OECD DOCUMENTS

Agricultural Aspects of Nuclear and/or Radiological Emergency Situations

AEN NEA OECD NUCLEAR ENERGY AGENCY

OECD DOCUMENTS

Agricultural Aspects of Nuclear and/or Radiological Emergency Situations

OECD/NEA *Workshop*
Fontenay-aux-Roses, France
12-14 *June* 1995

PUBLISHER'S NOTE
The following texts are published in their original form to permit faster distribution at a lower cost
The views expressed are those of the authors,
and do not necessarily reflect those of the Organisation or of its Member countries

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

Publié en français sous le titre :

LES ASPECTS AGRICOLES DES SITUATIONS D'URGENCE NUCLÉAIRE ET/OU RADIOLOGIQUE

Cover photo: Photothèque EDF, *Centrale de Golfech* – Photo: P. Berenger

FOREWORD

For many years the OECD Nuclear Energy Agency has been involved in the field of nuclear emergency preparedness and management. As part of this work, a programme in the specific area of off-site nuclear emergency exercises was launched in 1990 to contribute to the identification of those aspects of off-site emergency response which involve neighbouring countries and international organisations, and which would benefit from improved international co-operation and co-ordination. Furthermore, the programme was intended to contribute to increased understanding between participating countries regarding national approaches to responding to nuclear emergencies. This work led to the organisation of an international nuclear emergency exercise, INEX 1.

Conducted in 1993, INEX 1 comprised two stages. The first stage was a national table-top exercise, which was carried out during the months of March-May in 16 countries (14 NEA Member countries and 2 non-member countries). The table-top exercises involved key decision-makers and experts responsible for emergency response matters. The second stage involved an international meeting, held in Paris in June 1993, at which representatives of each participating country shared experience from the exercise and discussed possible follow-up work in the area of emergency response and exercises.

To capture the experience gained and information gathered during INEX 1, a detailed analysis was performed and published as an OECD document: *INEX 1: An International Nuclear Emergency Exercise*. One of the issues which was identified early in this analysis was that of the management of agricultural problems following a nuclear accident. Specifically:

> "Several broad topics were identified which could benefit from international discussions. It was suggested that NEA sponsor and organise workshops to address the topics discussed below. There was a strong consensus that the focus of these workshops should be on the practical and implementation aspects, as opposed to theoretical aspects, of the areas addressed." One of these topics was:
>
> "the management of agricultural problems following a nuclear emergency, including the management, waste handling, and disposal aspects of large amounts of contaminated milk, feedingstuffs, and other agricultural products, as well as the management (stabling, feeding, etc.) of domestic livestock."

Based on this identified need, it was recommended that the NEA organise a workshop for discussing this topic in detail among international experts. The intent of this workshop was, broadly, to share experience in, and review national approaches to, the agricultural aspects of nuclear and/or radiological emergency situations. It was also agreed that the scope of the workshop should be limited to the agricultural aspects of large-scale radiological emergency situations. Based on these specifications and on the detailed analysis of INEX 1, the following were identified as the workshop's objectives:

1. To identify the main agricultural aspects of radiological emergency situations, and to review the standards and criteria for action.
2. To discuss the assessment and management of crops/food stocks, domestic livestock and wildlife, food processing, contaminated foodstuffs and waste, and soil decontamination needs.
3. To analyse the economic and social aspects of the agricultural issues associated with a radiological emergency situation.
4. To review the mechanisms for the exchange of information between agricultural and nuclear emergency experts during the different phases of a radiological emergency.
5. To discuss the various national approaches to the agricultural aspects of radiological emergency situations.
6. To develop conclusions and recommendations based on the workshop discussions.

The workshop took place in the Paris area from 12 to 14 June 1995, and was hosted by the French *Institut de Protection et de Sûreté Nucléaire* (IPSN) in Fontenay-aux-Roses, France. This document constitutes the proceedings from the workshop, including the papers presented, and the conclusions and recommendations agreed upon by the participants during the last session.

The opinions expressed are those of the authors only, and do not necessarily reflect the views of any OECD Member country or international organisation. These proceedings are published on the responsibility of the Secretary-General of the OECD.

TABLE OF CONTENTS

Chairperson of the Workshop – M. CARRETTE (France)

SESSION I: INTRODUCTION

Chairperson: Jean Brenot (France)

SESSION II: ASSESSMENT AND MANAGEMENT OF AGRICULTURAL ISSUES

Chairperson: Frances Fry (United Kingdom)

SESSION I

INTRODUCTION

Chairperson: Jean Brenot, France

THEORETICAL CONCEPTS, DECISION SUPPORT AND PRACTICAL ASPECTS

by

Andrea Schenker-Wicki and Dominique Rauber
Switzerland

Summary

Emergency exercises are part of the daily life of emergency organisations. Most attention is normally devoted to the early phases of an emergency while the later stages which visualise problems in agriculture and the food industry are often neglected. To test its theoretical concepts and its co-ordination role the National Emergency Operations Centre initiated exercise BACCHUS, for people from different authorities. For the first time in Switzerland, people responsible for the agriculture and the food industry were integrated into the decision making process of the later phases, in order to simulate the reduction of ingestion dose after an accidental release of radioactivity. The main conclusion from the exercise was that contamination criteria applied by the radiation protection experts and the food industry will be very different where uncontaminated food is available.

1. Theoretical Concepts

1.1 Introduction

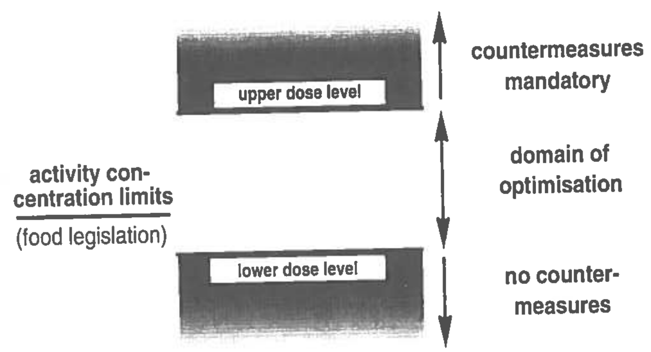
In recent years, the governments in the different countries affected by the accident Chernobyl have invested large sums of money in logistics, in hardware and software and in developing know-how for their emergency organisations in order to better safeguard their population. As a consequence of the accident at Chernobyl, computer-aided decision support systems, new communication-lines, and a better understanding of the radio-ecological as well as the epidemiological processes are commonly available today. Even though the emergency organisations are better equipped than ever before, the anxiety of the population with respect to the use of nuclear energy and the consequences of a possible accident has not decreased. According to general inquiries made in Switzerland, the population still has irrational fears with respect to radioactivity.

