroid dose.

3. It has been established that among all thyroid cancers, the papillary morphological form comprises more than 95%. Because of the high incidence of this specific type, it can be safely assumed that this form is radiogenic in nature. It was also shown that this papillary

form of cancer results in early metastasis into the lymph collector in the neck, and owing to this, the radiation induced cancer is considered to be the most aggressive type. It is our view that children are particularly susceptible to this form of cancer. During the first 4 years of life, there is an intense development of the follicular apparatus of the thyroid gland, accompanied with formation of the stroma, basal membranes, and capsula of the gland. This developmental physiology opens the possibility for tumor growth in the form of endofit and subsequent transformation into papillary cancer. The existence of a rich network of lymphatic capillaries facilitates the fast transfer of cancer cells into neighboring lymph nodes and the subsequent development of early metastasis there. As a result, in young children (0-3 year old), the papillary form of cancer will be induced with early metastasis into lymph nodes. The absence of formed capsula in the thyroid gland permits the easy exit of a tumor outside the gland. With the maturing of the organism and the completion of the thyroid gland formation, the one should anticipate a decreasing of the papillary form of the disease, and an increase of follicular form.

4. We believe that hypothyrosis is the trigger in development of pathology. We are of the opinion that the development of thyroid cancer in children after the Chernobyl accident takes place against the background of *non*-oncological thyroid pathology – diffuse goiter, hypothyrosis, autoimmune thyroiditis. We initially adopted this position with great caution, but are finding it to be true with growing reliability. We theorize that a chronic deficiency of thyroid hormones induces a diffusion of local hyperplasia of thyroid tissue. Thyroglobulins are synthesized in excess, but are non-realized. These compounds enter into thyroid tissue and blood, which, in turn, stimulates the production of antibodies. As a consequence, autoimmune thyroiditis occurs. The elevated level of TSH, in this case, might stimulate the accelerated growth of malignant tumors. This mechanism may have particular importance and prevalence in iodine endemic zones.

The above mentioned items are of importance not only to children affected by the Chernobyl accident, but also to other cohorts of the affected population, particularly personnel involved in the recovery of the Chernobyl plant ("liquidators"), pregnant women, and lactating women.

It is still too early to make final conclusions related to the nature of incidence, development, treatment, rehabilitation and prophylaxis of thyroid pathology in the after-Chernobyl period. Long-term, cross-disciplinary efforts for the continued collection and analysis of data are still vitally needed.

CONCLUSION

The primary health effect of the Chernobyl disaster was the increased incidence of childhood thyroid cancer. After ten years of study of the problem, a process model is proposed that explains the main contributors to the onset of this disease. The clustering of cases around transportation arteries suggests that significant levels of radioactive contamination were carried in by motorized vehicles leaving the Chernobyl region immediately after the accident. The effect of this contamination on children was heightened due to the developmental stages of the thyroid in these children, which increased susceptibility to the induction of cancer from radiation exposure. In addition, the cancer appears to develop from a background of non-oncological disease, and a pathway for this induction was proposed.

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Potassium Iodine Prophylaxis in Case of Nuclear Accident; Polish Experience

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INTRODUCTION

It is now established that both external and internal radiation can be tumorogenic for the thyroid [1,2]. Therefore, in case of radioiodines contamination, thyroid dose, especially in risk groups (pregnant and lactating women, newborns and children), should be kept as low as possible. The accumulation of radioiodines by the thyroid gland can be effectively decreased by administration of pharmacological dose of stable iodine [3,4], although prior to the Chernobyl accident such action aimed to protect the thyroids of large population was not undertaken. The aim of the present paper is to describe the objectives which led to the decision to implement potassium iodine (KI) prophylaxis in Poland in time of Chernobyl accident, and to present the model of prophylaxis and its effiacacy. The side effects of KI in different ages groups and the problems of cost-benefit of this protective measure will be also discussed. Part of these data presented were already published [5,6].

Radiological contamination in Poland following the Chernobyl accident and objectives for decision to implement KI prophylaxis

At the time of the accident, reliable information about its size and possible health consequences were not available from former Soviet Union authorities. In Poland increased air radioactivity and external radiation were first time identified on the night of April 27 and confirmed on April 28 by all Polish monitoring stations. Because of environmental findings in the whole country showing radiological contamination a governmental commission was called in the morning hours of April 29 to assess damage potential and if necessary to protect public health. The commission made several decisions. First, it accepted the scenario of the accident presented by members of the Center for Radiological Protection which stated that the accident was very serious and would lead to a prolonged release of radionuclides including radioiodines. Second, it recommended the following intervention levels:

(1) Whole body committed dose should nor exceed 5mSv
(2) Thyroid committed dose should nor exceed 50 mSv in children and 500 mSv in adults
(3) Thyroid content in children at any moment should not exceed 5700 Bq

Third, the commission defined the population at risk as about 11 million children and adolescents where thyroid uptakes of radioiodines might be higher due to relative iodine deficiency which was suspected in Polish diet.

At 10 AM on April 29, monitoring stations were reporting continuing and growing radiological contamination especially in eastern and central Poland. In the same time neck measurements taken in children at different ages showed, that in some of them, the thyroid content of 131-I was quite high. It was then concluded that at least in 11 Voivodoships (Provinces) the thyroid committed dose in children might well exceed the 50 mSv limit. It was realized that although some thyroid radioiodines uptake already occurred the gland should be protected against continuing radioiodine contamination coming from damaged Chernobyl power station reactor. At this moment Poland had no sufficient supply of KI tablets, however, the Central Pharmacy Organization (CEFARM) had stores of KI in substance sufficient to prepare the KI solution containing about 90 millions doses of 100 mg of KI each.

Potassium iodide prophylaxis in Poland

Evidence from literature [7] showed that mean effect of 70 mg of iodide is similar to that of 100 mg of iodide. The information about side effects of iodide, although they came from observation of small group of patients, suggested that intrathyroidal and extrathyroidal side effects might depend on the final dose of iodide [3,4]. Those, who proposed the final model of prophylaxis realized that total block of radioiodines uptake in Poland is not possible on April 29. On the other hand, it was realized that final burden to the thyroid gland should be reduced to the level which would be relatively safe in terms of possible tumorogenic effects of internal radiation. It was also expected that single dose of iodide would not lead to serious side effects. At noon hours of April 29 the Minister of Health ordered to prepare and distribute KI solution in all hospitals, public health care centers, drug stores, schools, kindergartens and so forth. The KI prophylaxis was mandatory to all under 16 years old and voluntary to all others. Pregnant and lactating women were advised to take prophylaxis. The following protocol was used: 15 mg of iodide for newborns, 50 mg for children 5 years or under and 70 mg for all others. The prophylaxis was first introduced in 11 eastern Voivodoships. On April 30 as the radiological situation further deteriorated, the prophylaxis was ordered to be country-wide It was also decided that a second dose of KI would be distributed if radiological contamination in air would continue to be high. Fortunately, by May 3 air contamination had decreased at least fourfold and in the next days further reduction of radioactivity was observed therefore distribution of a second dose of KI was postponed.

Thyroid committed doses in Poland, efficacy of KI prophylaxis and adverse reactions

In December 1986 a research follow-up programme coded MZ-XVII was approved. This population studies had the following main objectives:

1. To estimate thyroid 131-I committed doses in children and adults living in different regions of Poland and to investigate possible effects of thyroid irradiation;
2. To evaluate the degree of thyroid protection achieved by KI administration and by other protective measures and to obtain estimates of the incidence of intrathyroidal and extrathyroidal side effects of single dose of KI in newborns, children and adults;
3. To evaluate thyroid function of newborns who were exposed to the radiation and KI administration while *in utero* or soon after delivery;
4. To evaluate possible detrimental effects of single dose of KI on subjects with past history of thyroid disorders.

The MZ-XVII programme (1987-1990) was described in detail elsewhere [5,6] Briefly 52,092 randomly selected persons were questioned and 34,391 completed medical and laboratory investigations. The sample represented approximately 0.09% of the population of Poland and its distribution (age, sex, living in towns and villages) was typical for the country as a whole. In addition, in the middle of 1997 we started A second research programme coded PBZ-38-08 and aimed to reexamine the same sample which had been studied under THE MZ-XVII programme. Although the PBZ-38-08 programme will come to the end in 1999, the thyroid dose reconstruction which used the results of population study on iodine intake in diet was already completed in eastern part of Poland.

As previously described in detail [5,6], thyroid burden was evaluated by both the direct method and by an indirect method based on 5 compartmental models of iodine metabolism developed by Johnson [8]. The maximal 131-I thyroid committed doses (without KI prophylaxis) in 12 highly contaminated provinces for children < 1 year old, < 2-5 years, < 6-10 years and adults were 136.2 mSv, 69.4 mSv, 55.1mSv and 30.8 mSv, respectively. These preliminary data on thyroid dose reconstruction suggests also that about 17% of children of all age groups who reached maximal thyroid doses all exceeded 50 mSv limit without protective action. The thyroid maximal doses in the remaining provinces of Poland where radioactive contamination was estimated as average or mild in all age groups were below 50 mSv. However it should be added that in all Poland there were a number of "hot spots" wherein the thyroid doses could have been 6-10 times that of the surrounding areas. More comprehensive results of thyroid committed dose reconstruction will soon be available.

It has been estimated [5,6] that approximately 95.3% of Polish children (about 10.5 million) and 23.2% of adolescents (above 16 years old) and adults (7.5 million) took potassium iodide dose. In 12 provinces where KI prophylaxis was ordered on April 29, the bulk of KI distribution occurred during the next two days. In areas bordering former Soviet Union almost 75% of children were given KI within the first 24 hours of the prophylactics. In the remaining provinces where KI protective action was ordered on April 30, the bulk of children received potassium iodide on May 2. In Ostroleka province where the thyroid burden and the efficacy of single dose of KI were investigated by direct method [5] the dose reduction in subjects who took prophylaxis on April 29 was estimated to be 45% and in those who took KI on April 30 to be 41%. On the basis of indirect method it was assumed that KI dose given on April 29 reduced thyroid burden by about 40% and KI given on April 25 by about 25%. If there were prompt warning from former Soviet Union and if KI prophylaxis were implemented in Poland on April 27 the thyroid radioiodines committed dose reduction would have been close to 67%[5].

The acute and transient intrathyroidal side effects of a single dose of KI were seen only in 0.37% of newborns who received prophylaxis on the second day of life [5,6]. The mild increase of serum TSH and decrease of serum FT4 disappeared after 10 days without treatment. This transient Wolff-Chaikoff phenomenon was without effect on further development of these children and on their thyroid status as examined in the 3rd year of life. Although re-examination of these children in their 10th year of life is not yet completed the preliminary results suggest that neither thyroid irradiation nor KI given on the second day of life affected the function of their thyroid gland. The single dose of KI was without effect upon the course of thyroid diseases in those with the history of thyroid pathology [5].

As previously described [5,6] the number of extrathyroidal side effects after the single dose of KI were more common than could be expected. These reactions were identified in about 4.6% of children and about 4.5% of adolescents and adults. All of these adverse reactions were of hypersensitivity type and all were mild and transient. As estimated [5,6], majority of these reactions disappeared without medical assistance. In addition, acute respiratory distress developed in two adults with chronic obstructive lung disease and well documented allergy to iodides who regardless of this allergy decided to take KI dose. They were cured by hydrocortisone administration.

CONCLUSION

At the time of the Chernobyl accident there was no international agreement on early warning in case of nuclear accident, such regulations, however, are now in place. Therefore it should be expected that if a severe nuclear accident happens, with a risk for public health, KI prophylaxis would be if needed introduced very early. The present evidence [9,10] that even low thyroid doses of radioiodines can lead to thyroid cancer in children, strongly support the need for such protective action for pregnant and lactating women and for children. It also suggests that intervention levels for these risk groups should be lower than previously established. The Polish experience showed that even in the absence of KI tablets protective action (KI solution) can be quite efficiently implemented. As KI tablets at present available have long shelf-time their predistribution seems to be a crucial issue for most effective prophylaxis in case of nuclear accident. In conclusion, it is suggested that the decision to block the thyroid uptake or to reduce final committed thyroid dose of radioiodines depend on the evaluation of radiological contamination, size of population at risk, approved intervention levels and preparedness.

We proved that even a single dose of KI can significantly reduce final thyroid burden and that a single dose of KI is a safe procedure.

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Emergency Response after the Chernobyl Accident in Belarus: Lessons Learned

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INTRODUCTION

The Chernobyl accident is one of the most dramatic reactor accidents that affected different countries and millions of people. Belarus is one of the most contaminated countries due to this accident. Twenty three percent of the entire area of Belarus was contaminated with the long-lived radionuclides with different levels of contamination density.

During about 12 years of the post-accident period, radiation protection of the population of Belarus has been one of the crucial problems aimed at reducing the exposure doses and risk of radiation induced effects. Different protective actions with various levels of effectiveness have been performed during all phases of the accident.

DISCUSSION

At the early phase of the accident, evacuation of about 24,700 people was performed. This measure allows to prevent deterministic health effects among the Belarusian population. At the intermediate and late phases of the accident, about 130,000 of people were relocated. At present, average annual doses for the majority of the inhabitants of settlements located on the contaminated territories do not exceed 5 mSv. Of 2,2 million of Belarusian inhabitants, who were exposed in 1986, less than 300,000 people now receive annual doses in the range of 1-5 mSv. The maintenance of doses at such low levels has become possible due to conduction and maintenance of a number of protective measures. To restrict the internal exposure, the following protective actions were carried out: establishment of permissible levels for radioactive contamination of foodstuffs, conduction of regular control of foodstuffs contamination and a wide range of agricultural protective measures.

One of the most important experience that was obtained, based on the analysis of the effectiveness for different types of the carried out intervention, is connected with the protection of the thyroid gland. After the Chernobyl accident, the majority of Belarusian territory was contaminated with I-131. In five out of 6 regions of Belarus, density of contamination with I-131 ranged from 0.4 to 37 MBq/sq.m. The highest levels of contamination density were registered on the territories closest to the NPP (southern part of Belarus). The contamination decreased with the distance from the NPP.

Because of late warning of the population and incompleteness of measurements for thyroid protection, significant doses were formed to the thyroid glands of Belarusian people. According to the recent estimation, the collective thyroid dose for all population of Belarus is 510,000 person-Sv.[1] This estimation takes into account only doses from ingestion of I-131 and does not count short-lived isotopes of iodine, as well as inhalation of I-131. Children up to 6 years old who lived in the south part of Belarus, received highest thyroid doses. Exposure from I-131 developed conditions for thyroid stochastic consequences among the exposed population.

The level of the thyroid cancer incidence in Belarus before the Chernobyl accident (1971-1985) was low for children (0.04 per 100,000 children population annually) and relatively higher for adults (0.3-2.5 per 100,000 population for men and 1.2-3.9 per 100,000 population for women).[2]

After the accident, the thyroid cancer incidence started to increase and since 1990, the significant increase of the incidence rate among the exposed children was registered. Among children and adolescents who were under 18 years of age in 1986, the incidence rate of thyroid cancer was: 1.15 per 100,000 in 1990; 2.7 per 100,000 in 1991; 3.17 per 100,000 in 1994; 5.0 per 100,000 in 1995; 4.63 per 100,000 in 1996.[3] Similar increase in the incidence was observed among the exposed children of Ukraine and Russia.[3,4,5]

Specialists attribute the increased rate of thyroid cancer to the development of radiation-induced excess cases. Nevertheless, there are some aspects that are still not well known now: effectiveness of internal exposure of I-131 in comparison with external gamma- and X-ray exposure; role of short-lived isotopes of I and Te in the induction of thyroid cancer; role of non-radiation factors in carcinogenesis (iodine deficiency, genetical predisposition, use of stable iodine in 1986, chemical environmental pollutants, endemic disorders of the thyroid that are characteristic for some regions of Belarus, Russia and Ukraine).

The comparative analysis of dose levels for thyroid exposure of different cohorts shows that absolute risk of radiation-induced thyroid cancer after external gamma- or X-ray exposure may be close to the absolute risk of such cancer due to internal I-131 exposure after the Chernobyl accident (Table 1).

Table 1. Absolute risk of excess thyroid cancer after external gamma- or X-ray exposure and due to internal I-131 exposure after the Chernobyl accident

Study	Number of investigated subjects	Age of exposure (years)	Average thyroid dose (Gy)	Absolute risk per 10^4 (PYGy)
A-bomb survivors [6,7]	13000	<15	0.23	2.7
Tinea capitis [8]	10834	<15	0.09	7.6
Pooled analysis of seven studies [7]	120000	all ages	0.09-12.5	4.4
Exposed children of Belarus, Russia, Ukraine [4]	2328000	<14	0.05-0.92	2.3
Exposed children of Belarus [3].	500347	<6	0.23	4.5

Although the risk values are relatively close, these levels were obtained for cohorts of different age groups. The data of the table shows that the question is under investigation, but because of different uncertainties that still exist, the investigations have to be continued.

Recent studies conducted in Belarus try to find the influence of non-radiation factors on the excess of thyroid cancer among the exposed persons. The comparison of iodine excretion level with urine for the regions where the persons with thyroid cancer are living, does not allow to find the relationship between the thyroid cancer and the level of iodine deficiency that is investigated using this method. It is important to take into account that such investigation of iodine excretion with urine was not performed before the Chernobyl accident. There are no consistent data to be compared. Because of that, it is difficult to estimate the real role of iodine deficiency in the increase of thyroid cancer incidence.

Estimation of thyroid doses brings a significant contribution to the uncertainty of risk assessment. For 1.4 % of the Belarusian population of 0-18 years of age, the dose estimation is based on the results of the direct measurements that were performed in 1986. For the rest of the cohort of this age group (2,683,621 persons), the dose estimation is carried out using different methods of dose reconstruction based on radioecological models with high level of uncertainty.

Possibly, different thyroid disorders (goiter, hyperplasia, etc.) that existed before the accident, could also contribute to the total uncertainty of thyroid dose estimation. Dose models are based on biokinetic models and peculiarities of the exposure for normal thyroid tissues of a reference healthy man. There are no dose models for the thyroid that take into account the changes in thyroid volume, functional conditions, the presence of nodules, etc.
After the Chernobyl accident, a significant increase in thyroid cancer among the exposed population and, in particular, among the exposed children was registered. The level of this increase is correlated with doses of exposure within some limits. However, for the correct risk assessment of radiation-induced thyroid cancer, the investigation should be continued.

CONCLUSION

Radiation-induced thyroid cancer is one of the Chernobyl lessons that should be summarized and learned for the purpose of its effective use for protection of people in the case of potential future radiological emergencies.

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Session F, Track 1: Clean-Up Levels

Friday, September 11, 1998
8:00 a.m. - 9:50 a.m.

Chair: Craig Conklin, United States Environmental Protection Agency

Philosophical Challenges to the Establishment Of Reasonable Clean-up Levels

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INTRODUCTION

Limitation of low-level radiation as applied to such issues as projected waste storage, decontamination and decommissioning of nuclear facilities, and in many cases, with the cleanup of contaminated land, can be considered to be properly within the classical system of dose limitation recommended by the ICRP and the NCRP. In these cases, the exposure comes about as the result of the deliberate introduction of a source of radiation with consequences which can be reasonably expected. For example, the decision on waste storage is justified on the basis of justifying the practice which led to the generation of the waste. This is a decision which does not rest with radiation protection issues alone. Clearly, society, commercial interests, and government all participate in such decisions, either by legislative decree or by Federal and State regulation. This is the first principle in the three-part system of dose limitation.

The second principle is related to reducing exposures to as low as reasonably achievable (ALARA), economic and social considerations included. This is a radiation protection issue, and one which will be addressed.

The third element in the system of dose limitation is the system of establishing dose limits for both individual workers and for members of the public. Perhaps the greatest driving force for establishing limits is the need to insure that individuals or groups of individuals are not placed in the position of receiving an inordinately high exposure simply because the collective dose is low. In addition, ALARA considerations may establish the acceptability of a given radiation source, whereas the individual may be exposed to many such sources.

DISCUSSION

For emergencies, the situation is inherently different. Here the exposure is unplanned, and for many scenarios, unexpected. The exposure exists simply as a result of the event having taken place, and the system of dose limitation cannot embody the classical justification step since the exposure is already taking place. What then are the appropriate parts of the dose limitation system that should be applied in the event of an accidental release of radioactive material?

The concepts inherent in the dose limitation system as it applies to introducing a practice are somewhat reversed. The first order of business is to keep individual exposures below the threshold of serious deterministic effects and prevent any unacceptably high risks of stochastic effects in individuals. When exposures are at these levels, action to prevent individual exposures will be obviously necessary. For example, whole-body absorbed dose rates in excess of a tenth of a Gy (10 rads) per month fall into this category. Since, as pointed out above, the justification step doesn't make sense when dealing with an emergency, a simple objective is in order. For exposures resulting from emergencies, ***simply do more good than harm.*** Sounds simple, but of course it isn't. Let's look at one particularly formidable aspect of the detriment associated with any exposure -- anxiety.

"Anxiety" can be associated with a decision not to take an action to reduce exposure by virtue of both reasonable and unreasonable concerns about perceived risk. On the other hand, once the decision maker decides to take an aggressive approach to reducing exposure, the affected public will likewise respond with anxiety. For example, the anecdotal evidence from the former Soviet Union indicates severe psychological stress related to the Chernobyl accident when actions were taken. The Three Mile Island experience suggests that among those for whom emergency actions were not imposed there was also severe psychological stress. Public anxiety over low-level radiation is perhaps the most difficult issue which the decision-maker must address in trying to establish an acceptable and workable approach to handing radiation exposure issues that must be made in the event of a radiological emergency. As a result, decisions are often made on the basis of perceived risks rather than the actual risks related to exposure.

Returning to ALARA (optimization), the second element in the system of dose limitation, the application to an emergency situation is also somewhat different from that applied to introduction of a new practice. Here, we must focus on insuring that each protective measure is evaluated to determine how far the action should be taken based on balancing the cost of the action such that the net benefit from such action is maximized.

The third element -- establishment of a dose limit -- is perhaps the most difficult in that the system of dose limitation for accidents brings us to the establishment of an action level, as mentioned above. For the emergency situation, the source of exposure already exists, and the derivation of an exposure limit must be related to the basic concept of deriving the level where the action will do more good than harm. Perhaps a review of the ICRP's thoughts related to intervention are in order here.

From ICRP Publication 63,[1] "Principles for Intervention for Protection of the Public in a Radiological Emergency," we find Figure 1. We assume that the accident or event has resulted in widespread contamination which will deliver the exposure as depicted in the smooth curve shown in the figure. The ICRP refers to this dose as the projected dose. It is the dose that would be received if no action is taken. The objective in intervening is to intercede so as to eliminate a fraction of the projected dose. That is called the averted dose. It is also clear from this figure that the duration of the intervention is important. However, the relative effectiveness of any intervention decreases with time (i.e., with dose rate). One of the truisms in these decisions is that the cost of introducing some action is quite great, while continuing it is considerably less. Rather than to get into a detailed analysis of how intervention is determined, I would again refer you to ICRP's Publication 63. Table 3 from that report, shown below, introduces some recommended intervention levels.

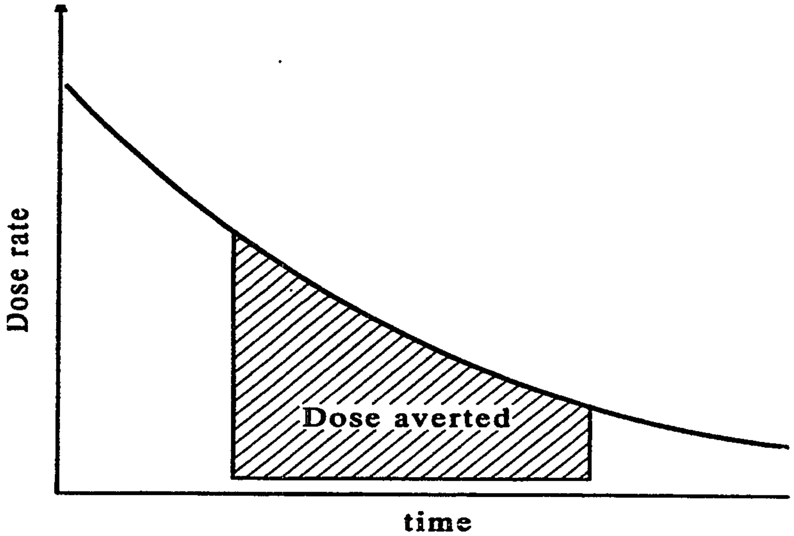

Fig. 1. Effect of intervention in averting dose.

Table 3. Summary of recommended intervention levels*

Type of intervention	Intervention level of averted dose (mSv)	
	Almost always justified	Range of optimised values
Sheltering	50	Not more than a factor of 10 lower than the justified value
Administration of stable iodine – equivalent dose to thyroid	500	
Evacuation (< 1 week) — whole body dose —equivalent dose to skin	5005000	
Relocation	1000	5-15 mSv per month for prolonged exposure
Restriction to a single foodstuff	10 (in 1 year)	1,000-10,000 Bq kg^{-1} (beta/gamma emitters) 10-100 Bq kg^{-1} (alpha emitters)

*Taken from ICRP Publication 63.

The table and the magnitude of the values in it, brings us to my main objective. Fundamentally, that position is that we cannot use the radiation levels like .15 mSv/y (15 mrem/y), or .25 mSv/y (25 mrem/y), or even 1 mSv (100 mrem/y) as our basis for planning the response to radiation emergencies.

The primary difficulty in establishing reasonable action levels is the extraordinary emphasis placed on low dose effects. EPA and NRC are in open disagreement on a clean-up level of 15 or 25 mrem, respectively. This is, perhaps, appropriate when someone has clear responsibilities for paying for remediation (i.e., you degrade the environment, you pay).

Now let us suppose that there is widespread contamination of prime real estate resulting from terrorist events. Let us further suppose that the individual dose will range between .1 mSv and 1 mSv (10 and 100 mrem) per year for seventy years. Using the concepts behind the EPA-suggested 15 mrem, we find the maximumly exposed individual will receive 100 mrem x 70 years - 7 rem or 70 mSv. The individual's fatal cancer risk will be approximately 7 rem x 5 x 10^{-4}/rem or 3.5 x 10^{-3}. Since this exceeds EPA guidance that the public should incur risks of no more than 1 x 10^{-4} to 1 x 10^{-6} fatal cancer risk in a lifetime, it would seem that the residents of our expensive real estate will have to abandon their homes. This would be accompanied with widespread fear and concern by the people who will expect the regulators and the politicians to correct his horrendous health effect.

CONCLUSION

But let us remember that the several million residents of Denver, Colorado, already have faced the same risk from their exposure to an increment of natural background just about that much greater than the exposure to natural background here in Washington. They even build nurseries for little children in Denver. How crass; how careless. Where are the regulators, the public health officials, and the politicians?

My point is that we have created a conundrum of a problem not related to our assumption of linearity but a perception that small risks resulting from radiation exposure are somehow different dependent upon the origin at the exposure. My plea here is to emphasize that we develop a system of action levels that reflect the important differences between emergency response and regulating existing practices.

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Beyond Academia; An Argument for Clean Up to Background Levels to Minimize Property Stigma and Devaluation

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ABSTRACT

While the academic community focuses on a debate between regulated and risk-based analysis for determination of clean up levels following a release or other contamination event, little consideration is given to the long-term effects which may be equally injurious to the residents and property owner; property stigma and devaluation.

The lowering of property values after a release or contamination of the property may be attributed to several factors. These factors may include the requirement to disclose prior to sale any "environmental hazards including but not limited to... nuclear sources" on the Property Condition Disclosure Statement used by real estate agents and the stigma associated with property which still contains levels above natural background.

Several real estate experts have also argued that stigma value damage continues after clean up.

In addition, more than one legal case has resulted in tax rebates for property owners due to diminished value as a result of environmental damage. In the cases discussed, the property owner filed for tax rebates to the local taxing authority claiming the property is severely devalued due to the contaminants. Rulings in favor of the land owner may entitle the landowner to a rebate of taxes paid since the date of the incident resulting in the contamination. This has been successfully argued in asbestos contamination cases. The result can be significant financial losses and subsequent hardship for the taxing authority including county, State or local governments.

Additionally, a fundamental constitutional argument regarding the lack of "due process" in regulatory approval processes also results in loss of real property.

The EPA, in northern Florida was involved in an agreement to purchase homes located near a contaminated site, although the properties were not directly affected by the contaminants.

This paper will provide an analysis of clean up levels as they affect property value and the local real estate market. Using market analysis of communities affected by contaminants such as those surrounding Superfund sites and areas of radioactive releases, the authors will discuss and argue why clean up to natural background levels or purchase of properties may be reasonable consideration in the regulatory process.

Tradeoffs Between Post-Emergency Clean-up Levels and Costs Following a Severe Accident Release[1]

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INTRODUCTION

A severe accident at a nuclear power plant can potentially release a significant fraction of the core inventory of radionuclides to the environment. Radiation exposure of the affected population from this release can have both short-term consequences, such as radiation-induced early injuries and fatalities, and long-term consequences, such as latent cancers, through various exposure pathways. In the short-term, the important pathways are inhalation exposure due to breathing contaminated air, cloudshine exposure from the passage of the radioactive plume, and groundshine exposure from standing on ground contaminated by the deposition of radioactive material. Longer-term consequences are mainly due to three exposure pathways: inhalation exposure from the resuspension of deposited material, ingestion of contaminated food and water, and groundshine exposure from living on residually contaminated land.

Emergency protective actions mandated by Part 50 Title 10 of the Code of Federal Regulations, 10 CFR 50.47(a),[1] are meant to prevent or reduce short-term consequences. These actions include relocation or sheltering of the potentially exposed population downwind of the release. Long-term consequences can be reduced by: decontamination of land and buildings, banning the consumption of contaminated milk and other foodstuffs, prohibiting the production of crops or animal feed on contaminated farmland, or by permanently interdicting land that cannot be decontaminated within a certain time period in a cost-effective manner.

Each of these actions will lead to costs that have to be borne by society. The Protective Action Guidelines[2] (PAGs) of the Environmental Protection Agency (EPA) can be utilized to limit short-term plume exposures and ingestion exposures from contaminated food within a planning area around each reactor site. However, there are no specific guidelines for projected long-term doses from groundshine or resuspension inhalation which are below the respective PAGs. Long-term health effects depend on the clean-up level, also called the "long term interdiction limit," i.e. the allowable level of long-term exposure of a potentially affected population expressed in terms of the projected dose to an individual over a certain time period from the long-term exposure pathways. Relaxation of the long-term interdiction limit (i.e., allowing a higher dose over a certain period of time) will lead to higher doses to the population and more latent cancers but will decrease the offsite costs since smaller amounts of property and food will have to be

[1]This work was performed under the auspices of the U.S. Nuclear Regulatory Commission.

condemned. Conversely, a more stringent long term interdiction limit (i.e., a lower level of dose over the same time period) will lead to smaller health effects but increase the offsite costs. Thus, the two measures of offsite consequences—health effects and offsite costs—are inversely related and a particular choice of an interdiction limit is, in effect, a trade-off between these two consequence measures.

This paper evaluates the trade-off for five nuclear power plants studied in the NUREG-1150 program.[3] Using the severe accident source terms at each plant, the MACCS[4] probabilistic consequence code was run to calculate the offsite (or clean-up) costs as a function of the clean-up level (or, equivalently, the long-term projected dose limit) at each plant site. If a monetary cost is ascribed to the health effects, through the choice of a monetary value for a life saved or latent cancer averted (generally called a statistical-value-of-life, SVOL), then the sum of the clean-up costs and the health costs will be a minimum at some clean-up level and this level can be considered optimal from the standpoint of minimizing the total costs. Such a minimum is presented below for the five NUREG-1150 plants (Grand Gulf, Peach Bottom, Sequoyah, Surry, and Zion) and its implications for post-emergency clean-up levels are discussed.

DISCUSSION

Bases of Calculations

Details of the calculations presented below have been described elsewhere[5]; the bases are summarized below. (1) Accident source terms were taken from the individual plant studies in the NUREG-1150 program. (2) Consequence calculations were performed using the MACCS code (Version 1.5.11.1). In performing the consequence calculations, the emergency response assumptions were the same as those assumed in the NUREG-1150 study. The long-term protective assumption used in NUREG-1150 were to interdict land which could give a projected dose to an individual via the groundshine and resuspension inhalation pathways of more than 4 rem in 5 years (2 rem in the first year and 0.5 rem per year for the next 4 years). Banning of contaminated food and interdiction of agricultural land for crop growing was based on FDA protective action guides for exposure from ingestion for the food groups and crops modeled in the MACCS code (representative of an average U. S. diet). To estimate the effect of varying long-term interdiction dose limits on offsite costs, latent fatalities, and population doses, we recalculated the consequences at each of the NUREG-1150 plants for the following limits: 3.5 rem in 5 years (0.7 rem or 700 millirem per year), 2.5 rem in 5 years (500 millirem per year) and 1.5 rem in 5 years (300 millirem per year). These calculations were performed for all of the source terms at each plant out to a distance of 50 miles.

For each source term, the MACCS code calculates distributions of the consequences based on Monte Carlo sampling from one year of site-specific hourly weather and wind direction data. Apart from the variability due to weather, there is a very large variation in the consequences arising from the different source terms at each plant due to differences in the release parameters such as magnitude (that is, fractions of the core inventory released), timing and energy. To obtain a single value of mean (averaged over weather) consequences which is representative of all of the source terms analyzed at each plant we constructed frequency-averaged mean consequences defined as follows. For any mean consequence, C_i, for a source term i, the frequency-averaged value $\bar{C}$ is

$$\bar{C} = \sum_{i=1}^{N} \lambda_i \, C_i \bigg/ \sum_{i=1}^{N} \lambda_i$$

where λ_i is the frequency of source term i and N is the total number of source term groups. $\bar{C}$ can be understood as a frequency-averaged ***conditional*** mean consequence value, that is the mean value (averaged over weather) of the consequence conditional on the occurrence of the accident and weighted by the frequency of the accident.