This fact will complicate the task of the emergency organisations due to the unpredictable behaviour and possible panic reaction of the population. To help overcome these difficulties, the National Emergency Operations Centre decided to involve responsible people from outside the administration in the decision-making process in order to test its theoretical concepts and preparations, and to guarantee that the countermeasures the administration proposes are as realistic as possible. This will both increase the competence of the Emergency Organisation in view of public opinion and facilitate the implementation of countermeasures due to a better mutual understanding of agriculture, industry and administration. To improve communication processes and to test the countermeasures proposed for the different phases after an accidental release of radioactivity, with respect to feasibility and acceptance, the National Emergency Operations Centre carried out exercise BACCHUS.

1.2 Legal Bases: Intervention Levels and Legal Limits

The Swiss Radiological Emergency Organisation is based on different laws and regulations. For foodstuffs, the revised radiation protection law and the corresponding regulation (both fully adapted to ICRP-60) are of importance. The radiation protection law gives legal limits on contamination in foodstuffs, equivalent to an average dose of about 5 mSv, and the radiation protection regulation contains the flexible dose-action-concept with upper and lower bounds (see Figure 1) for intervention in an emergency. If these limits can not be complied with, the government is allowed to raise the activity limits based on the flexible dose-action-concept, until they are equivalent to a dose of 20 mSv. A dose of 20 mSv is the upper bound for health protection.

Figure 1. Limits and Dose-Action-Concept



Additionally, tolerance values were defined as criteria for purity in the foodstuffs and were set one hundred times lower than activity concentrations given in the radiation protection regulations. The interpretation of the tolerance levels is a special problem in Switzerland. For the authorities involved in radiation protection there is no doubt that the tolerance levels in foodstuffs are separate from radiation protection. They are treated as a purity criteria in the same way as those for heavy metals or microbes. The food industry and the cantonal laboratories, which are responsible for the control of good and 'healthy' foodstuffs, made clear during exercise BACCHUS, that no foodstuff with an activity concentration higher than the tolerance level would be processed, as long as uncontaminated alternatives were available.

2. Decision Support in a Radiological Emergency Situation

2.1 General Remarks

In a radiological emergency situation, whether large or small areas are contaminated, the necessary support for the responsible authorities and decision makers has to be given by both computer systems, allowing rapid simulation of the consequences, and by experts. In the early phases of the emergency, organisations have to cope with a rapidly changing environment and unstable situations, so there will be no computer system which includes all the possible scenarios and is flexible enough to allow the necessary changes to be immediately integrated into the system. Therefore, even if a Decision Support System DSS is available, the know-how of the experts has to be combined with the use of modern data processing techniques and artificial intelligence. With respect to the consequences of radioactive contamination on the population and the environment, national authorities have to cope with a situation where the objectives of the decision makers are often contradictory, where an interdisciplinary approach is important and the decision making environment can suddenly change due to public pressure. To help overcome such problems, the Swiss Emergency Operations Centre has decided to design a DDS for its own use, which can also assist an expert-team responsible for the evaluation and ranking of the countermeasures considered.

2.2 Decision Support Systems DSS to Reduce Ingestion Dose[1]

Decision support systems (DSS) are defined as computer-based systems which assist the users in making efficient decisions on ill-structured problems. A DSS can be most successfully implemented, where a number of similar alternatives are to be judged in a complex environment.

The conceptional design of the system used in Switzerland examines decision-making on two different levels, a technical and a political level. The system itself involves four modules. In the first module, the threat is assessed using a prognosis model, called ECOSYS[2], which simulates the activity concentration in different foods and feedingstuffs and the corresponding doses. The purpose of this module is to give its users a complete overview of the dose received by two different population group (adults and children) in various parts of Switzerland. The input parameters of the dose assessment module are nuclide concentration in soil, rainwater and air. As deposition of radioactivity is unlikely to be homogeneous, the entire territory of Switzerland is divided into nine regions. Areas with different levels of deposition and typical agricultural structures are distinguished. Based on these data, activity concentration in foodstuffs and the resulting ingestion dose for the population in the corresponding areas are calculated.

To ensure sound decision-making, the maximum possible number of methods for reducing activity concentrations in food and feedingstuffs are automatically generated in a second module. To prevent the system producing unfeasible alternatives due to physical, chemical, biological or time restrictions, the list of evaluated countermeasures has to pass a filtering system. This prevents harvesting of immature crops or seeding and planting during winter time. The alternatives which do not comply with the restrictions are eliminated.

---

1 Schenker-Wicki, A. and Gibbert, R.: A Crisis Management Decision Support System to Reduce Ingestion Dose, Radiation Protection Dosimetry, Vol. 50, Nos. 2-4, 1993, pp. 367-372.

2 Müller, H. and Pröhl, G.: ECOSYS 86, Ein Rechenmodell zur Abschätzung der Strahlenexposition nach kurzzeitiger Deposition von Radionukliden auf landwirtschaftlich genutzen Flächen, Benutzer Handbuch, Stand März 1988, Institut für Strahlenschutz, Gesellschaft für Strahlen- und Umweltforschung, München-Neuherberg, 1988.

In the third module, the time span is determined during which a countermeasure must be implemented. To do so, the decision makers selects a countermeasure and the corresponding intervention level for each foodstuff and nuclide can be either calculated automatically with respect to the dose-action concept, or introduced interactively with respect to the legal limits or tolerance values.

In the last module the technical experts as well as the political decision makers have to judge the different countermeasures generated and specified in the former modules. The input for the evaluation module consists of the evaluation tables which have to be completed by the decision makers. The output is a complete ranking order of the countermeasures generated for a specific foodstuff and a critical population group. The criteria used for decision making are:

Technical criteria: dose reduction, efficiency, radioactive waste-generation and food supply
Political criteria: dose reduction, cost, acceptance and consistency.

The technical experts select the most promising countermeasures from their point of view and judge them with respect to the technical criteria. After having completed the corresponding evaluation tables and given the weights for the technical criteria, the ranking order can be calculated. Since the political decision makers have to take over the political responsibility, they are asked to decide the final ranking of the proposed alternatives with respect to political and economic criteria.

2.3 *The Use of the System*

The acceptance of the system is dependent on a quick response time, highly interactive components for a rapidly changing environment, simulation possibilities, condensation of the available information to a relevant information package for a certain user unit and connection to the monitoring organisation with a well defined data transfer capability.

The Decision Support System to reduce ingestion dose has been tested by the army staff of the National Emergency Operations Centre with respect to its operational performance and acceptance. Their views of the system were generally positive, demonstrating that its use should not merely be confined to learning and training functions. The experts among the military staff responsible for the DSS have not only tested the system components, but have also insisted on the implementation of a large data base showing default values with respect to the cost of certain countermeasures and their technical feasibility as well as the consequences for the food-supply.