Total Costs as a Function of Long-Term Interdiction Limit

The total cost of an accidental release can be expressed as the sum of the offsite protective action costs, OC(r), and the health-related costs, HRC. The offsite costs are calculated by the consequence code for each selected value of the long term interdiction limit, r (denoted in mrem/year). To monetize the health effects, early and latent fatalities, calculated by the consequence code, the health-related costs are expressed as:

$$HRC = EFC + LFC$$

where EFC = early fatality costs and LFC = latent fatality costs. The early fatality cost can be simply written as:

$$EFC = SVOL * EF$$

where EF is the number of early fatalities and $SVOL$ (\$) is the selected statistical value of life. The latent fatalities are a function of the long term interdiction limit r and have to be discounted to present value due to the latency period between the time of exposure and the induction of the cancer. Table 1 displays the risks and latency periods for various types of cancer due to radiation exposure. We can then write the (discounted) latent fatality costs as the product of SVOL and the number of latent cancers:

$$LFC(r) = SVOL * \sum_{j=1}^{N} \frac{LF_j(r)}{(1+d)^{l_j}}$$

where
$Lf_j(r)$ = number of latent fatalities due to cancer type j at the assumed interdiction limit r,
l_j = latency period of the jth type of cancer, (yrs)
d = discount rate, (%/yr)
N = number of cancer types, and
r = interdiction limit, (mrem/year)

The total cost, *TC*, of an accidental release can then be written as:

$$TC(r) = OC(r) + SVOL * \left\{ EF + \sum_{j=1}^{N} \frac{LF_j(r)}{(1+d)^{t_j}} \right\}$$

With the exception of the statistical value of life, SVOL, all the other quantities in the above equation are calculated by the consequence code. Estimates of the mean of SVOL from various public exposure and hazardous occupation risk studies are approximately $10 million (1990 $).

CONCLUSION

The total costs to 50 miles as a function of the interdiction limit, r, have been calculated for Grand Gulf, Peach Bottom, Sequoyah, Surry and Zion, respectively. Figure 1 shows the results for the Zion plant; the results for the other plants are very similar. As the interdiction limit is reduced, the offsite costs progressively increase while the population dose and latent cancers decrease. Ultimately, a law of diminishing returns should set in as the interdiction limit is reduced; the reduction in total dose (and thus the number of latent cancers) should get smaller as progressively larger costs of condemning land and property are incurred.

The curve for total costs in Figure 1 assumed an SVOL of $10 million and a discount rate of 7% per year.

For most of the plants, the minimum of the total cost curve for the chosen SVOL lies in the range of 500 to 700 mrem per year. In other words, for a SVOL of $10 million, which represents a mean across many different public risk studies, an interdiction limit of 500–700 mrem per year represents an optimum from the standpoint of minimizing the total costs. Lower values of avoided dose limits, for example down to 200 mrem per year, will be associated with a significantly higher value of SVOL, which would be out of line with risk allocation decisions in many other areas.

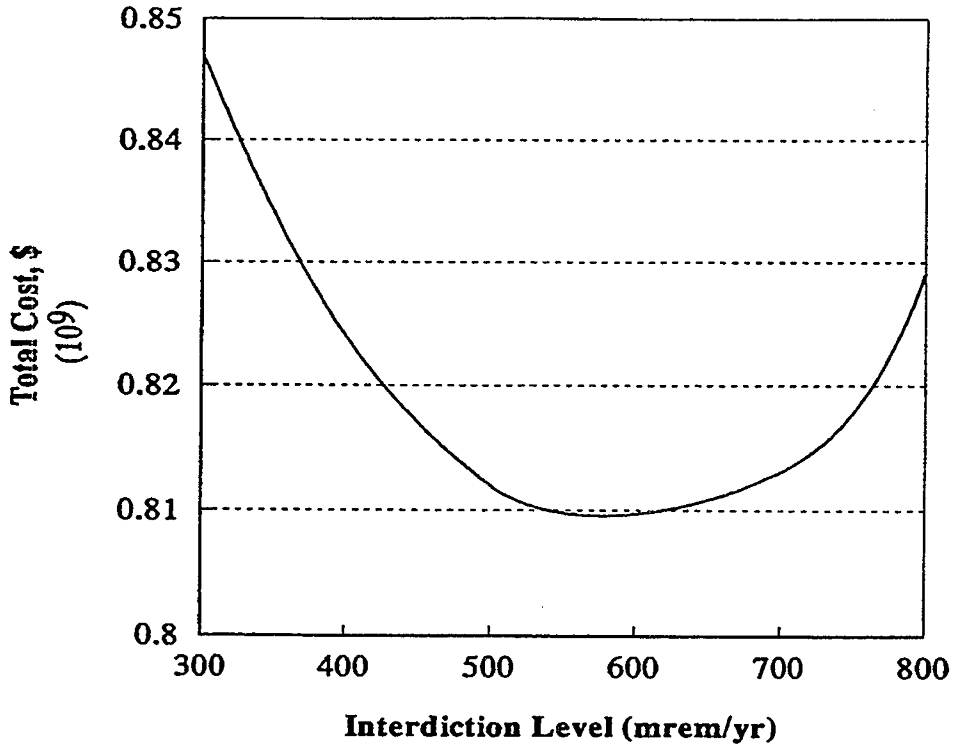

Figure 1 Total Cost at 50 Miles vs. Interdiction Level, Zion

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Session F, Track 2: Lessons Learned from Chernobyl II

Friday, September 11, 1998
8:00 a.m. - 9:50 a.m.

Chair: Jim Fairobent, United States Department of Energy

Cleanup Criteria and Technologies for a ^{137}Cs-contaminated Site Recovery

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INTRODUCTION

The 19 km long banks of the Bohunice NPP waste water recipient has been identified as contaminated by ^{137}Cs as a result of two accidents on the CO_2 cooled and heavy water moderated NPP-A1 unit in 1976 and 1977. Until 1992, NPP waste water had been derived through the 5 km-long, concrete paved Manivier canal to the smaller rated Dudvah River (Qaverage=1.8 m^3/s which is conjucted with the Vàh River (Qa=150 m^3/s) after 13 km downstream at 90 km from Vah's mouth into the Danube River (see Fig.1). In the period between 1976 and 1978, when both accidents happened, construction of a flood control project on Dudvah River had just been implemented in the length of 8 km upstream of its mouth. In the next upstream part of the River approximately a 5 km long river section which was affected by NPP, the flood control conditions are insufficient and have, hitherto, caused permanent public concern.

The contamination of the banks and its significance was discovered in 1991 in connection with preparation of a flood control project implementation. As a result of the conducted radiological survey of the concerned banks, the flood control project implementation was stopped during its licensing. Soon after, proper restoration action was requested by the competent authority from the operator of the Bohunice NPP who has been considered responsible for the bank contamination. A preliminary cleanup level was given as well, being set up ad hoc by the authority on a low level of 1 Bq/g of ^{137}Cs.

The goal of this paper is to give a brief characterization of the site and to summarize the working efforts spent after discovery of the site contamination problems in line of the post-emergency response and planning for recovery of the site. Emphasis is put on the cleanup criteria development and the proposed characterization and remediation technologies for the ^{137}Cs contaminated banks.

DISCUSSION

Initial Response and Radiological Site Characterization

In 1992, a bank restoration project including site characterization for the concerned part of the river was initiated by the NPP with a projected disposal capacity of 5,000 m^3 of removed soil. It was assumed that the soil would be dumped into a subsurface concrete structure inside the NPP area, which is considered to be the most acceptable disposal site of the removed soil for the nearby public. Consequently, during the ongoing monitoring exercises, other parts of the affected river banks were found to be contaminated as well. Therefore, a comprehensive post-emergency survey was needed to be conducted on the overall potentially influenced banks and its nearby surroundings.

First, a mobile ground based screening survey exercise was applied to the flood plain area of the Dudvah (18 km) and Vàh rivers (25 km) including the Kralova Reservoir to identify locations of the contamination in the site. Gamma radiation readings and sliced bulk soil samples for laboratory gamma-spectrometric and radiochemical analysis were taken at the surface of the banks inside and outside of the built levees. These analyses determined that ^{137}Cs is the dominant contaminant in the site.

For the accessible places in the outer side of levees, scanning by a vehicle mounted mobile gamma survey system (VMGS) was used.[1] A contaminated land-field in a spread of 2000 m^2, alongside the Dudvah bank and in a limited flood plain area of the Vàh and the former Dudvàh River were discovered and evaluated this way, as well. Inside the levees, a hand-held gamma survey meter was used for discrete measurements, mostly, with about 20 m spacing within the monitoring line established on the 18 km-long banks.

The detailed and comprehensive survey done between 1991 and 1994 shows that the top soil contamination on the banks widely varies from background level to 20 Bq/g (3.8 MBq/m^2) on the Dudvah River and reaches 250 Bq/g of ^{137}Cs for the spottily-contaminated section on the Manivier canal banks. The contamination is spread over a 0.5 to 3m wide strip on the lower part of the banks and the average level of ^{137}Cs in the top 10 cm soil layer reaches 6.3 Bq/g. The overall contaminated area in the site with activity level exceeding 1 Bq/g of ^{137}Cs has been identified as to be about 67,000 m^2 and the volume of soil which had to be removed according to this preliminary cleanup criterion exceeds 13,000 m^3.

After finalization of the monitoring exercises, it was recognized that the applied 1 Bq ^{137}Cs/g is too low and inappropriate for use as a justified cleanup criteria. The previous restoration project demonstrated that it was necessary to reconsider with emphasis the complexity of the proposed cleanup measures including alternative remedial technologies (fencing, clean covering, trenching), the cost-analysis and development of justified cleanup criteria. Since 1993, VUJE Research Institute has been involved in comprehensively addressing of the above mentioned contamination problems.

A typical feature of these efforts, clear legislation in the field has been hitherto absent. This is why a primary demand to develop some principles for evaluation of the justified scale of cleanup measures including appropriate cleanup criteria development became the first priority in order to achieve confidence and authorization of the final reconsidered environmental restoration plan. Of course, this demand was realized in close cooperation with competent hygiene authorities and experts.

Dose Assessments and Cleanup Criteria Development

The contaminated banks are accessible for 16,000 residents living in a 3.5 km wide strip alongside the river. Selected exposure pathway scenarios with authorized parameters (stay on the bank and land field residential use of the contaminated soil for housing) were applied for dose characterization assessments and development of the proper cleanup criteria for the proposed cleanup measures. Ingestion pathways using transfer factors for goat's milk, meat and loamy soil according to the reference[2] was also part of the completed dose assessments.

Moving a large amount of the contaminated soil from the river banks, and its release into the environment during and after a planned flood control project implementation poses the most serious potential risks for the nearby population.

The contaminated soil from the banks is assumed to be relocated, and used as a landfill or fertile soil around a resident's living house. This type of radiation risk, but with a smaller amounts of contaminated soil arising (e.g., even from some maintenance works on an arbitrarily contaminated bank section could be considered as the most critical exposure pathway for the site). So, according to these conditions, the effective dose from a stay on a bank does not exceed 0.35 mSv/a, although, the potential risk from the use of contaminated soil reaches higher levels of effective dose to up to about 2 to 3 mSv/a. The annual collective dose from the stay on the banks is low, maximally, on the level of about 100 - 200 man mSv, accordingly to not too-intense use of the banks.

Cleanup criteria for the contaminated banks were derived on the basis of authorized principles and the mentioned site specific soil use scenario dose factors[3] (0.14 or 0.21 mSva=1/(Bq.g=1)). According to the recovery approach of the ICRP, accepted by the authority, both the actual dose and potential risk to critical individuals from the contaminated banks must not exceed 1 mSv/a. Average ^{137}Cs activity concentration levels in the bank soil (top 10 cm) AL200=6.0 or 8.0 Bq/g over 300 or 80 m long sections, competently, correspond to the above dose constraint requirement. In addition, ^{137}Cs activity concentrations AL.3 =25 Bq/g for isolated small spots on the canal banks.

The derived criteria are in good relation with the results of the volume distribution of the activity concentration analysis carried out on the basis of detailed measurements for the bank soil. It was possible to demonstrate by this way that cleanup measures, even, for a small part of the identified contaminated area on the banks-namely clean soil cover or removing, only, of the mostly contaminated soil (i.e. the soil with contamination above 6-7 Bq.g-1) would lead to significant improvement in remediation of the contaminated banks in the site.

Technologies and Scale of Resulting Cleanup

Exceeding the developed cleanup criteria justifies implementation of more cost-consuming restoration techniques, from which two remedies have been selected as the most appropriate for the contaminated banks remediation:

a) dilution/fixation of contaminated top soil by clean cover on flat contaminated areas; and
b) removing/disposal of top soil layer for the steep banks.

The clean cover technique sufficiently reduces the anticipated radiation risk, however, its price is about 10 times lower compared to the standard removing/disposal technique.

To be in compliance with these criteria, it is necessary to subject to cleanup measures about 11,000 m^2 of contaminated area on the Dudvàh River banks and 8,000 m^2 on the Manivier canal banks. As engineered flat terraces prevail on the Dudvàh River banks, according to the authorized principles, clean soil cover is sufficient to be applied over 9,500 m^2 of contaminated flat area.[4] On the spotty contaminated Manivier canal section, only the isolated spots of contamination are proposed to be removed. So, the resulting volume of soil to be removed from the steep banks and safely buried in a disposal facility inside the Bohunice NPP area equals to about 1,100 m.[3]

CONCLUSION

Re-evaluation of a ^{137}Cs contaminated bank restoration project has been conducted for NPP Bohunice site on the basis of comprehensive and detailed site characterization technique application. As there is no clear legislation in the subjected field, principles for contaminated bank evaluation had been developed and approved by the competent authorities. Site-specific cleanup criteria have been developed, which are 6 or 8 Bq $^{137}Cs/g$ in soil depending on the size of the contaminated area. Thanks to the application of consistent site characterization techniques and planning of clean covering use as a justified cleanup measure, unnecessary waste soil disposal is going to be avoided within the prepared new bank restoration project.

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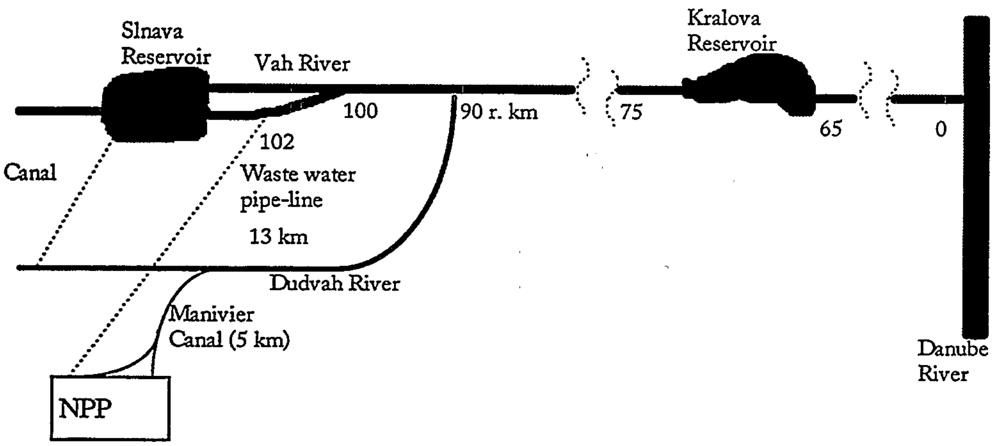

Lessons of the Chernobyl NPP Accident Regarding Potable Water Supply

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INTRODUCTION

The world's greatest radiation catastrophe at the Chernobyl NPP has reflected the faults in the organization of water supply for the town populations and water resources monitoring in the Ukraine. Prior to the accident, in spite of known advantages of groundwater among available sources for town water supply and the good state of groundwater prospecting, the preference was paid mainly to river water. (In Kiev, the Capital and the largest town of the Ukraine, with an existing possibility of all water being supplied by prospected groundwater of very good quality, more than two thirds of the water supply is maintained from the rivers Dnieper and Desna).

For the organization of the centralized water supply of Kiev by groundwater, of the most practical importance are the Cenomanian-Callovian (depths 100-150 m) and Middle Jurassic (Bajocian, depths 250-300 m) aquifers, which are protected by 2-3 regional aquitards with filtration coefficients of the order of 10^{-3}-10^{-4} m/day. For these two aquifers the exploitational resources are proven to exceed 700 thousand m^3/day (60% from Cenomanian-Callovian and 40% from Bajocian). Present water intake from these aquifers does not exceed 50% of this amount.

Initial composition of the radioactive contamination found in the river water formed in May 1986 was represented by several dozens of nuclides, the majority of which by their input in exposition dose for biocenoses are ^{141}Ce, ^{144}Ce, ^{103}Ru, ^{140}Ba, ^{131}I, ^{95}Zr, ^{95}Nb, ^{14}La, ^{134}Cs, ^{136}Cs, and other products of uranium decay. The input in total activity from each of these nuclides was different, but starting from 1987, the dominating in dose formation became ^{137}Cs and ^{90}Sr.

It is worth emphasizing that the maximum allowable concentration (MAC) of ^{137}Cs in potable water at that time was 37 Bq/liter (1 10^{-9} Ci/l). By May 3, 1986 the Dnieper water exceeded the MAC for ^{137}Cs by 35 times.

DISCUSSION

Systematic observations for the content of nuclides in surface and subsurface water and analysis of their content in fish and other hydrobionts were started only in the beginning of 1987. But from May 1986, the works on surface water monitoring were performed by specialists of different organizations of the former USSR (Scientific-Industrial Union "Taifoon", USSR State Committee of Hydrometeorology, Institute of Radium, State Hydrological Institute, etc.) and Ukrainian organizations (UkrNIGMI, Institute of Nuclear Studies, Institute of Geochemistry and Physics of Minerals, Institute of Geology of Ukrainian Academy of Sciences, etc.).

Unfortunately, the majority of the observation results obtained by different monitoring groups were secret or available only "for service use". For this reason the active coordination of researches and data collection was impossible. The same reason was for the large amounts of unconditional data which entered the database created in the Institute of Cybernetics of NASU for systematization of monitoring information on the environment's state of radioactive contamination.

Based on the fact of fast radioactive contamination of water in the Dnieper, the decision was made in May 1986 by the Government of Ukraine to drill over 80 wells to deep aquifers (Cenomanian-Callovian and Bajocian) in Kiev City, and urgent construction of the water pipeline for additional transport of water from the Desna River which was contaminated to a much lesser extent than the Dnieper. The wells and pipeline were constructed over a period of two months. During this time the tendency was set for surface water quality improvement. The example is that the maximum concentration of ^{90}Sr in May 1986 in the water of the Pripyat River close to the Chernobyl NPP reached 15 Bq/l, and at the end of June the same year it dropped to 1-4 Bq/l.

Within the Kiev region, contamination of groundwater with ^{137}Cs and ^{90}Sr during the whole post-accidental period did not exceed several tens or a few hundreds of mBq/l. In spite of this fact and the proved vulnerability of surface water sources, the decision was not made or practically realized concerning the necessity of a preferable water supply on account of groundwater. The wells drilled in May-June 1986 were conserved.

The research performed after the accident has shown that notwithstanding the relatively fast penetration of initial portions of contamination into groundwater to the depth of 100-300 m within the regions of operating water intakes, the water-bearing aquifers remain much more protected than surface water.

Especially important in this research was the revealing of the pathways of nuclide penetration into groundwater. Among such pathways, the technogenic and natural ones can be considered. The technogenic are the pathways which originate in weak zones of round-wells space, cavities or breaks in wells casing. Special experiments have been done at several exploitational wells, which confirmed these suppositions. The quality of isolation of the wells from surface contamination appeared to be low.

Natural migration pathways correspond to the vertical component of infiltration within regions of groundwater recharge. The lateral flow from the Chernobyl accident epicenter is of no importance because of the general character of groundwater exchange and small horizontal flow velocities as relative to the area scale. Groundwater of the most contaminated 30-km exclusion zone area discharges into the Pripyat Valley with no access to aquifers lying north from the lower current of Uzh River.

Hence, observed contamination, besides technogenous pathways, might occur only by vertical filtration through the bulk of rock being enhanced in the central part of the water intake depression cone which provides significant pressure differences between the subsurface aquifers. In order to confirm the validity of this supposition, observations were made in drainage tunnels disposed at the Dnieper right bank slopes in Kiev, and during the Kiev subway tunnels driving in marls at depths of about 60 m. The ^{137}Cs was found in groundwater and rock samples at concentrations of 10^{-3}-10^{-2} Bq/l and 2-20 Bq/kg respectively. So, the nuclides' migration by natural pathways through the bulk of rocks is a matter of proven facts. According to these data, the vertical velocity of downward migration should be no less than 2.5 m/year, but sometimes may reach 15-20 m/year and more.

Such significant velocities demonstrate the existence of fast vertical migration pathways through the bulk of alternating water-bearing and semipermeable rocks reaching great depth. These pathways may be related primarily to the zones of present tectonic fracturing of mountain rocks and disintegration of unconsolidated rocks. Also, of high importance are the facial variability, mineralogical and granulometric inhomogeneity of deposits. The openness of these pathways is registered only by rather toxic indicators such as radionuclides and pesticides.

To obtain the modeling assessment of geological rock medium contamination with ^{137}Cs in the Kiev industrial agglomeration, we performed the modeling of vertical convection/dispersion transport for typical sections of this region with downing infiltration low of about 100 mm/year rate, taking into account the equilibrium sorption process. Modeling parameters (dispersion coefficient D and partition coefficient Kd) were calibrated according to observation data for the contaminant content in liquid and solid phases at different depths. Prognostic vertical distributions until the year 2050 obtained for the concentration with its maximum values in 2005-2010 of 70-100 mBq/l for most exploited Cenomanian-Callovian, and Bajocian aquifers. So, the results of modelling confirmed that the possible groundwater contamination is significantly lower than the MPC levels.

In spite of the reliability and sufficient degree of protection of groundwater and vulnerability of surface waters, which were proven by the events during the post-accidental period and results of special research, the authorities of the former USSR, as well as of the independent Ukraine, did not perform practical measures on increasing of water supply of population by groundwater. It also is obvious that the measures are urgent but still not implemented on improvement of the protection state of ground-wells space and well casing from nuclide penetration by this way from the surface.

The assessment should be done for the possibility of potable water supply of population by groundwater during periods of surface water contamination in different accidental situations. Essentially, for each town which is partially or wholly supplied by potable water from the surface sources, the programs should be elaborated and realized of partial or entire water supply by groundwater or from other well-protected sources.

The Chernobyl disaster has shown that the pre-accidental system of surface and groundwater monitoring was insufficient with respect to the amount of observation points, data types and condition, system of analysis and forecasting of water quality. During the pre-accident period, the permanent models were not created for sites and areas of dangerous technogenous objects (NPPs, Plants, etc) and town agglomerations, and the modeling scenarios were not simulated for the consequences of possible accidents and for taking optimal administrative decisions in such situations.

In spite of a relatively low present contamination of groundwater by nuclides, further improvement of the monitoring network for surface and subsurface hydrosphere is necessary.

In particular, for substantiation of the groundwater monitoring system, the following research has been performed:

- Characterization of main origins of contamination and its state for groundwater and its neighboring media;
- Studying of the observation wells state within the depression cone of Kiev water intakes and their correspondence to the criteria of the monitoring regime network;
- Characterization of specific natural and technogenic conditions of KIA;
- Characterization of studied factors in the monitoring system;
- Elaboration of criteria for assessment of the factors of geological environment changing.

Many examples are known from groundwater exploitation practice that when operating water intake structures were fully excluded from the cycle of industrial-potable water supply because of groundwater quality deterioration first in recharging, and later in pumped aquifers. So, it is very important to register in proper time the initial stages of contamination of the elements of the water exchange system and their dynamics. In this connection, the suggested scheme of the observation network is primarily based on construction of the gungs of regime wells for each of the storey aquifers, not only for exploited ones.

Creation of a regime network should be performed gradually and should take into account the observation data during changing groundwater exploitation conditions and periodically refined information about hydrogeological conditions and technogenic loads. Substantiation for construction of each gung or separate well should be proved by modelling on the existing and periodically refined permanent hydrogeological model.

CONCLUSION

1. The world's largest technogenic radiation catastrophe at the Chernobyl NPP has reflected the faults in organization of water supply of population and monitoring of water resources in Ukraine. Notwithstanding the disaster which revealed the vulnerability of surface water sources, the conclusions about preferable water supply on account of groundwater have not been made, nor practically realized.

2. In spite of the revealed initial contamination of groundwater by radionuclides of Chernobyl origin, the confined aquifers remain the most reliable sources of water supply within the affected regions.

3. For conditions of accidental situations leading to partial or full contamination of surface water sources, the reserve system of water supply should be elaborated and introduced, based on maximum use of groundwater, spreading of surface water intakes over the area, creation of a system of water purification, and other reserve possibilities.

4. The priority among towns requiring the accidental water supply measures implemantation should be determined taking into account:

   - existence in the neighborhood of potentially dangerous potable water contamination sources; and

   - intensive use of surface water for water supply.

5. The protection degree of groundwater water intakes should be assessed and checked with respect to technogenous pathways of fast migration of contaminants;

6. In order to perform reliable groundwater quality forecasting and, if needed, management of their state, it is necessary to create the monitoring system, which includes:

   - periodic examination of exploitation and regime wells according to developed techniques accounting for the wells conditions assessment;

   - construction of regime test sites embracing the storey system of aquifers, their interstitial semipermeable aquitards and aeration zone in different landscape-geochemical, hydrogeological and technogenic conditions;

   - creation and improvement of permanent hydrogeological models of large water intakes, other water-economy objects, regime observation sites providing reliable forecasting and, if necessary, development of variants of managerial decisions for optimization of the ecological state of water resources and their environment;

   - creation of the system of independent controls for the cases of revealing of anomalous radionuclides concentrations with guarantee for results reliability.

Radio-hydrogeochemical Monitoring of Area Adjacent to the "Shelter" Object

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INTRODUCTION

The accident at the Chernobyl NPP that happened in 1986 could be undoubtedly described as one of the greatest technogenous catastrophes of modern civilization. Into the epicenter of the accident there were involved large territories of Ukraine and Byelorus, which are now referred to as the Chernobyl exclusion zone. In its scale and diversity of the negative consequences, the Chernobyl accident turned out to be a national tragedy for the people of Ukraine, Byelorus and Russia. Its influence can be traced to this or that degree in many countries of Europe, Asia and all over the world.

The Chernobyl exclusion zone area within the Ukraine borders equals 2044.4 km^2. After evacuating people from the large territories, the excluded areas automatically extended approximately by 1800 km^2. As a whole, this area exceeds the territory of such a European state as Luxemburg by 1.5 times.[1]

As a result of the explosion, the active zone and the upper part of the reactor were completely destroyed. Barriers and safety systems for protecting the environment from radionuclides produced by irradiated fuel were also ruined. Therefore, immediately after the accident the most urgent problem was to build an available structure to protect the environment from further spreading of radionuclides out of the destroyed NPP 4th unit as well as working personnel from exposure to radiation. It took only six months to construct a structure which had no analogues in world practice. This structure was called the "Shelter" object (SO).

Having protected the area from direct radiation of the destroyed reactor, the SO did not provide complete reactor isolation from the environment and prevention of groundwater contamination by radionuclides. The reality of groundwater contamination is substantiated by the large amount of nuclear fuel in the ruined reactor (about 200 ton)[2] and radionuclide occurrence in internal SO water with activity of a few million Bq/l for strontium and tens of millions of Bq/l for cesium. At 2-3 km from the SO, down the groundwater gradient, the Prypiat river is located. Thus, the urgent problem after the Chernobyl NPP accident was to accomplish geological environmental monitoring around the SO, involving groundwater as the most mobile and the least protected component of the environment.

In the course of geological prospecting for Chernobyl NPP construction, appropriate geological-engineering and hydrogeological investigations were performed giving the principal estimate of soils and groundwater over the study area. However, the creation of the radiohydrogeochemical monitoring system was not intended to be the permanent control of the groundwater levels, chemical composition and radionuclide concentration over the area close to NPP power units. This omission was eliminated in the post-accidental period by spending large financial, human and technical resources.

DISCUSSION

In 1991, creation of the modern system of radiohydrogeochemical monitoring was started, involving the area around the SO.

According to the "Arial" program in 1991-1992, the first prospecting wells of 10m in depth were installed near the northern barrier of the SO site, and were drilled with continuous core sampling from the different soil layers. This provided for the pioneer geological-engineering examination of the SO site in the post-accidental state.[3] Determination of nuclear fuel and radionuclide distribution in deep soil layers down to the groundwater table was performed based on dosimetric and radionuclide core analysis. Experimentally, the amount of nuclear fuel within the operating site was evaluated (about 600 kg).

In 1993, an international contest was held concerning the conversion of the SO into an ecology- and radiation-safe system. As a result, Conversion Strategy was developed. One of its main items was the SO state examination and environmental monitoring.

In 1994, the net of observation wells was completed within the SO site which provided for the pioneer study of:

- Radionuclide contamination and groundwater levels dynamics;
- Recent geophysical and technogenous geolithological sections across the SO site and a more precise assessment of the fuel amount remaining after land surface deactivation.

There was also a determination concerning: distribution of airflow temperature, moisture and velocities; the principal water pathways inside the SO and major places of its accumulation; and the dynamics of radionuclides and nuclear fuel accumulation in SO water.

While analyzing the obtained data, it was revealed that the radionuclide concentration in the internal SO water abruptly increased (by 3 orders over 3 years).[4] This fact allowed us to consider the internal SO water as a new source of nuclear contamination for the geological environment. The possible hydraulic connection between the internal SO water and Quaternary aquifer initiated their parallel studying.

In 1995, it was determined that the main ways of water income to the SO premises was namely by: atmospheric precipitation, moisture condensation and technological solutions. Inside the SO, water moves along the principal water pathways. Depending on weather conditions, its discharge can vary in large ranges (up to 800 m^3/year). After interaction with concrete, water takes on alkaline carbonate composition and gains the capacity to dissolve cesium and uranium compounds. Water flow washes out the fuel-containing mass and removes the fuel particles and soluble radionuclides. Eventually, water is accumulated in the lower SO premises. In some cases, the water level inside the SO is much higher than the groundwater table in the adjacent SO area that can lead to water removal outside the SO, its inflow to groundwater, and then to the rivers.

The other source of groundwater contamination is the area around the SO containing, at the land surface, 0.5% of nuclear fuel ejected from reactor and other active zone elements .

Deactivation works performed in 1986-1987 considerably improved the radiation situation around the destroyed 4th unit of the Chernobyl NPP. Hence, by the moment of completion of the SO construction the radiation level at the site equaled 0.3-1.2 R/hour (compared to 40-1000 R/hour as of 1 August 1986). However, there was a large amount of fuel still remaining on the operating site covered by the artificial bank composed of gravel-sand mixture, concrete and asphalt coating. It was built as a special radiation-resistant layer to reduce the radiation level. The remaining fuel mass is a real danger for the environment because the artificial bank can't provide for safe isolation from physical-chemical influence of natural and technogenous factors.

The most dangerous factors for the geological environment are possibly water migration outside the SO and radiocontaminated area of the SO site.

In the course of hydrogeological studies the thickness of the Quaternary aquifer was determined to be 25-28m, the depth of the unsaturated zone is 3.5-7.4 m. The unsaturated zone is composed of both technogenous soils (formed during the Chernobyl NPP construction and accident consequences liquidation) and Quaternary deposits.

The Quaternary deposits within the unsaturated zone are represented by fine- and medium-grained sands with sandy loam and loam interbeds. The conductivity of water-bearing sands is 15-20 m/day (medium-grained); 2-4m/day (fine-grained); 1-2m/day (powdered); -0.1m/day (loam) and 0.5m/day (sandy loam).

The magnitude of the groundwater table fluctuations in 1996-1997 equaled 0.4-0.6 m. The groundwater flow gradient was 0.001 m/m. In the summer period, groundwater temperature varied from 10.4°C to 14.2°C.

Mineralization of groundwater sampled from wells located close to the SO site and down the groundwater gradient from the SO was 503-962mg/l. This parameter for wells located up the groundwater gradient from the SO was 174-256mg/l.

According to the anion composition, groundwater is hydrocarbonate, hydrocarbonate-sulfate*, and sometimes sulfate-hydrocarbonate. By cation composition it is sodium-calcium, rarely sodium and calcium-sodium; pH varies from 4.2 to 9.8.

As a result of different chemical substances, penetration into the destroyed reactor (for stopping the fire, decreasing the probability of chain reaction, deactivation, dust suppression, etc.), some of them with time migrate into groundwater changing its natural composition by increase of sulfate, chloride, phosphate and nitrate concentrations.

In the course of monitoring improvement, radioisotopes (T-tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239+240}$Pu, ^{241}Am) in groundwater were also studied.

Concentration of radioisotopes in groundwater is as follows: ^{137}Cs -444Bq/l, ^{90}Sr -229Bq/l (excluding well 3-g with all-time high concentration of ^{90}Sr up to 3820Bq/l); ^{238}Pu -3Bq/l; $^{239+240}$Pu -5.6Bq/l; ^{241}Am -8.5Bq/l.

Water concentration of ^{90}Sr and ^{137}Cs in the SO lower premises reaches 4,400,000Bq/l and 98,000,000Bq/l, respectively.

Tritium was chosen as an indicator for migration of the internal SO water to the Quaternary aquifer. The groundwater sampled from wells located along the same flow streamline down the groundwater flow from the SO are of higher concentration of tritium (to 4,037Bq/l) as compared to its concentration in the other area (10-20Bq/l). Probably, it indicates the migration of the internal SO water into the geological environment, because the tritium concentration in the internal SO water achieves 20,000Bq/l. At the same time the groundwater flow rate near the SO is rather low (up to 50m/year). The time when the contamination front reached the Prypiat River was evaluated at 150-200 years. This evaluation is conservative, because it does not take into account the broadening of the first part of the contamination front and sorption properties of soils. To provide precise information of contact between the internal SO water and groundwater, long-term observations are required.

The soils within the SO site were studied with radiochemical and radiometric methods by analyzing core samples and wells gamma-logging. Uranium, plutonium and products of nuclear fuel fission were identified by laboratory analysis of core samples.

The highest concentration of uranium (5.11E-2**%) was detected in the northeastern part of the SO site at the depth of 2.6-2.9 m (pre-accidental land surface). In the deeper soil samples, the uranium concentration does not exceed 8E-4%. Within the zone of natural soils it equals nE-5%, where "n" ranges from 1 to 10.