Due to the fact that a DSS not fully integrated in the emergency standard procedures will be handled with difficulty in an emergency situation, the National Emergency and Operations Centre has decided to build up a special organisational structure around the DSS. Therefore, administration and army staff were assisted by a liaison officer to ensure direct and continuous communication between the emergency Centre and the experts in the federal agencies. This form of organisation has considerably enhanced the acceptance of the system and the belief that the evaluated data and countermeasures are realistic.

3. Practical Aspects

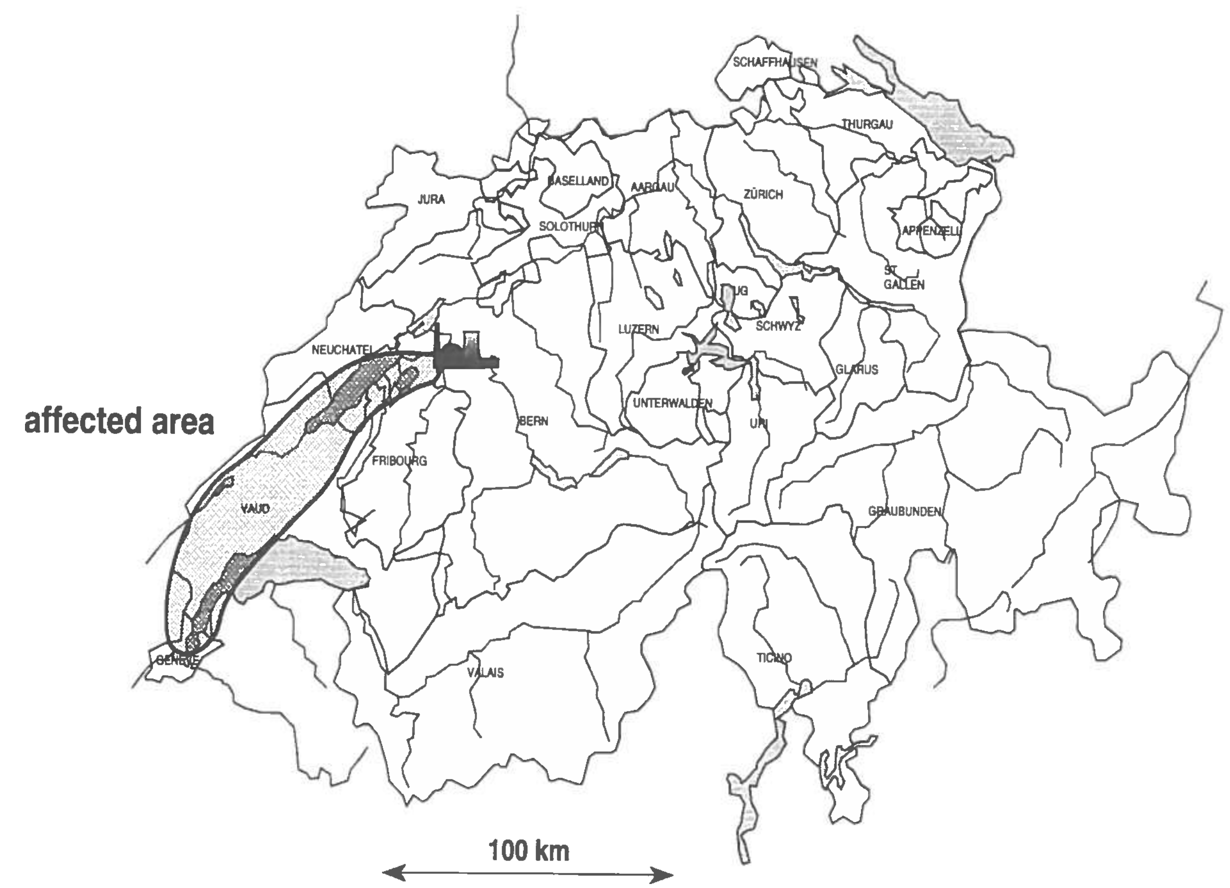
3.1 *Scenario*

A day was spent discussing the different phases of an accidental release of radioactivity and its implications for the authorities, the public and the agriculture industry as well as the food-industry.

The exercise was carried out as a table-top exercise, where the responsible people from the agriculture and food industries, and from the radiological emergency organisation were invited. It was the first time in Switzerland that people from the agriculture-and food industries have been introduced into the decision-making process of the radiological emergency organisation.

The scenario chosen was an accidental release of radioactivity in a Swiss nuclear power plant, assuming a melting core and the use of the new venting system established in Swiss nuclear power plants (see Figure 2). The use of a venting system allows the radioactive aerosols to be washed out and filtered. It considerably reduces the amount of aerosols and leads to a smaller area of contamination, with a diminished level of activity concentration. Staff from the nuclear power plant were not involved in the exercise. In order to get a structured discussion and some results at the end of the exercise, the directing board determined the focal points to be discussed at the beginning of each phase.