In sampled soils, plutonium concentration correlates with that of uranium. Its maximum value is close to that of uranium and equals 1.6E+4 Bq/g. In the deeper soil samples, the plutonium concentration does not exceed 1-13.4 Bq/g, within natural soils zone it is 0.01 Bq/g and less.

At present short-living fission products (^{144}Ce, ^{106}Ru, ^{125}Sb, ^{154}Eu, ^{60}Co) are identified only in the sampled soils with high uranium concentration by gamma-spectrum at long exposition of measuring.

^{137}Cs and ^{90}Sr were found in all geological zones in different concentrations. Maximum concentration of ^{137}Cs was observed in well 4g (2.5E+4Bq/g) and 9-1A (8,7E+4Bq/g) at the depth of pre-accidental land surface. Minimum ^{137}Cs concentrations (0 3-0.6Bq/g) were observed in the natural soils zone.

^{90}Sr concentration in post-accidental technogenous deposits varies from 0.2 to 2.5E+4Bq/g. Maximum concentrations are associated with pre-accidental land surface. In the upper part of the Quaternary aquifer ^{90}Sr concentrations are 0.0 -0.2Bq/g.

Therefore, in the vertical cross-section of the study area, the most radiocontaminated are soils near pre-accidental land surface. The less contaminated are post-accidental technogenous deposits. Water migration of radionuclides or their mechanical removal caused contamination of pre-accidental soils (both technogenous and natural).

CONCLUSION

To the Chernobyl accident lessons, we can ascribe the necessity of preventive monitoring accomplishment in NPP areas to control the soils and groundwater state during regular NPP work and to evaluate the sources, scales and dynamics of radiocontamination of the geological environment in the case of extraordinary situation.

The principal monitoring wells should be disposed in the direction of the lateral groundwater flow.

It was revealed that the groundwater radionuclide concentration is non-uniform along the aquifer thickness, being maximum in the upper part of the aquifer. Therefore, the long well filters providing for only averaged sampling of the whole aquifer thickness are not suitable. Short filters installed in the upper part of aquifer are preferable to long ones.

In the case of a multi-aquifer system a group of wells should be equipped for studying interaction of these aquifers both in ordinary and extraordinary situations.

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* by hydrocarbonate-sulfate water is meant the prevalent concentration of sulfate ions in groundwater composition

** by 5.11E-2 is meant 5.11x10-2

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Session G, Track 1: Public Health Issues III

Friday, September 11, 1998
10:10 a.m. - 12:00 p.m.

Chair: Gary Goldberg, United States Department of Energy

Public Health Issues: Considerations for Post-Emergency Response Panel Discussion

Presented by the Radiation Emergency Assistance Center/Training Site (REAC/TS)

Shirley A. Fry, MB, BCh, MPH, Ronald E. Goans, PhD, MD,
Robert C. Ricks, PhD, Richard E. Toohey, PhD, CHP

INTRODUCTION

In 1895, Professor Conrad Reontgen published a report on the discovery of x-ray (Roentgen, W.C., 1898). Shortly thereafter, the first x-ray induced health effect was reported in scientific literature (Edison, T., et al, 1896). Over the next 45 years, radiation accidents were often unreported and associated medical data were archived in personal files of treating physicians. In the early 1940s, the development of nuclear weapons and their subsequent use in Hiroshima and Nagasaki resulted in the establishment of a medical/epidemiological database for follow-up on the Japanese atomic bomb survivors. With the advent of peacetime applications of nuclear energy for electrical power generation, as well as applications in industry, agriculture, medicine and consumer products, more and more radiation accidents were reported. Many of these accidents were studied and medical information archived in the accident registries as part of the programs of the Radiation Emergency Assistance Center/Training Site (REAC/TS). (Lushbaugh, C.C., Fry, S.A., Ricks, R.C., 1980). The majority of the reported serious worldwide radiation accidents involved not more than 10 persons.

DISCUSSION

Prior to 1979, multi-casualty incidents involving radiation were limited to events in the Marshall Islands (1954); Palomares, Spain (1966); and Thule, Greenland (1968). In March, 1979, the accident at Three Mile Island Nuclear Power Plant, although not a radiological disaster, caused considerable re-evaluation for post-emergency response capabilities to radiation accidents in the United States. It was quickly realized that the potential impact of multi-casualties on overall health care systems and population follow-up could be significant. More and more attention was therefore given to pre-planning, medical capabilities, and training for radiation accidents. Subsequent accidents in Chernobyl (1986) and Goiania, Brazil (1987) reinforced the need for continued planning and preparation for major multi-casualty radiation accidents.

While accidents are by definition, unplanned, there exists today another potential for multi-casualties associated with ionizing radiation. We live in a community at risk from terrorist acts involving weapons for mass destruction, including chemical, biological, and nuclear devices. Nuclear terrorism may involve crude or sophisticated nuclear weapons, radiation dispersal devices, sabotage of commercial nuclear power plants, or simple radiological devices such as stolen sources. As part of the Nunn-Lugar Weapons of Mass Destruction legislation, training of fire, police, technical, EMS and medical personnel for post-emergency response is being conducted throughout the United States. Two hundred cities are currently on the list of training sites.

Over the past 22 years, the REAC/TS program has trained 4,373 physician, nurses, EMTs, health physicists, and others in medical management for radiation accidents through courses sponsored by the United States Department of Energy. Specific courses are offered for the emergency department personnel, health physics support personnel, and physicians/nurses involved in post-emergency care. Historically, course participants have come from areas of the country where the use of nuclear energy for electrical power production, R&D employing ionizing radiation, or military applications are concentrated.

An incident resulting in a number of persons having exposure to penetrating radiation sufficient to result in the acute radiation syndrome (and possibly to serious localized injuries) will have significant impact on the medical community and health care organizations, even after the early problems of victim extrication, triage, trauma management, medical and radiological assessment, decontamination, and supportive treatment are taken care of. Those with the acute radiation syndrome may require transfer to facilities for long periods of costly hospitalization by highly skilled staff, while those with less severe exposures will require frequent assessments and careful follow-up by local practitioners and admission to hospitals when infections, bleeding, skin injuries or other problems are manifest. Planning for emergency response and emergency care have been published by Leonard & Ricks (1980) and Berger & Ricks (1992).

Decisions regarding administration of antiviral and antibacterial prophylactic agents, appropriate growth factor therapy, the use of peripheral or cord blood stem cell transfusions, and assessment and interpretation of dose information will require consultation with experts in radiation medicine, hematology, immunology, radiobiology, and transplant therapy, while management of localized injuries will require experts in radiation medicine, dermatology, vascular and reconstructive surgery. If radioiodines are released in an incident, medical personnel will be needed to assess thyroid function of involved persons.

In addition, during and after an incident, health care practitioners will be inundated with requests for medical evaluation and treatment for conditions which may be psychosomatic in origin.

CONCLUSION

This panel discussion will address ways the medical community will be impacted by a serious radiological emergency, beginning with hospitalizations for the seriously ill, home/community care for others, and the usual medical problems associated with evacuation of the population. In addition, considerations for bioassays, whole-body counting, internal dose assessment, and requirements for epidemiological information will be discussed.

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Medical Considerations for Post-Emergency Response of Radiation Accidents

Panel Discussion Presented by the Radiation Emergency Assistance Center/Training Site (REAC/TS)

Ronald E. Goans, PhD, MD
Richard E. Toohey, PhD, CHP
Shirley A. Fry, MB, BCh, MPH
Robert C. Ricks, PhD; Director, REAC/TS

INTRODUCTION

In the initial evaluation of a radiation accident, it is crucial to estimate the maximum credible accident that has occurred since reliable health physics data may take days to accumulate. Radiation effects usually take hours to days to even weeks to manifest and there is always time to formulate a plan of management and enlist the aid of appropriate medical and surgical sub-specialists. However, because of the evolving nature of radiation-induced lesions, this means that most of the definitive care takes place outside of the Emergency Department. Since management of a radiation accident also can involve medical and surgical complications, it is important to resolve these issues first.

It is important to evaluate population radiation dose in perspective in order to deal with radiation accidents in an informed manner. Average background radiation dose to the population is approximately 0.36 cSv/year (1), dose from a PA and lateral chest film is approximately 0.006-0.02 cSv, and dose from a pelvic or skull CT is 1.5-4.0 cSv/slice. This may be viewed in contrast to the current occupational limit of 5 cSv/year. In contrast, the acute whole body dose for lethality of 50% of a population (LD_{50}) is approximately 4 Gy, somewhat dependent on the state of health of the patient, dose rate, and the availability and sophistication of medical resources. For an exposed population, the dose for 5% mortality may differ from the dose for 95% mortality by only 2-3 Gy. Therefore, an increase in dose by only a factor of 2 may represent the difference between total survival of an individual and essentially total mortality.

DISCUSSION

It is possible to subdivide radiation accidents into four categories: (1) body surface contamination with or without wounds; (2) whole-body irradiation; (3) acute local injury; and (4) internal contamination. The injured patient may exhibit only one or a combination of these effects.

Wound or Intact Skin Contamination

Decontamination of a minor wound or intact skin is relatively straightforward, is commonly practiced and has been presented in detail elsewhere (2). Generally, decontamination procedures start with the mildest agents possible (soap and water) and progress to more aggressive techniques as indicated. In decontamination of intact skin, it is important not to irritate the skin, thereby disrupting the skin's normal protective barrier and possibly increasing transdermal absorption of any deposited radionuclides. The most important consideration of decontamination of wounds and lacerations is copious irrigation of the area under sterile conditions. Surgical debridement of contaminated areas may also be of help in some cases.

Acute Effects of Whole-body Irradiation (Acute Radiation Syndrome)

It is instructive to look at early deterministic effects of whole-body irradiation:

(1) < 10 cGy, whole body - No detectable difference in exposed vs. non-exposed patients.

(2) ~ 20 cGy, whole body - Detectable increase in chromosome aberrations. No clinical signs or symptoms.

(3) ~ 20-100 cGy, whole body - Detectable bone marrow depression with minor lymphopenia, leukopenia and thrombocytopenia.

(4) ~ 100-800 cGy whole body - Bone marrow depression with dose-related depression of all blood elements.

The Acute Radiation Syndrome (ARS) is an acute illness, which follows a roughly predictable course over a period of time ranging from a few hours to several weeks after exposure to ionizing radiation. ARS has classically been subdivided into component syndromes as follows:

(1) Hematopoietic .....100 - 800 cGy
(2) Gastrointestinal ...800 - 3000 cGy
Cardiovascular/Central Nervous System... > 3000 cGy

The ARS is characterized by the development of groups of signs and symptoms which are manifestations of the reactions of various body systems to irradiation of the whole body or to a significant portion of it. Prodromal signs and symptoms include anorexia, nausea, vomiting, diarrhea, fever, conjunctivitis, and skin erythema. The latter is especially observed if there has been a dose to a localized portion of the body. The higher the whole-body dose, the more quickly one expects to see the prodromal symptoms of nausea and vomiting.

Most radiation accidents involve doses under 100 cGy and are therefore subclinical. However, for higher doses, the hematopoietic syndrome is the symptom complex most commonly seen. The etiology of the hematopoietic component of the ARS basically arises from destruction of radiosensitive bone marrow stem cells and a consequent decrease in circulating white cells and platelets. Clinical stigmata of this syndrome include immunodysfunction, increased infectious complications, hemorrhage, anemia, and impaired wound healing. Significant neutropenia can develop some 20-30 days post-exposure, depending on the magnitude of the whole-body dose. The radiosensitivity of circulating lymphocytes has formed the medical basis for an improved technique to estimate total body dose after a severe accident involving low LET radiation (3,4).

As in all accidents, medical management of a severe whole-body exposure includes a complete history and physical examination. Besides the classical components of the medical history, it should also include time of exposure if possible, time of onset and severity of prodromal symptoms, as well as possible exposure to toxic chemicals. A hematological profile (CBC with differential) should be obtained every 2-4 hours following exposure to monitor any initial fall in lymphocyte count. Cytogenetic dosimetry is also an important adjunct to retrospective accident analysis and accident reconstruction involving time and motion studies.

Post-emergency management of the ARS includes treatment of infections (bacterial, viral, fungal, CMV, HSV), trauma surgery as indicated for conventional trauma or thermal burns, and surgical management of radiation-induced skin injuries. Immediate treatment of ARS includes supportive care, platelet transfusions as indicated, psychological support, infection control, and, most importantly, stimulation of the hematopoietic system. The primary goal of radiation casualty management involves therapy to correct radiation-induced bone marrow aplasia and infection from opportunistic pathogens.

Hospital care of mild cases (< 2 Gy) involve triage by prodromal symptoms and by lymphocyte depletion kinetics, evaluation of biological and physical dosimetry, emergency surgery if indicated during an appropriate early time window, and close observation of the patient with frequent hematologic profiles. It is also appropriate to consider management of residual skin contamination and medical management of internal contamination, if present. For the more severely injured patient (2-5 Gy), reverse isolation techniques are appropriate, GI tract decontamination with antibiotics, growth factor therapy to reverse marrow aplasia, and viral prophylaxis. If the patient exhibits a febrile neutropenia, then antibiotics and urine and blood cultures are appropriate. For a patient with whole-body dose beyond the LD_{50}, it is important to utilize aggressive growth factor therapy with transfusion of peripheral blood progenitor cells (PBPC) or cord/placenta blood progenitor cells (CBPC). These cells are transfused after mobilization and *ex vivo* expansion by cytokines. Examples of hemopoietic cytokines currently either in use or in development are GM-CSF, G-CSF, IL-6,11, PIXY321, MGDF, and Erythropoietin.

Clinical cases involving the gastrointestinal syndrome (GIS; 800-3000 cGy) or the cardiovascular/central nervous syndrome CV/CNS) are rare and effective treatment modalities do not exist, especially for the CV/CNS syndrome. Effects resulting from the GIS include malabsorption, Ileus, fluid and electrolyte shifts, dehydration, acute renal failure, cardiovascular collapse, GI bleeding, and sepsis. Typically the patient dies within 5-9 days post-exposure. The Cerebrovascular / CNS Syndrome (CV/CNS; > 3000 cGy) generally exhibits vomiting and diarrhea within minutes, confusion and disorientation; severe hypotension, hyperpyrexia, convulsions, and ultimately coma. The literature contains very few of these cases, but they have all been fatal within 24 to 48 hours.

Acute Local Injury

Acute local injury is seen reasonably frequently in industrial settings, typically after handling high-level sources at small distances. Common sources inducing local radiation injury are ^{192}Ir, ^{60}Co, and ^{90}Sr. Local injury was also seen in the weapons testing program from fission product betas, and is seen currently in industrial radiography and in misuse of X-ray machines, X-ray diffraction units and X-ray fluorescence units. Since these are deterministic effects, certain approximate thresholds with common signs are observed:

(1) 300 cGy threshold - Epilation, beginning around day 17.
(2) 600 cGy threshold - Erythema; developing minutes to weeks post-exposure, depending on dose.
(3) 1,000 - 1,500 cGy - Dry desquamation.
(4) 2,000 - 5,000 cGy - Wet desquamation, 2-3 weeks post-exposure, depending upon dose.
(5) >>5,000 Gy - radionecrosis with deep ulceration.

Medical management of local injury generally involves history and physical exam, laboratory tests as indicated, slit lamp ophthalmoscopy, and documentation of the evolution of the lesion(s) with serial color photos. One significant problem with the management of local radiation injury is that the actual dose is rarely known when the patient is first seen. The radiation dose is estimated after the lesion has run its course (usually over several weeks). Mock-up of the accident from a retrospective scenario is quite often helpful and medical management often is supervised by a plastic or reconstructive surgeon.

Internal Contamination

Exposure situations involving internal contamination are more common than accidents involving acute whole-body irradiation. Potential workplace accidents involve stages of the nuclear fuel cycle, fabrication of fuel elements, reactor operation and repair, decommissioning, reprocessing, and waste disposal, and accidental intake with radioactive sources in the medical and industrial sectors. Environmental uptake associated with accidental or intentional releases of radioactivity (e.g., reactor accidents, terrorist activity) is also possible. Pathways of contamination include inhalation (particularly likely with explosion or fire), absorption from wounds, and ingestion. In inhalation incidents, the size of the aerosol particles determines the region of the respiratory tract where most are deposited. The fate of inhaled particles is dependent on their physico-chemical properties and highly insoluble particles can remain in the lung for long periods of time. As in all radiation accidents, it is important to attempt to determine the maximum credible accident.

Nasal swabs taken within a few minutes post-exposure can aid in nuclide identification and estimation of the maximum credible accident. Whole body counting is an important adjunct modality to estimate internal deposition for those nuclides that emit penetrating x or gamma rays. It is also useful for nuclides, such as ^{90}Sr, which emit energetic beta particles; these nuclides can often be detected by the bremsstrahlung radiation given off as electrons slow down in soft tissue. In internal contamination incidents, 24-hour urine and fecal bioassay is usually necessary to estimate intake using various, well-accepted biokinetic models.

CONCLUSION

General principles of treatment of internal contamination include: minimizing intake, reducing and/or inhibiting absorption, blocking target organ uptake, isotopic dilution, promotion of excretion, altering the chemistry of the substance, displacing the isotope from receptors, or utilizing chelation therapy. It is important to remember that radioactive isotopes deposited internally metabolize in the same manner as their stable counterparts. It is instructive to consider some selected examples:

(1) Tritium - ^{3}H; follows pathway of water in the body; penetrates skin, lungs, and GI tract, either as tritiated water (HTO) or in the gaseous form. Single exposures are treated by forcing fluids. This has the dual value of diluting the tritium and increasing excretion. Forcing fluids to tolerance (3-4 L/d) will reduce the biological half-life to 1/3 to ½ of the normal value (10 days).

(2) Uranium- exists in various solubility classes; inhalation is the usual occupational exposure. Overall biological half-life is 15 days and 85% of retained U resides in bone. Kidney toxicity is the basis of occupational exposure limits. Oral doses or infusions of sodium bicarbonate are the treatment of choice and should be administered in a dosing schedule to keep the urine alkaline.

(3) Radioiodine - The dominant internal exposure after a reactor accident, nuclear weapons test, or any incident involving *fresh* fission products is likely to be ^{131}I. The thyroid is the target organ and medical management involves blocking the thyroid by stable iodine, either by KI tablets or SSKI (Saturated Solution of Potassium Iodide).

(4) Radiocesium - ^{137}Cs (physical half-life, 30 years; biological half-life 109 days) is the dominant radioisotope in *aged* fission products. Cesium distributes in body fluids similarly to potassium. The most effective means for removing radioactive cesium is the oral administration of the ion-exchange resin, ferric ferrocyanate, commonly called Prussian blue.

(5) Actinides - Plutonium, Americium, Curium, and Californium (all have long biological half-lives). Inhalation is approximately 75% of industrial exposures and these accidents are generally seen in the DOE complex or in universities supporting weapons research. Ca-D TPA and Zn-DTPA chelation therapy is the treatment of choice.

(6) Additional Chelating agents - Chelation has an active history in radiation medicine and much research is still directed toward developing better chelating agents. For example, Dimercaprol (BAL) forms stable chelates with mercury, lead, arsenic, gold, bismuth, chromium, and nickel. It

may therefore be used for the treatment of internal contamination with radioisotopes of these elements. Deferoxamine (DFOA) has been effective in treatment of iron storage disease and may be used for chelation of ^{59}Fe. Penicillamine chelates copper, iron, mercury, lead, and gold. It is superior to BAL and Ca-EDTA for removal of copper (Wilson's Disease).

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Post-emergency Response: Epidemiological Considerations

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INTRODUCTION

During the three decades following the nuclear explosion in Japan, radiation accidents worldwide generally were contained within secured and often remote environments, involved small numbers of active participants, and with a few notable exceptions, had little or no impact on the public health. More recently however, accidents such as those originating at the Three Mile Island and Chernobyl nuclear power generating plants, at metal processing facilities in Juarez, Mexico and in Taiwan, and at medical facilities in Goiania, Brazil and Indiana, Pennsylvania had, or were perceived to have the potential to affect the health of members of the general public in addition to those at the accident site. The potential for similar situations to occur in the future raises questions about the need or desirability to follow groups of individuals for epidemiological purposes, and how to prepare for such eventualities. Such questions are likely to be relevant or applicable in the case of non-radiological emergencies.

DISCUSSION

Reasons for implementing epidemiological follow-up of groups of persons 'at risk' after an emergency event include:

1. To identify adverse health effects in the 'at risk' group, and to determine if the risk of such effects is greater relative to some comparable 'non-exposed' group or population.
2. To determine if increased risks that may be identified are associated with exposure to known agents (e.g., radioactive materials, released in the emergency).
3. To determine if the increased risks observed are related to or influenced by other factors associated with or independent of the emergency.
4. To add to the scientific basis for establishing or modifying protection standards for workers and the public.

Outcomes of the first three of these follow-up objectives potentially can benefit individuals in the 'at risk' group by:

1. Identifying a need for medical awareness of verified or suspected exposure to potentially hazardous agents.

2. Identifying the need to include 'at risk' persons in medical monitoring or screening programs that are known to be effective in early detection of diseases inducible by the agent involved in the emergency, so that interventions can be implemented to avoid or minimize future morbidity.

Implementation of actions to achieve these objectives are likely to reassure the individuals and groups that: 1) something is being done; 2) they will know if they are or are not at increased risk for developing exposure – related diseases in the future; and if so 3) appropriate actions to prevent or minimize the effects of the increased risk can be implemented.

Although increasing the scientific basis for protection standards may not be of direct benefit to the individuals in the 'at risk' groups, it may contribute to improved protections for others at risk of similar exposures in the future.

Unfortunately, implementing such follow-up programs is not without its technical or scientific difficulties and limitations, the first of which is 'who should be included?' Other practical considerations included: 1) whether or not the exposure is known to cause an unique disease; 2) what 'measures of exposure' are available; how certain are they?; and 3) is there likely to be a definitive answer in the short-term. Factors that can affect or influence the interpretation of the results of epidemiological studies include: 1) whether the population or number of individuals available for inclusion or the follow-up program, and the exposure levels are sufficient to identify an effect of the exposure of interest, if any exists. This is especially important when the outcome is not uniquely caused by the exposure part as in the case of radiation and cancer. In these cases, attribution of the increased risk to the exposure must rely on statistically significant differences between the risk of the outcome (disease) in the 'exposed' compared with a 'non-exposed' group. Large populations generally are needed to achieve this objective. The interval between an exposure and an exposure-related health outcome, such as cancer, especially is long, so that long periods of follow-up may be necessary before a valid result is available. Also, human health is inevitably affected by inherent genetic and life-style factors that must be considered in interpretation of results. Such factors would include the stresses of the emergency itself, such as evacuation, loss of economic support, and the benefits that may accrue to the 'exposed' population such as increased medical attention, or improved diets.

CONCLUSION

Proper consideration of issues relating to epidemiological follow-up is appropriately included in the planning for radiation and other potential emergencies to the benefit of the public health. Such planning should include capabilities to immediately and adequately document persons impacted by the emergency so as to permit their follow-up directly by contact, or indirectly through national records systems such as the Social Security Administration or State Drivers' License Bureaus.

It is likely that there will be emergency or accident situations in which epidemiological follow-up of the 'survivors' is not justifiable on scientific grounds but in which socio-economic and political considerations necessitate implementation of a follow-up program. Being prepared to act effectively in either situation is to the advantage of the responders and in the interests of the public health.

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Post-Emergency Response: Health Physics Considerations

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INTRODUCTION

The health physics response to radiation accidents that involve only a few people are easily manageable; however, when many persons have been actually or potentially exposed, the majority of resources allocated to recovery operations may well be involved in one or another aspects of health physics. The goal of health physics operations will be to determine and control the radiation exposure of affected persons, and the decisions made will be based on determination of: 1) the geographical extent and magnitude of radioactive contamination of the environment, 2) the resulting external radiation dose rates to resident or responding persons, and 3) the external and internal contamination levels of exposed persons. Each of these tasks will require numerous measurements, whose sophistication and interpretation will be greatly affected by the particular radioactive materials involved. During the early post-emergency phase, the measurement results may be used to determine the need for evacuation, sheltering in place, importation of uncontaminated food and drinking water, treatment for internal or external exposure, and radiological safety constraints for responders. Later in the post-emergency phase, the measurements may be used to determine the need for decontamination, and to verify that decontamination goals have been achieved. Finally, the measurements may be used to reconstruct radiation doses to the exposed populations, thereby providing the "dose" component of the dose-response function for epidemiologic studies, and no doubt the basis for compensation for real or perceived harm to the exposed populations.

DISCUSSION

Well-established procedures exist for environmental monitoring of external (penetrating) radiation levels; the instrumentation is relatively simple, easy to operate, and provides instant read-out. Guidance on selecting instrumentation for post-emergency monitoring has been published, based on the experience gained in the Goiania accident (Becker et al., 1991.) The main problem lies in compiling the data into a usable form for decision-makers. Normally, dose rate or integrated dose contours are generated on standard regional maps. Measurements of radioactive contamination in or on environmental samples (air, water, soil, foliage, foodstuffs, exposed surfaces, etc.) are also reasonably straight forward, but may be more-or-less complex depending on the exact radionuclide involved. Gamma-ray emitters such as Cs-137 or Co-60 require minimal sample preparation; however, the detectors used may require extensive shielding, may need to be operated at liquid nitrogen temperature, and typically involve a computerized analysis of the data collected. Pure beta emitters, such as Sr-90, and especially low-energy beta emitters such as tritium (H-3), require careful sample preparation, usually including chemical separation, and more complicated detection procedures, such as liquid scintillation counting. Finally, alpha emitters such as Pu-239, are the most difficult to detect, normally involving extensive wet chemistry and sophisticated alpha spectrometers to determine their levels. In a reactor accident or weapon detonation, easily measured radionuclides such as Cs-137 normally serve as markers for the entire inventory of radioactive materials released; however, in dispersal of only one or a few radionuclides, such as a weapons accident with detonation of the conventional explosives, but no nuclear yield, only limited "marker" radionuclides are available (e.g., Am-241, which emits a low-energy (60 keV) gamma ray, may be used as a marker for Pu-239.)

Environmental measurements are still rather simple compared to measurements of radioactivity on or in exposed persons. External contamination monitoring requires about ten minutes to do a thorough survey, or "frisk" of a single person by an experienced technician; as the numbers of people to be surveyed mount, the time required quickly becomes unacceptably long. Every person will want to be measured as soon as possible, because of the extensive fear of radiation that permeates the general public. An initial triage of persons by likelihood of exposure is required, but very often, security personnel will be required to provide crowd control. As an example, after the Goiania accident in Brazil, persons who lived adjacent to the accident scene were told to report to the town's Olympic stadium for contamination monitoring, and 112,800 people presented. Of these, 129 were found to be contaminated on their clothes or shoes only, and another 129 were found to be contaminated on their skin or internally. Of the latter, 21 required hospitalization. (Rosenthal et. al., 1991.) Fortunately, the radionuclide involved, Cs-137, is easy to detect.

Determination of internally deposited radioactivity in exposed persons is the most complex set of measurements to be performed in the post-emergency period. Although it can be argued that persons who are found not to be contaminated externally are unlikely to be contaminated internally, such a triage method may or may not be acceptable to the population involved. In addition, external contamination with tritium is very difficult to detect with survey instruments, and in such a case, there may be few ways to determine the likelihood of internal contamination other than by place of residence or work versus environmental monitoring results. Again, gamma-emitters are relatively easy to detect, and normally whole-body counters (mobile, unless a fixed facility is nearby) are used for the measurements. In Goiania, more than 300 persons, ranging in age from a few months to 72 years, received whole-body counts; some were so contaminated that special arrangements to reduce analyzer dead time were required (Oliveira et al., 1991.) After the accident at Three Mile Island, 760 persons, both plant workers and local residents, were counted with a single mobile whole-body counter over a period of eight days (ten minutes per count, 24 hours per day), and the measurement program was terminated when no radionuclides attributable to the accident were found in this population (Berger, 1981.) Following the Chernobyl accident, a total of 119,306 children were measured for Cs-137 content at five fixed facilities located in the Bryansk, Kiev, Zhitomir, Gomel, and Mogilev regions from May 1991 to April 1996; Cs-137 was used as a marker for the radioiodines released in the accident, and the resulting dosimetry information was used to determine the risk factor for thyroid cancer (Sharifov et al., 1997.) Another series of whole-body counts was performed on residents of the Rovno oblast of the Ukraine, not so much to determine individual intakes and doses, but to validate a mathematical model for environmental exposures and intakes through the food chain, that would be widely applied to the exposed population. (Likhtarev et al., 1996.) Other countries have prepared mobile whole-body counting facilities specifically for use in the post-emergency environment. For example, the French have prepared a railroad car with twenty whole-body counting stations, that can easily be deployed to the vicinity of an accident; no such capability exists in the United States.

In an accident involving primarily alpha (e.g., Pu-239) or beta (e.g., tritium) emitters, whole-body counting is either inappropriate or has inadequate sensitivity to be used, and measurements of radioactivity in excreta must be employed. Although the analytical methods used are essentially identical to those used for radioactivity in environmental media, the logistics of sample collection are much more complicated. Urine samples are relatively easy to collect, and most people have had the experience of providing a urine sample as part of a physical examination; however, for accurate dose assessment, a twenty-four sample is preferred, and for low-levels of intake, a sizable sample (one liter or more) may be required. Urinalysis is of course limited to soluble radionuclides that may be excreted in urine; in the case of inhalation or ingestion of insoluble compounds, such as the oxides of plutonium, fecal sample collection and analysis may be the only reliable means of detecting intakes. Most people are reluctant to provide fecal samples, although collection kits are readily available from medical supply firms. The logistical problems involved with urine samples, such as provision of containers, recovery of samples, and sample storage pending analysis are magnified in the case of fecal samples.

Once the data have been collected, the dose assessment can be performed, either for individuals from bioassay measurements, or for populations from environmental measurements. Standard biokinetic models have been published by the International Commission on Radiation Protection (ICRP Publications 30 and 54) and by the U.S. Nuclear Regulatory Commission (NUREG/CR-4884) that can be used to relate the results of a bioassay measurement to the intake of a radionuclide, if the time between the intake and the excreta collection or whole-body count is known. Similarly, standard models of environmental transport and pathway analysis are available to estimate population intakes based on the concentrations of radioactivity measured in environmental samples. Once the intakes have been determined, dose coefficients published by the U.S. Environmental Protection Agency for adults (Federal Guidance Report 11), and by the International Atomic Energy Agency for all ages (Basic Safety Standards, Safety Series No. 115) may be applied to calculate the resulting radiation doses. However, the estimation of the dose to a particular individual from environmental pathway analysis is particularly uncertain, and may be of little use for epidemiological studies attempting to determine dose-response functions.

CONCLUSION

The final health physics consideration in the post-emergency situation may well be the verification survey following decontamination efforts; that is, verifying that contamination levels have in fact been reduced to whatever level has been determined to be the goal of those efforts. Again, the logistical requirements for such efforts may be enormous; in Goiania, some fifty houses were decontaminated after the accident (some by complete removal), and the top 1.5 cm of soil were removed for distances of up to 100 m from the most contaminated sites (da Silva et al., 1991; Amaral et al., 1991), generating thousands of cubic meters of waste, all of which required monitoring.

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Session G, Track 2: Protective Actions

Friday, September 11, 1998
10:10 a.m. - 12:00 p.m.

Chair: Dorothy Meyerhof, Health Canada

The German Guide for Selecting Protection Measures

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INTRODUCTION

After the accident in the Chernobyl Nuclear Power Plant, many countries were first forced to perform ad-hoc countermeasures as well as to impose criteria and reference values with regard to the effects of the accident. Without detailed knowledge of the accident course, they had to estimate the radiological situation, to recommend protection measures and to inform and reassure the public. Different assessments of measured data resulted in considerable confusion, contradictory recommendations on how to behave put the public in a state of unnecessary uncertainty. Taking into account the experiences made and the recognized insufficiencies, the emergency plannings were checked worldwide, with the objective to be better prepared for the various types of radiological accidents - like accidents with contaminations over large areas, but also transport and satellite accidents.

Finally, the basis was created for an improved co-operation in the case of an incident/accident and the scientific and technical basis for a more efficient emergency planning and preparation through the intensive efforts of the responsible organizations.

DISCUSSION

The experiences with the radiological effects of the Chernobyl accident triggered off a corresponding evaluation also in the Federal Republic of Germany. Among other things, this led to new legal regulations, in order to be able to act rapidly and appropriately in the case of an event with considerable radiological effects. According to the Radiation Protection Ordinance (Strahlenschutzverordnung, StrlSchV) [1], all necessary countermeasures have to be initiated in the case of incidents/accidents so that hazards to life, health and material goods are reduced to the minimum. According to the Precautionary Radiation Protection Act (Strahlenschutzvorsorgegesetz, StrVG) [2], in order to protect the population, radioactivity in the environment has to be monitored and, in the case of events with possible considerable radiological effects, has to be kept as low as possible, taking into account the state-of-the-art of science and technology and all circumstances.

Considering these objectives, a strategy of measures has been developed for the implementation of §§ 6, 7, 8, 9 StrVG which authorizes the Federal ministries - on the basis of the data compiled according to §§ 2, 3 StrVG and summarized by the Integrated Measuring and Information System (IMIS) for the monitoring of environmental radioactivity - to demand or, respectively, recommend together with the competent highest Federal State authorities certain modes of behaviour. As a guide for this strategy, the Catalogue of Countermeasures ("Survey of measures designed to reduce the radiation exposure after events of considerable radiological consequences") was elaborated.

In addition to the radiation protection precaution measures, the Catalogue of Countermeasures contains disaster measures like evacuation, for which the Federal states are competent. Intervention levels for precautionary measures are lower than those for disaster countermeasures.

The Catalogue should be a guide for experts from competent governmental and State authorities as well as persons belonging to the respective advisory and supporting panels, which have to make the assessment and evaluation in the case of a nuclear event with radiological consequences off-site.

The first version of the Catalogue was submitted in the summer of 1992 [3]. It is currently being revised. A new and more synoptical version is expected and will probably be published by the end of this year.