Figure 2. Scenario of exercise BACCHUS



3.2 *Actions in the first phase after an accidental release of radioactivity*

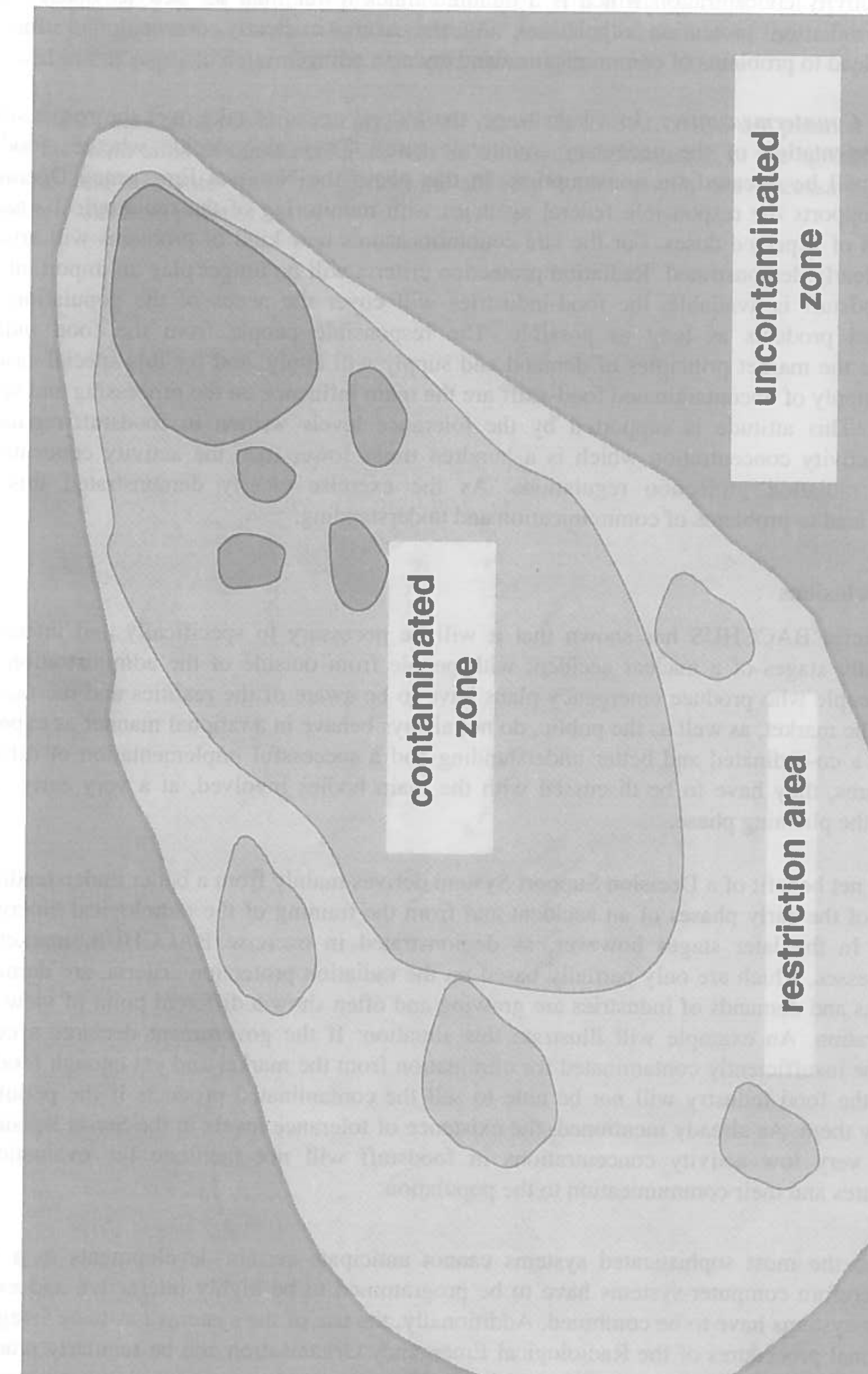
Alert Phase: The National Emergency Operations Centre is the first stage action team, ready to react in case of an accidental release of radioactivity. A contact point operating 24 hrs/day at the meteorological institute, a duty officer and automatic monitoring networks assure instant readiness, rapid warning and alerting of authorities and the public. The National Emergency Operations Centre operates from a protected installation with modern data processing and communication systems. For the first phase after an accidental release, text-modules will be broadcast to inform the public.

Checklists are available and an immediate monitoring programme can be built up with different measurements teams. It is obvious that in the very early phase, only the National Emergency Operations Centre can guarantee that the necessary prevention measures are taken, due to its high level of information and preparedness. Neither the federal and cantonal authorities nor the industry have a corresponding task force. As soon as the National Emergency Operations Centre gets the information about an incident in a nuclear power plant, it will transfer this information to the authorities and the public concerned. Even though the level of preparedness is high, there will always be problems in transmitting the necessary information to all authorities and the mass media in a short time. As most houses in Switzerland are equipped with basements and/or shelters, the main precaution in the very early phase of an accident is for people to stay indoors. External evacuation is not the first preventative action, it will only be used at a later stage, if necessary. With respect to countermeasures in the agricultural sector, in the very early phase the farmers are advised to stable the livestock, to protect it and provide it with ample fodder. The food-industry however will not be concerned in this phase, except if production plants are situated in the contaminated area.

Early Countermeasures: First actions with respect to the agricultural sector consist of determining a restriction zone, where the collection and selling of fresh agricultural products is prohibited. After the passage of the contamination, this restriction zone is determined, based on the available data from gamma-dose-rate measurements. For the chosen exercise scenario, core melting with the subsequent use of venting techniques, the restriction zone included an area where the gamma-dose-rate exceeded 200 mSv/h during cloud passage or where the net gamma-dose-rate exceeded 20 mSv/h after the cloud passage (see Figure 3). Outside the restriction zone, the expected activity concentration and the calculated doses were below the legal limits. Restriction zones have to be discussed for different types of nuclear accidents to enable the quick determination of a restriction zone after an accidental release of radioactivity. The concept of a restriction zone was accepted by the participants as a reasonable and necessary measure in order to avoid the transport of contaminated foodstuff to non-contaminated areas and provide time for the authorities to measure the activity concentration in food and feedingstuffs. As laboratory measurements of the different foodstuffs in the contaminated area shows results which are below the limits given by the regulations, the restriction would have been cancelled in increments, working from the outside of the area to the centre. As far as the feedingstuffs are concerned, there are no intervention levels in the Swiss legislation. This will allow the Radiological Emergency Organisation and the agencies concerned to evaluate the best use of the contaminated fodder with minimal constraints, though the recommendations of the European Union will be taken into account.

Late Countermeasaures: In a later stage, the federal agencies take over the responsibility for the implementation of the necessary countermeasures. They also decide whether food-and feedingstuffs will be released for consumption. In this phase the National Emergency Operations Centre only supports the responsible federal agencies with monitoring of the radiological situation and evaluation of expected doses. For the late countermeasures new kind of problems will arise, as the exercise clearly demonstrated. Radiation protection criteria will no longer play an important role. If enough foodstuff is available, the food-industries will cover the needs of the population with uncontaminated products as long as possible. The responsible people from the food industry confirmed that the market principles of demand and supply will apply, and for this special case the

Figure 3. Relationships between the contaminated zone and the restriction area



demand and supply of uncontaminated food-stuff are the main influence on the processing and selling of foodstuffs. This attitude is supported by the tolerance levels written in foodstuff-regulation, showing an activity concentration which is a hundred times lower than the activity concentration described in radiation protection regulations. As the exercise clearly demonstrated this will unfortunately lead to problems of communication and understanding.

Late Countermeasaures: In a later stage, the federal agencies take over the responsibility for the implementation of the necessary countermeasures. They also decide whether food-and feedingstuffs will be released for consumption. In this phase the National Emergency Operations Centre only supports the responsible federal agencies with monitoring of the radiological situation and evaluation of expected doses. For the late countermeasures new kind of problems will arise, as the exercise clearly demonstrated. Radiation protection criteria will no longer play an important role. If enough foodstuff is available, the food-industries will cover the needs of the population with uncontaminated products as long as possible. The responsible people from the food industry confirmed that the market principles of demand and supply will apply, and for this special case the demand and supply of uncontaminated food-stuff are the main influence on the processing and selling of foodstuffs. This attitude is supported by the tolerance levels written in foodstuff-regulation, showing an activity concentration which is a hundred times lower than the activity concentration described in radiation protection regulations. As the exercise clearly demonstrated this will unfortunately lead to problems of communication and understanding.

4. Conclusions

Exercise BACCHUS has shown that it will be necessary to specifically and intensively discuss the later stages of a nuclear accident with people from outside of the administration. The responsible people who produce emergency plans have to be aware of the realities and the fact that industry and the market, as well as the public, do not always behave in a rational manner as expected. To guarantee a co-ordinated and better understanding and a successful implementation of different countermeasures, they have to be discussed with the main bodies involved, at a very early stage, preferably in the planning phase.

The net benefit of a Decision Support System derives mainly from a better understanding of the planning of the early phases of an accident and from the training of the radiological emergency organisation. In the later stages however, as demonstrated in exercise BACCHUS, market and political processes, which are only partially based on the radiation protection criteria, are dominant. The influences and demands of industries are growing and often show a different point of view from the administration. An example will illustrate this situation: If the government declares a certain foodstuff to be insufficiently contaminated for elimination from the market and yet enough foodstuff is available, the food industry will not be able to sell the contaminated products if the population refuses to buy them. As already mentioned, the existence of tolerance levels in the Swiss legislation, which show very low activity concentrations in foodstuff will not facilitate the evaluation of countermeasures and their communication to the population.

Even the most sophisticated systems cannot anticipate certain developments in a crisis situation. Therefore computer-systems have to be programmed to be highly interactive and experts and computer-systems have to be combined. Additionally, the use of the systems has to be integrated in organisational procedures of the Radiological Emergency Organisation and be regularly practised in training. The involvement of people from outside the Emergency Organisation allows a critical and constructive review of the theoretical concepts designed by the radiological experts. As exercise

BACCHUS demonstrated, many problems, particularly the use of tolerance values, the feasibility of countermeasures and the passage from an emergency to an normal situation have to be discussed more intensively. One of the main problems however, which has to be solved by the Radiological Emergency Organisation, consists in a verification and detailed testing of the measurement values proposed in this paper to determine the restriction area.

To focus on specific problems, similar exercises to BACCHUS are planned for the future. One of the main aims of these exercises will be to transfer information to the agricultural and food industries and motivate them to participate actively while giving the necessary input from a completely different point of view.

AGRICULTURAL ISSUES

by

George E. Bickerton
United States

Although there has never been a major radiological release at any of the one hundred and ten licensed commercial nuclear reactors in the United States, an incident at the Three Mile Island Nuclear Power Station in 1979 highlighted the need for the United States to be prepared should a major radiological release occur. My office has been directly involved in approximately 600 Federal, State, and local radiological exercises as planners, plan reviewers, evaluators, and players. Through these exercises we have gained significant experience in plan development, exercise planning and scenario development, and in learning about the potential impact an accident could have on the agricultural community. Additionally, we have participated in several international exercises, the most recent being INEX 1 and the International Radiological Exercise 1994 (RADEX 94). We have observed that agricultural issues are a significant concern in most exercises whether they be International, National, State, or local.

In the United States, the individual States are principally responsible for the health and safety of their citizens. The primary responsibility of the Federal government is to provide guidance and assistance to the respective States in planning for and effectively responding to radiological emergencies. Specifically, the US Department of Agriculture responsibilities include:

- assisting State and local governments develop agricultural protective action recommendations for food producers, processors, and transporters to prevent or minimise contamination of agricultural products within the Ingestion Exposure Pathway Zone [an area approximately 50 miles (80.5 km) in radius around commercial nuclear power stations];
- assessing damage to the agricultural community following a radiological incident.

In order to effectively perform these functions, designated USDA officials collocate with other Federal officials at the Federal Radiological Monitoring and Assessment Centre (FRMAC). The FRMAC is an operations centre usually established near the scene of a radiological emergency where the Federal field monitoring and assessment activity is directed. The US Department of Agriculture is also represented on the Advisory Team for Environment, Food, and Health, along with representatives of the Department of Health and Human Services, the Environmental Protection Agency, and other Federal agencies as needed, to provide interagency co-ordinated advice and recommendations to the Lead Federal Agency concerning environmental, food and health matters. To facilitate the transfer of radiological monitoring and assessment data and to effectively co-ordinate with Federal, State, and local representatives, the Advisory Team is normally collocated with the FRMAC. The Nuclear Regulatory Commission is the Lead Federal Agency if the incident involves a licensed commercial facility.

In the United States, the Ingestion Exposure Pathway Emergency Planning Zone, which was mentioned earlier, is characterised by the deposition of radionuclides, notably iodine and cesium, on crops, other vegetation, bodies of water and ground surfaces, and the subsequent ingestion of contaminated food, milk, and water. The safety of the food supply within the 50-mile ingestion exposure pathway emergency planning zone will be of great concern to members of the agricultural community.

State and local governments use guidance developed by the US Food and Drug Administration[1] to determine whether levels of projected radiation dose warrant protective actions, and, if so, what protective actions or countermeasures are appropriate. With respect to human food and animal feed that are involved in interstate commerce, the Department of Health and Human Services and the Department of Agriculture are assigned Federal regulatory authorities and responsibilities.

The decision to recommend protective actions will be based on the emergency condition at the nuclear power station, available information on the amount of radiation that has been released to the environment, and consideration of the potential health, economic, and social impacts of the proposed actions.

Following are examples of specific protective action recommendations and related information that may be transmitted to the agricultural community by appropriate State or local government officials and related issues of concern that must be considered.

MILK

- The most critical early ingestion pathway is the milk pathway (pasture ⇨ cow ⇨ milk ⇨ processor ⇨ distributor ⇨ consumer) because of its possible effects on children. Radionuclides will appear in milk several hours after dairy cows consume contaminated forage and will reach a maximum between 24 hours and several days after a contaminating event. Farmers would be advised by the public emergency broadcast system to remove all lactating animals from pasture, shelter if possible, and provide them with protected feed and water. In order to determine if products are contaminated, State and local government officials will take milk, feed, and water samples for laboratory analysis.
- If dairy products are found to be contaminated, it may be recommended that milk be withheld from the market to allow for the radioactive decay of short-lived radionuclides. This may be achieved by freezing and storing fresh milk, concentrated milk or milk products. Storage of milk for prolonged periods of time at reduced temperature is also possible provided ultrahigh temperature pasteurisation techniques are used during processing. Using fluid milk for the production of butter, cheese, non-fat dry milk, or evaporated milk may also be possible.