Content of the Catalogue of Countermeasures

The compilation of measures in the Catalogue is based on a literature analysis. The measures are arranged regarding the time phases of an accident (pre-release, release and late phase). For each measure, the effectiveness, the operational intervention level (OIL) and problems that may arise during the application of the measure are mentioned.

When using the Catalogue, it must in principle be presumed that not all measures will apply to all situations. Still, an attempt was made to provide a comprehensive overview as a basis for possible argumentation if, for example, a specific measure should not be initiated on account of its low effectiveness.

The main criterion for initiating and executing a protective measure is the radiation dose expected to be received from each of the considered pathways (external radiation, internal radiation after inhalation or ingestion). Since radiation dose is generally not measurable directly, directly measurable quantities (the OIL's) like the time-integrated concentration in air, soil contamination, etc. are used for decision-making.

To calculate OIL's, models must be used which include, (e. g., the circumstances of the release due to the condition of the nuclear installation) the dispersion of radioactive substances in the atmosphere, the radioecology as well as the incorporation-related metabolism of the radioactive substance.

The following OIL's are used:

- released activity in Bq,
- time-integrated air concentration in Bq•h/m^3,
- ground contamination in Bq/m^2,
- surface contamination in Bq/m^2,
- specific activity in Bq/kg or Bq/l,
- gamma dose rate in mSv/h.

Structure of the revised Catalogue

The revised Catalogue will consist of two parts. The first part, in form of diagrams and tables, will allow for short-term decisions on initiating precautionary measures on the basis of available data. It includes:

Introduction

This section represents information required for the understanding of the objective and directions of the Catalogue.

Chapter 1: Foundations and structure of the Catalogue

This chapter contains explanations for the used designations, the general conditions, the structure and use of the Catalogue.

Chapter 2: Orientation diagrams and tables

The orientation diagrams in this chapter serve as a guide for the use of orientation tables, including criteria for the selection of required measures. On the basis of actual available information, (e.g. measured or prognosticated data on the time-integrated air concentration of specific nuclides), the table of relevance for these data can be determined from this chapter and identified from a model. For each countermeasure, the table refers to relevant additional information and data contained in other chapters of the Catalogue.

Chapter 3: Nomograms

This chapter contains additional information about the radiological situation in the form of nomograms for dose estimation. With the help of nomograms a quick dose estimation based on the time-integrated concentration in air or the surface contamination is possible.

Chapters 4 to 6: Compilation of commentaries on all countermeasures

Based on each area where countermeasures apply, the compilation is divided into respective focal points:

- disaster measures (chapter 4),
- precautionary radiological protection measures (chapter 5),
- measures in the agricultural and feeding area (chapter 6).

The text and tables summarize important information on countermeasures, particularly emphasizing on preconditions, feasibility, effectiveness, advantages, and disadvantages.

Chapter 7: Combination of data , information and documents

This chapter contains additional information which may be helpful for the work with the Catalogue. Among others, it includes data on nuclear power plants in Europe, tables referring to the nuclear inventory and the International Nuclear Event Scale.

Chapter 8: Example of use

The example serves to explain the work with the Catalogue in several time phases of an accident.

Appendix: Theoretical foundation

The appendix, the second part of the Catalogue, contains a summary of the theoretical principles and the most important equations used for the calculation of OIL's in the Catalogue. It provides the background for a more detailed familiarization with the Catalogue.

Limits of the Catalogue

In consequence of the manual-like character of the Catalogue, its universality is considerably limited compared to computer programs:

- For pre-calculation, it is necessary to establish specific model parameters. Under certain circumstances, such model parameters must be changed, if this should result in a better estimation of the actual accident situation.

- By a computer program essential quantities like contamination and radiation exposure can be determined by one process for all involved sites and points of time. With a manual, however, these quantities can be determined for only one site at a time and one point of time. Therefore, it is essential to gain first an overview of the sites and points of time for which estimations are to be prepared from measurement results.

- A particularly important restriction applies to the intervention level (IL). In the Catalogue, the dose corresponding with the IL is assumed to be fully exhausted by one exposure pathway. In practice, however, it must be assumed that next to one pathway there may also be others that play a more or less important role. Accordingly, the OIL which corresponds with the respective IL is generally too high. Nevertheless, this approach seems to be justified by the fact that the OIL is calculated based on the lower IL of the ICRP bandwidth concept. In addition, the proportions of the various exposure pathways contributing to the total exposure by one single nuclide may be determined by prepared nomograms.

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Protective Action Guidance For Nuclear Emergencies In Canada

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INTRODUCTION

In Canada, approximately 15% of the electricity generated is produced using nuclear reactors. The process for dealing with nuclear emergencies is essentially similar to that in the United States. The operators of nuclear generating stations, research reactors or other nuclear facilities are responsible for *on-site* emergency planning, preparedness and response. The provincial governments, like the states in the United States, have the primary responsibility for protecting public health and safety, property and the environment within their borders. The role of the Federal government is to develop, control and regulate the peaceful uses of nuclear energy, manage nuclear liability, and coordinate support to the provinces in their response to a nuclear emergency. The Federal government is also responsible for liaison with the international community.

Health Canada is the lead Federal department for planning and execution of the Federal Nuclear Emergency Plan[1]. This plan, recently revised, is intended to establish and organize a coordinated response by the Federal departments and agencies during a nuclear emergency in Canada or abroad. This Department also participates in a Joint Canada-United States Radiological Emergency Response Plan.

The Protective Action Guides (PAGs), or Protective Action Levels (PALs), are pre-specified levels of radiation dose that would justify the introduction of countermeasures to protect health and safety, property and the environment. These include sheltering, iodine prophylaxis and evacuation in the early phases of an accident, and relocation and food controls in later phases. All three Canadian provinces with operating nuclear power plants have their own protective action guides with specified radiation dose levels. However, there remains a need for a set of PAGs at the Federal level in order to coordinate the response to radioactivity that may cross provincial or national boundaries. Furthermore, it is recognized that countermeasures could also be introduced in response to the status of a damaged nuclear facility, without reference to explicit dose criteria.

DISCUSSION

In order to establish Federal PAGs, it was decided to review the international guidance on the subject. The ICRP-40 (1984)[2] recommended three basic tenets of radiation protection for planning purposes, viz., dose limitation, justification and optimization. This document also proposed projected upper and lower dose levels for different countermeasures as summarized in Table 1 which also contains doses from other agencies. The IAEA Safety Series No. 72 (1985)[3] introduced the concept of Derived Intervention Levels (DILs) (i.e., a dose rate or Becquerel concentration of activity that would correspond to a prescribed dose level for intervention). No numerical values for DILs were cited.

The ICRP-63 (1993)[4] supersedes the ICRP-40, and introduces the concept of dose averted (i.e., a dose that would be avoided by the introduction of countermeasures (Table 1)). At the time of an emergency, the actual intervention levels will be based on accident-specific parameters. The IAEA Safety Series No. 109 (1994)[5] was prepared as a revision of Safety Series No. 72. It incorporates the latest recommendations from ICRP-60 and ICRP-63. Safety Series No. 109 abandons the concept of a range of doses between upper and lower limits, and instead recommends single numerical values, called *generic* intervention levels, for the various countermeasures. Each generic intervention level is based on an optimization procedure for a generic accident scenario. When details of a specific accident become available, it will then be possible to carry out a further optimization to obtain *specific* intervention levels. The generic intervention dose levels are summarized in Table 1.

The protective action guidelines operative in the United States are most relevant to Canadian conditions because of the Canada-United States Joint Radiological Emergency Response Plan (1996).[6] At the U.S. Federal level, the Nuclear Regulatory Commission is responsible for technical advice and coordination among different levels of responsibility centres. The Environmental Protection Agency establishes Protective Action Guides at varied projected dose levels as enunciated in the Manual of Protective Action Guides and Protective Actions for Nuclear Incidents (1992).[7] As in ICRP-40 (1984), this Manual distinguishes between different phases of accidents as follows:

> *Early Phase:* This period refers to the beginning of a nuclear accident when immediate decisions for effective protective actions are required. This phase may last from hours to days.
>
> *Intermediate Phase:* The intermediate phase is the period beginning after the source and releases have been brought under control, and reliable environmental measurements are available for use as a basis for decisions on additional protective actions. This phase may overlap the early and late phases, and may last from weeks to many months.
>
> *Late (Recovery) Phase:* This is the period beginning when recovery action designed to reduce radiation levels in the environment to acceptable levels for unrestricted use are commenced, and ending when all recovery actions have been completed. This period may extend from months to years.

The protective actions recommended in the EPA manual are based on projected doses as shown in Table 1. Based on optimization, dose rates may vary significantly depending upon weather and personal conditions.

The food restrictions were developed by the U.S. Department of Health and Human Services, and Food and Drug Administration in the event of a nuclear incident. The Protective Action Guides for the consumption of contaminated foodstuff are set at an equivalent dose of 5 mSv (500 millirem) for the whole body and at 15 mSv (1.5 rems) to the thyroid; these guidelines are being reviewed at the present time.

All three Canadian provinces with operating nuclear power plants - Ontario, Quebec and New Brunswick - have their own protective action guides with specified radiation dose rates and/or levels. They are essentially based on international guidance and consensus as developed by the ICRP and IAEA.

Health Canada has drafted guidelines for the restriction of radioactivity in food in the event of a nuclear emergency. Presently, these guidelines are being discussed with other Federal agencies and the provinces for adoption. For drinking water, it has been decided that the existing Guidelines for Canadian Drinking Water Quality (1996)[8], meant for non-emergency conditions, be adopted in order to sustain public confidence. These guidelines are based on a lifetime exposure of 0.1 mSv/year; however, this exposure may be raised up to a level of 1 mSv/year during a nuclear emergency, if the conditions warrant. Thus, it appears that the Federal guidelines will be based on 1 mSv/year for each of the three food groups, viz. fresh milk, other foods and water. All the Federal guidelines and PAGs, existent or when developed, will become an integral part of our Federal Nuclear Emergency Plan.

A simplified summary of the Protective Action Guides from all jurisdictions discussed above is presented in Table 1. Some details (e.g., dose rates) have been omitted in order to simplify the comparison. With these considerations, it is remarkable to see the degree of consistency between the PAGs of different agencies. For nearly every countermeasure, the dose levels overlap.

In developing Federal protective action guidance, review of the international literature, including that of the United States, is essentially complete. We have also reviewed our provincial protective action guides. In the near future, we hope to specify projected radiation dose levels for different countermeasures. When completed, the PAGs will be discussed with our regulatory agency, the Atomic Energy Control Board, the provinces and the U.S. Federal agencies before adoption. Nonetheless, it is very likely that our protective action levels are likely to be in the range of those accepted internationally and by our provinces.

Table 1. Summary of Protective Action Guides by various agencies. All entries are expressed in mSv to the whole body except for KI administration, which is expressed as mSv to the thyroid.

Organization	Sheltering	KI Amins.	Evacuation	Relocation	Food Control
ICRP-40	5 - 50	50 - 500	50 - 500	50 - 500	5 - 50
ICRP-63	5 - 50	50 - 500	50 - 500	1000 lifetime	10
IAEA, SS109	10	100	50	1000 lifetime	~5
WHO, Codex					~5
EPA & FDA	5 - 50	250	10 - 50		~5
Health Canada					~3
Ontario	1 - 10	100-1000	10 - 100		~5
New Bruns.		500	50		~5
Quebec	3 per 12 hr	100	50 per 7 days	100-1000 life	2 in 1st year

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Integrated Analysis of Accident Scenarios, Radiological Dose Estimates and Protective Measures Efficacy Following a Radioactive Release

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INTRODUCTION

A nuclear accident may result in radioactivity being directly released to the atmosphere, to rivers, to the sea and to the ground. The main threat to urban areas and their inhabitants is generally considered to be from releases to the atmosphere, which are then carried over and deposit their radioactivity on towns and villages. The radiological assessment of the consequences of an accidental release of pollutants is an important tool for an emergency decision-making process, especially during the early and intermediate phase of an accident in which radioactive materials escape from the installation into the environment. The development and evaluation of adequate protective measures are part of the decision-making process and have to be concerned with several components. Among them, the technical and scientific components, such as the knowledge of the source-term (features of the release), availability of meteorological data, modeling of atmospheric dispersion, modeling of deposition and modeling of exposure (and health effects, if required). However, the social and economical components are also very specific for each region and need to be carefully considered.

Internationally, safety analysis studies ensuring that the public and the environment are adequately protected, are a requirement to obtain the permission for the operation of a nuclear power installation (operation license). More recently, a considerable amount of effort has gone into developing more realistic methods to fulfill the safety requirements. In addition to a huge amount of data gathered from studies during the pre-operational phase, up to the construction and operation of the power plant, there has also been a considerable development of environmental analysis techniques. These techniques demand an integrated approach taking into account all the relevant information to provide a better knowledge of the potential environmental impact associated with hypothetical accident scenarios in those plants.

All these developments have led to an increasing demand for greater levels of geographical data analysis and mapping procedures in the planning and implementation of major decisions, and also for the monitoring and evaluation of the results of these decisions. Geographic information systems (GIS) is an efficient method for storing information about complex relationships and plays an important role to improve the user's ability to make decisions in research, planning and management.

This study is concerned with the application of this integrated approach in the planning and selection of protective measures to protect the public in the case of an accidental release of radioactive material into the atmosphere. A very simple methodology was established taking the Brazilian nuclear power plant site as a case-study. By selecting a hypothetical accident for a generic pressurized water (PWR) to define the source-term, it is possible to estimate the radiation dose to the public. This layer of information is integrated to other layers of information related to specific environmental, demographic, social and economic features of the region where the plant is located. The objective of this approach is the identification and a previous selection of areas requiring a more detailed planning for the establishment of protective measures.

DISCUSSION

Background

Dose Estimates

The first consequence analysis study of nuclear power plant operation was introduced in the middle 70's: the Reactor Safety Study (WASH-1400).[1] In this publication, nine accidental-release categories and their respective source-term are described. After the accident in Three-Mile Island, further studies presented a much lower fraction of radionuclides in the source-term, indicating that a conservative approach had been adopted by the first study. However, in spite of these studies, the categories described by the WASH-1400 are still used as a technical basis for decision-making procedures.

The category selected for the purpose of this study is classified as PWR-4, which is described by a sequence of events leading to serious accident, including core melting and failure in the containment building. According to Dolores [2], the description of the PWR-4 category shows many similarities to those defined as BEED (Best Estimate from Empirical Data). Presently, the BEED category is considered the most reasonable one, as compared with empirical data available. Once defined as the source-term, the radiation dose can be estimated for different distances from the source.

Local Factors

In addition to dose estimates and local environmental factors, the establishment of a set of protective measures following a radioactive release, also depends on characteristics of population including social and economical conditions. In general terms, these factors can be listed as below:

1) Existence of groups of population
2) Distance from the emission source
3) Communication
4) Means of transport

5) Adequate roads or via of transport
6) Existence of appropriate shelters

The existence or absence of population is an important factor in the evaluation of the area to receive the first basic protective measures. The number of people in the different villas or groups will influence in some way the application of different protective measures. The higher the population, the higher the resources required for the implementation of protective measures. In another way, a high number of people could cause for example, a traffic jam in the case of an evacuation measure.

The distance of the emission source is an essential factor to be considered, since the accident-related dose is proportional to the distance. The application of certain protective measures is only required above a defined limit, below which no action is taken.

Communication capacity is related not only to the possibility of communication, via equipment of radio, TV, etc, but also to the capacity of understanding the situation as an emergency.

The existence of adequate roads and means of transport are especially important in the case of evacuation of people from the affected areas.

The shelters in the areas should be considered under two aspects: 1) as a shelter against bad weather conditions, allowing people to wait for further transferring or additional information; 2) as a radioactive shelter, reducing the radiation exposure and ingestion of radioactive material.

Case-Study

A brief description of the study-site and population characteristics are presented in the next paragraphs, giving emphasis to some aspects of geography, meteorology and population.

Local Characteristics

The study-site is located at the southeastern coast of Brazil (23.0° S, 44.5° W) about halfway between Rio de Janeiro and Santos (state of São Paulo). It is a bowl-shaped area with hills on three sides and a bay on the fourth side. The highway Rio de Janeiro-Santos (BR101) is directly beside the northern and eastern fences of the nuclear power plant site (NPP). The curved shoreline is oriented NWW to SSE with the bay to the west. To the north of the NPP and the highway, there are bluffs rising up to 700 m and to the southeast of the NPP hills rise to less than 300 m. Generally speaking, 50% of the area is occupied by hills and 50% by ocean. The hills are covered with a tropical forest of a dense canopy (Mata Atlantica). Local wind-systems and turbulence are complicated by the land-sea interface and high insolation due to low altitude. The region is also characterized by intense precipitation, low average wind speeds (about 1.5 m/s) and stable atmosphere (Pasquill class E). Agricultural and fishing activities are mainly of subsistence nature. Spotty cattle are raised on small-scale. The industrial activity is basically non-existent. Boating and swimming activities are practiced by the small population and by an increasing number of tourists during certain periods of the year [3].

Population

The site region is sparsely populated by small villages along the coast. According to a recent local census, a population of 10,804 people live within the area of 5 km around the NPP. Three categories can be used to describe the population:

Workers: all the individuals who work in the operation of the unit 1 and those involved in the construction of the unit 2. They are considered a special group of people who remain in the plant site on a daily basis. Presently, there are about 4000 workers in the NPP.