ISSUE: In some states, dairy cattle graze outdoors throughout the year and there is limited shelter available. Also, there is no available market for processed dairy products. If the milk is contaminated it must be disposed.

What if the milk is heavily contaminated with cesium? What procedures can be followed to effectively dispose of this milk?

---

[1] U.S. Department of Health and Human Services, Food and Drug Administration [Docket No. 76N-0050], Accidental Radioactive Contamination of Human Food and Animal Feeds; Recommendations for State and Local Agencies, Federal Register, Vol. 47, No. 205, Friday, October 22, 1982

FRUITS AND VEGETABLES

The public would be advised to wash, brush, scrub, peel, or shell locally grown fruits and vegetables, including roots and tubers, to remove surface contamination of short-lived radionuclides, such as iodine-131. Preserving by canning, freezing, or dehydration and storing to allow time for decay of Iodine-131 is another option.

ISSUE: Public Perception: In situations where people are permitted to remain in their homes how can the public information function be effectively implemented so the general public feels safe living in their homes even though they must take precautionary measures before eating the locally grown fruits and vegetables.

SOIL

- Radionuclides in the ingestion pathway may remain as a long-term problem since the radionuclides in the soil could be taken up by vegetation growing at the time, or by future crops including vegetables, fruit trees, grains and forage. This could endanger future harvests. Variations in deposition and uptake may require detailed field testing and long term protective actions. If State or local government officials find that the soil is contaminated, proper soil management procedures can be implemented to reduce contamination to safe levels.
- Idling, or the non-use of the land for a specific period of time, may be necessary in some cases. In cases of highly contaminated soil, removal and disposal of the soil may be more appropriate.
- Alternating field crops may be beneficial in some situations. For example, it might be feasible to plant non-food crops such as cotton and flax in place of fruit and vegetable crops.
- If the plant root system is near the surface, deep-ploughing the soil may keep radioactive substances below the plant root zone, prevent plants from taking up contaminated nutrients, and allow the level of radioactivity to decrease with the passage of time. Also, liming soil and treating with high potassium content fertiliser will limit the uptake of strontium and cesium, respectively, by the crops.

ISSUE: The removal and disposal of a contaminated soil layer may be relatively easy, but is has a long lasting effect.

- Changing land use is technically, economically and socially complicated and may take a considerable amount of time to establish.

WATER

- Establish priorities for sampling water supplies in the area and determine if the water supplies are safe for human and animal consumption.

- Collect raw water samples to determine if gross contamination of raw water is evident. The ground water source should be monitored over an extended period of time to ensure that it has not been affected.

- Open wells, rain barrels and tanks should be covered to prevent contamination of water. Covered wells and other covered water sources normally will not be affected by radioactive depositions.

- Filler pipes should be disconnected from storage containers that are supplied by runoff from roofs or other surface drain fields. This will prevent contaminants from entering the storage containers.

- Close water intake valves from any contaminated water sources to prevent distribution of, or irrigation with, contaminated water.

- The necessity of taking protective actions to prevent public consumption of contaminated water supplies is unlikely since the accident sequences which would result in major releases to water pathways are very remote possibilities. In addition, there will be significant reduction in the radionuclide concentration by dilution in the water course and chemical treatment prior to public consumption.

ISSUE: If there is a concentration of cesium or tritium, in the water supply, the treatment methods above would have little or no effect. Modifying the existing water treatment facilities to receive adjunct chemical treatment to specifically remove potential radionuclide contaminants is not considered a feasible alternative. If water contaminated at unacceptable levels reaches domestic supplies, substitution of alternate sources of uncontaminated water should be considered[1].

MEAT AND MEAT PRODUCTS

- The intake of Cesium-134 and Cesium-137 by an adult via the meat pathway may exceed the intake through the milk pathway. Therefore, levels of cesium in milk approaching the preventive protective action level should cause surveillance and protective actions for meat as appropriate, such as removing livestock from pasture, sheltering if possible, or corralling, and placing on protected feed and water.

ISSUE: If for some reason a decision is reached that livestock must be destroyed, an interesting problem may result. Disposition will probably occur through either incineration or burial. Incineration may not be feasible, depending on the size of the animal herd and the availability of suitable incinerators. Burial would require approval of environmental or sanitarian officials.

- Monitor *poultry* if they are raised outdoors, especially if they are used for egg production. If poultry are raised indoors and fed stored rations, contamination is unlikely.

ISSUE: The eggs of poultry raised outdoors would also need to be evaluated. If these eggs are contaminated, any strontium would contaminate the shell, iodine would contaminate the yolk, and cesium would contaminate the egg white.

---

1 U.S. Federal Emergency Management Agency, Guidance on Offsite Emergency Radiation Measurement Systems Phase 3-Water and Non-Dairy Food Pathway, Page 3-10, May 1990

- *Fish and other marine life* raised in ponds should not be harvested until an appropriate State or local government official has been notified and arrangements have been made to sample and analyse the water, fish, and marine life.

ISSUE: Contaminated ponds present a serious problem for fresh water fisheries and fish farms. Cesium is extremely water soluble. (The ingestion of fresh water fish contaminated with radiocesium can be a significant source of radiation dose.) Since most fish raised in ponds are bottom feeding fish, any radionuclides that sank into pond sediment will probably be resuspended in the water when the fish are feeding and some would be ingested.

- *Grains* should be permitted to grow to maturity and then harvested. Milling and polishing will probably remove any remaining contamination.

ISSUE: If the incident occurs during the harvesting season, contaminated and uncontaminated grains should be stored separately.

- *Honey and bee hives* will need to be sampled and analysed by appropriate State or local government officials if radioactive contamination is detected in the area. The bee keepers would be instructed by the government officials on how to handle the hives and honey if they are contaminated.

ISSUE: In the United States, migratory bee keepers move through the area (probably in Spring). Crops pollinated by the bees include alfalfa, sweet cloves and soybeans. The beekeepers travel from Texas to Minnesota until Fall when they return South. Roughly 300 000 hives make the migration. It is only possible to move the hives in the evening, (during the day the bees are scattered). The meat/dairy pathway could be indirectly affected through alfalfa.[1]

- *Game and Wildlife*: The general public would be advised that game and wildlife may also be contaminated.

ISSUE: State and local officials need to be knowledgeable of the various species, and ensure that sportsmen understand the potential health hazards associated with ingesting contaminated meat.

In the event of an emergency, knowing which protective actions to recommend is important. However, to ensure that a State is prepared to successfully protect the public's health and safety, we believe that having an effective emergency response plan in place is essential. For several years, our staff has worked closely with the States in the development and exercise of radiological emergency response plans. We have developed several thoughts and ideas from these experiences. I will share some of what we consider the more significant issues.

PLANNING FOR AN INGESTION EXERCISE: It has been our experience that planning efforts have been enhanced when most of the following steps were followed:

- A planning meeting was held 6 months to a year in advance of the exercise. The meeting, which involved State and public utility planners, Federal and other State officials, served as an opportunity to identify and reach agreement on the exercise objectives.

---

1 Alan Marrson; America's Bee Keeper: Hives for Hire; National Geographic, Vol. 183, No. 5, Washington, D.C., May 1993

- Federal agencies were requested to provide exercise players as well as evaluators. (This enabled the State to learn under exercise conditions, the type of support they could anticipate from the Federal government.)
- Protective Action Recommendations that were developed were specific rather than general.
- Ingestion exercises were designed to include at least some play in ingestion counties outside the 10 mile or 16 kilometre plume emergency planning zone that might not otherwise be involved in exercise play.
- Exercise plans included provisions to release general public information to the agricultural community as well as relevant agriculture specific information.
- Exercise plans included provisions for ingestion, re-entry, relocation and return activity during the post-emergency phase.

To the extent feasible, provisions were made to involve key personnel as players in the post-emergency phase of the exercise.

ALERT AND NOTIFICATION: Even if all State and local officials are extremely knowledgeable and confident in the development of agricultural protective action recommendations, they will not be effective if the protective action recommendations are not transmitted to the agricultural community. I will briefly discuss several methods which are considered for distributing information in the United States.

- The Emergency Broadcast System is activated by the State and local officials during the early stages of an incident. This involves not only the initial notification to the general public, but also may include specific information relevant to the needs of farmers, processors, distributors, and other participants in the food production process located in the 10-mile plume emergency pathway zone.
- States are also required to publish and distribute an Agriculture Brochure to the agricultural community within the 10-mile radius of the commercial nuclear power station. This brochure provides emergency information to the agricultural community. For example, the brochure includes recommended protective actions to protect family, farm animals, and agricultural products. It must be available for distribution throughout the entire 50-mile ingestion emergency planning zone in the event of an emergency.
- Co-operative State Research, Education and Extension System: This is an electronic mail network that can transmit information from the Department of Agriculture's Co-operative State Research, Education, and Extension Service headquarters in Washington, DC to State Extension offices throughout the United States. The State Extension offices notify the County Extension Agents, and they notify the agricultural community through local television, radio, newspapers, or by telephone.

SAMPLING STRATEGY: Developing a sampling plan or prioritising sample collection is a key part of the planning process. Once radiation is released, State and local officials must be able to develop a "footprint" or map of the contamination. Having site specific information, such as maps and other documents that show land use data, (*e.g.* dairies, pastures, fruit and vegetable growers, processing plants, water treatment plants and reservoirs, dams, and canals) helps identify where to sample. After determining the location of samples to be taken, trained and experienced teams are deployed to collect, transport, and analyse samples.

FARMER RE-ENTRY: Many states have developed a policy of permitting farmers to renter evacuated areas for limited time periods for the purpose of tending livestock or performing other essential functions. A question that must be resolved is who will decontaminate farm animals and buildings and when?

CONTAMINATED WASTE DISPOSAL: States and local officials must know which officials have regulatory authority and responsibility for clean-up and reclamation.

In January 1987, following the accident at Chernobyl, the World Association of Veterinary Hygienists held an international round table conference in Stockholm, Sweden. The purpose of the conference was to help prepare veterinary food hygienists to respond appropriately and efficiently to possible radiological emergencies from accidental releases of radioactivity. It was acknowledged that veterinary food hygienists should play a vital role in minimising the public health consequences of such an accident by containing the spread of radioactivity throughout the animal food chain. The conference focused on veterinary food hygiene in the discipline's of physical and biological science, ecological science and veterinary science. Subsequently, the American Veterinary Medical Association appealed to the emergency planning community to involve veterinarians in emergency planning and response so that appropriate attention can be focused on protecting food of animal origin in the event of a radiological emergency. In the US many states and the Federal government are involving veterinarians in the development of emergency plans to protect food of animal origin. The veterinarians are an extremely valuable resource.

Recovering from an emergency: Finally, there are four critical issues that in my opinion require greater attention:

> *Public Perception*: I once heard public perception defined as "pictures in your mind." People often have a mind set about radiation. When we make such references as "radioactive contamination", "slightly contaminated" and "plume exposure pathway", we may be contributing to a public perception that is already misinformed. If we can assume that people will take action most of the time based on how they feel, not what they think, it is easy to understand why fear can often cause more damage than the potential danger from radioactivity. A key question we are beginning to ask our State officials is: Have you made provisions in your emergency for involving a credible, credentialed individual to explain to the general public why certain protective actions are being taken and what radioactivity is and what it can and cannot do? It has often been stated that following an emergency, things don't return to normal. A new norm is established. A credible expert can help facilitate this adjustment. Even with minimal or no environmental damage, a community may be faced with severe problems.

Social Issues: There are many social issues that could impact the agricultural community and might have to be addressed in a serious emergency. Following are some social issues that create their own challenges and are, at times, not explored in sufficient depth during exercises to determine their potential impact:

- return to homes/farms;
- staying in shelter;
- psychological: stress/anxiety;
- counselling: costs and availability;
- relocation to new areas;

- social services;
- recreational losses: closing of local, regional, State, or National Parks;
- environmental concerns: contaminated water supplies;
- medical impact/costs;
- travel restrictions: road, rail, air restrictions;
- loss of sentimental items;
- long term return to normal.

Political Issues: The political issues that may arise are many and varied and may be strongly impacted by public perception and reaction. Decisions may be made that are more emotion driven than objective or science based. Pressures and constraints that would not normally be a part of the decision making process are suddenly critical issues that have to be addressed. If these issues are not carefully addressed the results may include:

- loss of public confidence, (misinformation);
- loss of election;
- loss of reputation;
- lawsuits for improper decision-making;
- unfavourable public perception about decision making (lack of co-ordination among and between affected State, counties, and local emergency response officials);
- inhibited decision making and thus a slow recovery process.

This will probably impact all levels of government.

Economic Issues: When we start thinking economics one of the first things that comes to mind is money ; more specifically, lost income. Following an emergency, public perception can potentially have a great impact on the economics of the impacted area. Some concerns are often valid, some concerns are raised for selfish reasons and many result from misinformation and fear. The results can be devastating. The issues that are raised here may impact severely on agriculture:

- loss of harvested/growing crops and breeding stock;
- quarantine and embargo costs;
- loss of recreational areas;
- disposal/clean-up costs;
- temporary lodging;
- decline in business (producers, distributors, processors, suppliers, feed);
- petroleum, equipment;
- loss of tourism;
- loss of jobs;
- loss of farm equipment usage;
- bankruptcy;
- intra/inter state and international market loss;
- alternate feed source cost;
- safe area – public acceptance;
- medical/veterinarian assistance;
- depreciation of farm/home.