Permanent inhabitants: all the individuals who live permanently in the area. They are mainly concentrated in 3 areas: Residential Vila of Praia Brava (2102 inhabitants) fully occupied by workers and their families, as well by local people running small businesses in the area; Frade (2,354 inhabitants) and Cunhambebe (1,849 inhabitants).

Eventual inhabitants: mainly tourists, who spend the weekends and holidays in the region. Porto Frade and Praia Vermelha are the most popular resorts.

Most of the local population (98%) within the 5km radius, has some level of literacy, with only 2% illiteracy. In general terms, it can be said that the local population have a certain level of participation and a reasonable understanding of the NPP activities. Educational and information campaigns have been carried out by the plant operator. The installation of the plant in the region has also been an important source of employment.

Source-Term

Table 1 presents the probability of occurrence of the accident category PWR-4 including periods of time involved during the release of material and fraction of total inventory of fission products released into the atmosphere. Having defined the accident category, the dose estimates can then be evaluated using a proper code.

Table 1. Source-Term (PWR-4)

Probability and time					Fraction of the total inventory of fission products released from the core					
Probability/ reactor.year	Time(1) (h)	Dur(2) (h)	Adv(2) (h)	Energy 10^6Btu/h (7)	Xe, Kr	I	Cs, Rb	Ba, Sr	Ru	La
4×10^{-7}	2	3	2	1	1	0	0.04	5×10^{-3}	3×10^{-3}	4×10^{-4}

(1) Time interval between the beginning of the accident and the release of radioactive material into the atmosphere.
(2) Total time spent to release most of the radioactive material into the atmosphere
(3) Time interval between the acknowledgment of the release (to make the decision to apply protective measures) and the release of radioactive material into the atmosphere.

Scenario Analysis

Thyroid doses (4) were estimated for a range of distances up to 5 km from the source. The maximum doses are found within the range of 1-2 km from the plant, due to the release of heat energy in the considered accident category. Ground release, average wind speed of 1.5 m/s and Pasquill atmospheric stability class E were selected as being representative of the average conditions of the site. In addition, some other specific factors were established to identify those areas which need a further detailed investigation. Table 2 presents the factors which are considered in this integrated approach. Due to our limitation in terms of time, data availability and resources, some simplifications were made. However, the methodology can be applied to a wider range of scenarios or situations, taking advantage of more detailed information and resources available.

Table 2. Factors and weights adopted for the integrated analysis with GIS

Population	Weight	Thyroid dose (REM)	Weight	Commu nication	Weight	Shelte r	Weight	Roads	Weight	Means of Transport	Weight
100-500	1	25-50	1	yes	1	yes	1	yes	1	yes	1
500-1000	2	50-100	2								
>1000	3	>100	3								

As a starting point, it was considered that the selected areas should have at least 100 inhabitants. This limit was chosen due to the high number of very small localities scattered over the study region. Areas with a population higher than 1000 inhabitants were given the higher weight (3), since these areas would require a very well planned set of protective measures. The range of dose values shown in Table 2 were adopted as a result of the calculated dose distribution within a 5 km radius from the nuclear plant. Accessibility to any type of communication, capacity of understanding and existence of appropriate shelters were considered as being satisfactory (weight = 1) in the whole region, as well as the roads and means of transportation.

The integration of all the factors by using a GIS[5] has provided the identification of several areas falling into different categories. The areas showing the combination of the higher scores suggest the need of a prioritization in the investigation of adequate protective measures in the case of an accidental release of radioactive material into the atmosphere. The results could be summarized showing areas classified as having higher, intermediate and lower priorities. Figure 1 shows the location of these areas.

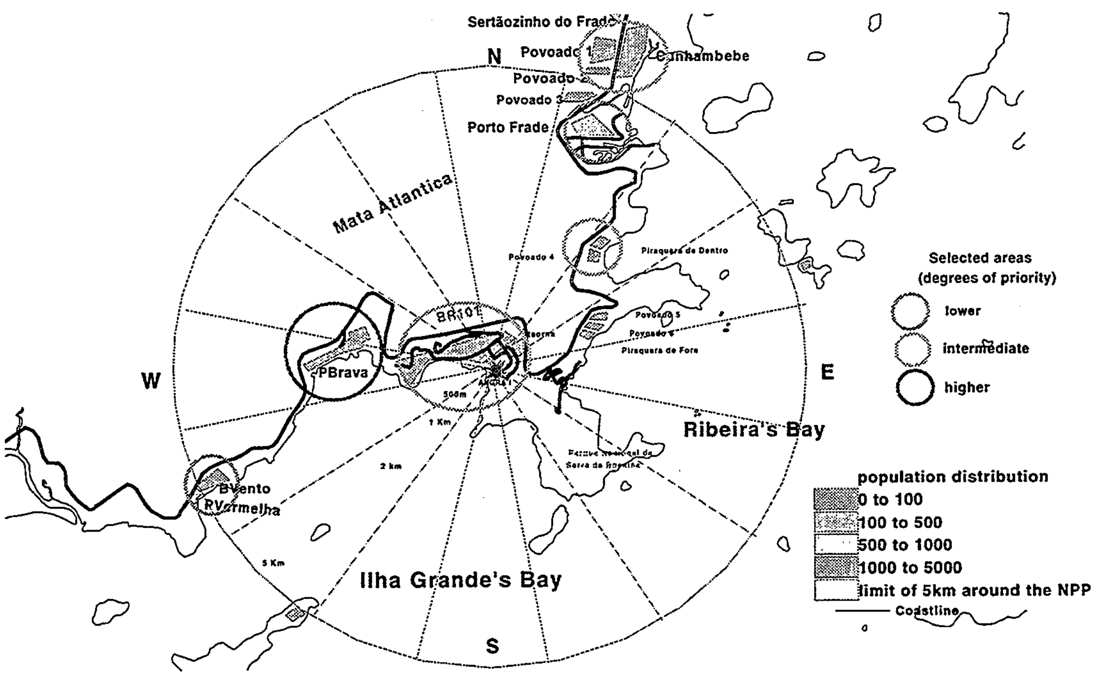

Figure 1. Study-area showing the location of the selected areas according to the criteria adopted by this study.

CONCLUSION

It was not the purpose of this work to exhaust all the possibilities of integration of information. A more detailed study would require the inclusion of additional relevant factors, improvement of dose estimates, meteorological data information, dispersion modeling, etc, would have to be introduced. However, even a simple approach has shown to be of great help by identifying critical areas in terms of planning of protective measures.

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Information Synthesis for Aiding Recovery Decisions

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INTRODUCTION

As part of NRPB's role to provide advice on appropriate actions to take after an accidental release of radioactivity, tools are being developed and investigations are underway to enhance the quality and scope of information provided to decision makers. Particular emphasis is placed on information that helps in the consideration of potentially protracted countermeasures (i.e., food restrictions, decontamination and access restrictions (including relocation)). The potential long term social and monetary consequences of applying such countermeasures reduces the scope for precautionary application and increases the need for confidence in the information to be acted on. However, for both radiological protection and social considerations, there is likely to be pressure for these decisions to be made as soon as possible. Thus, there is a need for tools that maximise the information extracted from measurements and provide guidance on the likely consequences and acceptability of countermeasures.

This paper describes three projects currently in progress at NRPB. They form part of a multilevel approach towards providing decision making support. The final section reviews how the results of these independent projects may link together, to provide a scheme that will provide more nearly optimal guidance on the application of such countermeasures.

DISCUSSION

Characterising the Problem

A four-year research programme called SECTAR* (Statistical Estimation and Characterisation Techniques for Accident Response), is investigating techniques for assessing the extent of contamination from limited quantities of measurement data. Two complementary approaches are being followed to provide data driven estimates of the extent of any contamination. In the first case, measurements are used to adjust model estimates through a process of Bayesian updating.[1] This process enables a gradual shift of emphasis from model estimates to estimates based almost entirely on the measured values of contamination, as more measurements become available. The alternative approach investigates how to use a range of established geostatistical techniques, successful in a data rich environment, in the data poor environment occurring in the early stages of an accident.

The two approaches, Bayesian updating and geostatistical techniques, naturally meld with an increasing reliance on measurement data to correct and eventually supersede model estimates as the accident evolves.

To test alternative geostatistical techniques, predictions using subsets of measurements are compared with the reality represented by a more comprehensive data set. Rainfall and other correlated information, possibly gathered from models, may also be used to support estimates of the extent and amount of contamination where direct measurements are sparse. An objective is to find out what sorts of inferences can legitimately be drawn for a given sample size.

An example of what may be achieved using a very simple geostatistical approach is shown in Figure 1. This figure shows the result of applying ordinary kriging,[2] to a few measurements from the accident in 1992 at the Tomsk reprocessing factory in Russia.[3] The figure shows that a few points can give a good representation of the final contamination pattern. However, further work is underway on the conditions under which this is likely and the range of errors associated with estimates based on limited data. Ideally, what is sought is not only the best estimate for a given amount and configuration of sampling, but an estimate of how reliable that estimate is likely to be. A primary application of this information (combined with practicality considerations) will be to decide if implementing a countermeasure is appropriate, based on what is known, or to delay until more data are available.

A key aspect of these investigations is the collection of information on accidents from around the world. The use of real data is an essential prerequisite, if the anticipated improvement over non-adaptive modelling is to be demonstrated. Data from the accidents at Chernobyl, Tomsk and Windscale are currently in use or preparation.

Options for Removing the Problem

NRPB has recently published advice on a framework for decisions on decontamination and restricted access countermeasures ('recovery countermeasures').[4] The advice promotes a proportionate response and recognises the need to consider countermeasure strategies, rather than treating each protective action independently. The emphasis is on considering the full impact of the proposed strategy, in terms of resources, time, waste generation, environmental and social impacts and the averted dose. Strategies that can be finished quickly with relatively low adverse impacts, whilst also being radiologically effective, should always be considered (Category A). More disruptive, less practical, but still effective procedures should be additionally considered if the dose to a resident population is likely to exceed 10 mSv y^{-1} (Category B). Generally, options that have low radiological benefit, but relatively high adverse consequences (Category C) should only be considered if other measures are unable to reduce lifetime doses from the accident to below 1 Sv, or for non-radiological reasons. The advice is summarised in Table 1 below.

Table 1. Summary of NRPB advice on recovery countermeasures

	Countermeasures	
Circumstance	To consider	Unlikely to be justified
Any offsite contamination	Category A	Category B Category C[#]
Dose > 10 mSv y^{-1}	Category A, Category B[+]	Category C[‡]
Lifetime dose > 1 Sv	All	None

[#] Potentially justified in support of other measures.
[+] Need to offset increasing resource requirements/disruption with increasing dose averted; in general relocation would not be justified at doses around 10 mSv y^{-1}.
[‡] Potentially justified in support of other measures, or if Category B measures impractical.

It is within this context that decisions on strategies involving decontamination will be taken in the UK. A PC-based decision aid CONDO (CONsequences of Decontamination Options)* has been developed to illustrate the practical consequences that follow from selecting alternative decontamination procedures.

Use of CONDO requires the contaminated area to be specified as a series of regions defined by contamination level and environment type (i.e., the relative proportion of different types of surfaces). This information is combined with the results of a major UK review on the effectiveness of decontamination techniques[5] and precalculated dose consequences obtained from modelling[6], to provide the following endpoints: level of decontamination achieved; monetary costs; resources required; timescale; waste arisings and level of activity; residual doses and doses to clean-up workers. For perspective notional relocation costs are also provided.

Placing Countermeasures in a Social Context

There are complex problems of acceptability and compliance associated with the application of recovery countermeasures. Whilst, there are only a few categories of countermeasure, the way they are applied and supported can have large, and long term, consequences on their effectiveness. A project on Social Psychological Aspects of Radiation Protection after Accidents (SPARPA)* is investigating possible interactions between countermeasures, doses and some social and psychological factors in the former republics of the Soviet Union affected by the Chernobyl accident.

The aim of SPARPA is to develop a structural behavioural model that explains, to some extent, how particular behaviours and hence doses arise. This knowledge will help in the development of decision models that aid the selection of countermeasures and the strategy adopted to implement them. The work involves the use of focus groups, questionnaire surveys and individual dose measurements, with greatest attention being given to the consumption of private milk and free forest foods. Previous studies[7] indicate that these are the dose pathways most likely to help elucidate key properties in the relationship between the context in which countermeasures are applied and their success in reducing doses. Additionally, the provision of compensation payments and information campaigns are also under study. One particularly novel aspect of SPARPA is the consideration of why particular population groups may comply with restrictions and the distress this or its converse may cause.

Clearly, an ideal decision may be expected to minimise cost and distress while maximising the dose averted. However, it is likely that tradeoffs will have to be made and the understanding gained from SPARPA will provide guidance[8] on how best to achieve this.

CONCLUSION

Synthesis - The Way Forward

The three example strands of NRPB research and development are key elements in a more comprehensive approach to improving information for the decision maker. SECTAR aims to provide optimum estimates of what can be known for a particular amount of sampling and support information, together with an estimate of the range of results consistent with the data. This improved understanding of the likely extent of contamination supports programs such as CONDO that provide estimates of the consequences of applying countermeasures. Such consequences are in turn supported by considerations of the influence of social psychological factors in countermeasure decisions[9]. SPARPA provides methods to generalise the discussion on the influence of social psychological factors that will result in a broader decision aiding framework, that better understands the limitations of the data and the complexity of the options available.

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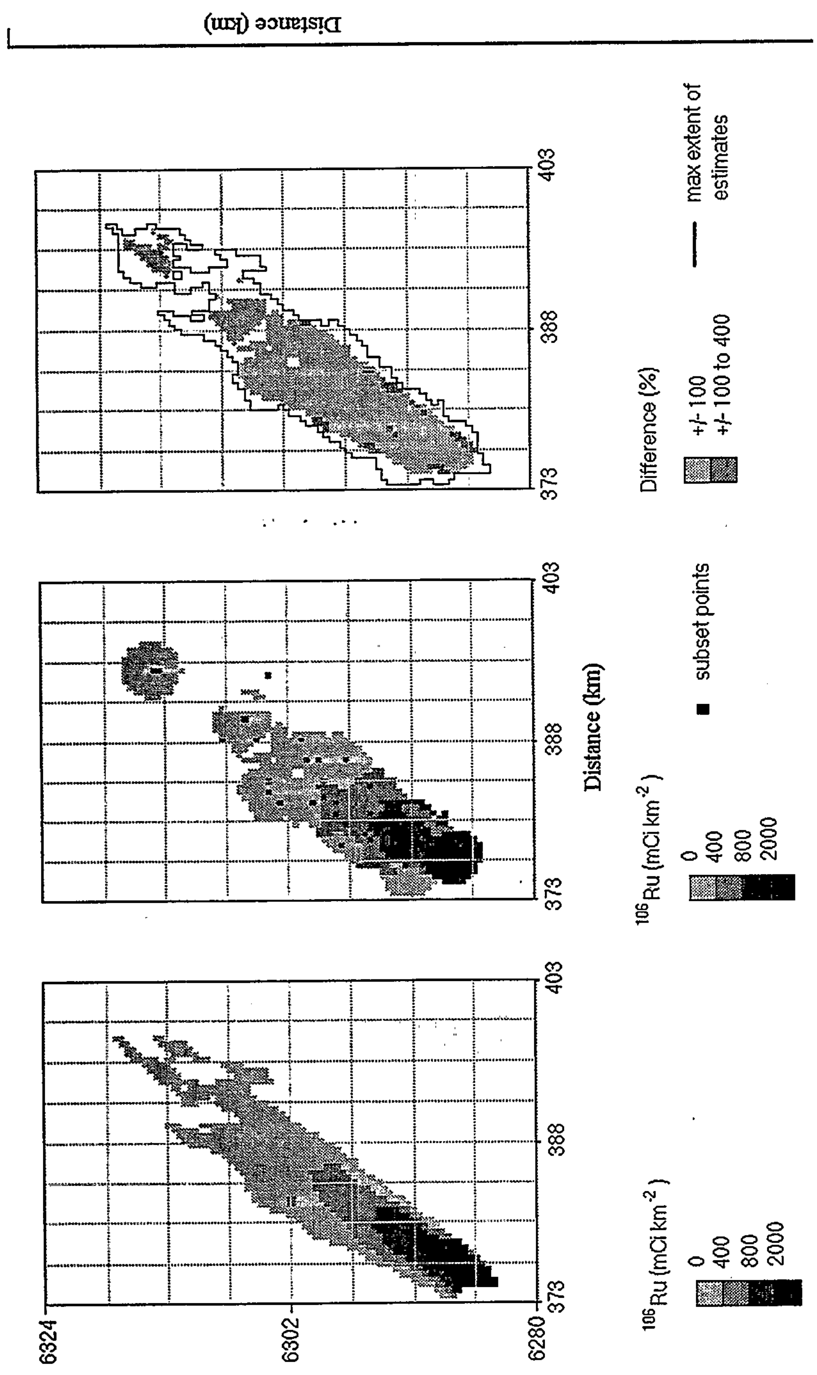

Figure 1 A comparison of an Ordinary Kriging estimate of 106Ru contamination from the Tomsk-7 accident using (700) measurements (left), a subset of 40 randomly selected measurements (centre) and showing the difference between the two estimates (right).