Public perception and the related social, political and economic issues present emergency responders with one of their greatest professional challenges. These are complex issues which require much thought and planning to minimise their potential negative impact should an emergency occur.

STANDARDS AND CRITERIA ESTABLISHED BY INTERNATIONAL ORGANIZATIONS FOR AGRICULTURAL ASPECTS OF RADIOLOGICAL EMERGENCY SITUATIONS

by

J.I. Richards, R.J. Hance
Food and Agriculture Organisation of the United Nations

and

M.J. Crick
International Atomic Energy Agency

1. Introduction

During the past 35 years, three major accidents at nuclear facilities have given cause for concern and required the implementation of countermeasures in agriculture. These accidents occurred at Windscale (United Kingdom) in 1957, Kyshtym (former Soviet Union) in 1957 and Chernobyl (former Soviet Union) in 1986.

Other nuclear accidents which caused some contamination of agricultural land occurred in Palomares (Spain) in 1986 when an aircraft carrying nuclear weapons crashed, and in Canada in 1987 following burn-up on re-entry of the nuclear powered satellite Cosmos 954. Clearly, despite the increased knowledge on the safety of nuclear power plants and the implementation of improved procedures, the possibility cannot be excluded of other accidents in future with the consequent deposition of radioactive material into the environment.

As nuclear facilities are not normally sited in densely populated areas, the adjacent land is typically agricultural or at least rural. The accident at Chernobyl showed that agricultural practices can be affected hundreds and even thousands of kilometres from the accident site. Therefore contingency plans are needed to initiate countermeasures that can be used to reduce contamination of agricultural produce, even in countries with no nuclear facilities or programmes of their own.

The main considerations for government (from central down to local) in preparing an agricultural countermeasures strategy are to:

- define national (or local) Intervention Levels for foods (and feed stuffs) and Maximum Permitted Levels for food in trade based on international recommendations;
- protect human health by reducing radioactive contamination of agricultural products;
- define countermeasures to be applied before and during fallout, and in the consequent medium and long term;
- return the land to normal use as far as possible;
- ensure that the countermeasures applied balance health protection measures, cost, disruption to daily life and the well-being of communities;
- take account of general environmental contamination (especially forests and water bodies) and its effect on agriculture.

One of the major guidelines employed in developing suitable strategies is the radiation dose or contamination level above which intervention is advised. This paper will deal largely with the development of international recommendations for intervention levels.

2. The development of intervention criteria and levels

Largely in response to the Chernobyl accident, the international community developed guidelines to assist competent national authorities apply established basic principles for intervention [1]. For instance, in 1986, the Commission of the European Communities (CEC) published a report on "Derived Emergency Reference Levels in Widely Distributed Foodstuffs" [2]. In the same year, the IAEA published Safety Series No. 81 which addressed the principles, procedures and data needed to establish levels of dose at which it was considered necessary to introduce relevant protective measures, so-called derived intervention levels (DILs), [3]. Also in 1986, a group of experts was requested by the Food and Agriculture Organisation of the United Nations (FAO) to recommend limits for radionuclide contamination of food [4]. In 1988, the IAEA published its "Revised Guidance on the Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency" [6], the World Health Organisation (WHO) published its "Derived Intervention Levels for Radionuclides in Food" [5], and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) published a report on "Sources, Effects and Risks of Ionising Radiation" [7]. Also, in 1989, the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) produced its "intervention levels for protection of the public" [9].

In spite of these efforts, there remained discrepancies in the application of both the principles and guidance for intervention. As a result, some of the protective actions taken may, in the most extreme cases, have detracted from rather than increased the welfare of the population concerned and the quality of the environment. In other cases, the actions taken led to an excessive expenditure of national resources. Furthermore, since the Chernobyl accident caused exposure to people across national boundaries, many instances occurred of contradictory national responses.

In particular, it became clear from the experience of the Chernobyl accident that there was a need for a simple set of consistent Intervention Levels that could have some generic application internationally. Such values were also considered desirable to increase public confidence in authorities charged with dealing with the aftermath of an accident. Since many countries have no nuclear facilities and hence no detailed emergency plan themselves, a simple internationally agreed set would assist them in the event of transboundary releases.

In drawing up these guidelines, the new recommendations of the International Commission on Radiological Protection (1991) [10], the FAO/WHO Codex Alimentarius guidelines on 'Levels of Radionuclides in Food Following Accidental Nuclear Contamination' (1991) [11] and the conclusions and recommendations of the International Chernobyl Project on the 'Assessment of Radiological Consequences and Evaluation of Protective Measures' (1991) [12] were considered. It is noteworthy that the newly established World Trade Organisation will invoke the FAO/WHO Codex Alimentarius levels for all contaminants, including radio-nuclides, in foods moving in international trade.

Because of the need for international consensus on the values of these generic intervention levels, an IAEA Advisory Group developed proposals that were published in a Technical Document (IAEA-TECDOC-698) in April 1993, entitled Generic Intervention Levels for Protecting the Public in the Event of a Nuclear Accident or Radiological Emergency [17]. This interim report was circulated

for comment to all 124 Member States of the IAEA and to relevant international organizations. Taking account of the many comments received, an IAEA Technical Committee Meeting on Intervention after Accidents modified the text and values proposed in the TECDOC-698. Safety Series Guide No. 109 [19] is the result of that process, and represents an international understanding on the principles for intervention and numerical values for generic intervention levels.

The recommendations of this Safety Guide are the basis for the standards and numerical guidance related to intervention contained in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [20] of the FAO, the IAEA, the International Labour Organisation (ILO), the NEA/OECD, the Pan American Health Organisation (PAHO) and the WHO.

Based on these recommendations, in 1994 the IAEA and FAO published guidelines of their joint undertaking on *Agricultural Countermeasures following an Accidental Release of Radionuclides* [17].

3. Concepts and criteria employed in identifying appropriate and effective countermeasures

3.1 Importance of adequate planning and appropriate response

In the event of a nuclear accident, the effectiveness of measures taken to protect the agricultural sector (people, land, crops and livestock) will depend upon the adequacy of emergency plans prepared in advance. In these emergency plans, criteria are specified for taking particular prompt action. Even after the immediate emergency, having predefined criteria for longer term action will do much to counter any loss of confidence in the competence and integrity of the authorities on the part of the public. Such criteria for intervention are based primarily on radiological protection principles.

3.2 The management of accidents

There are two distinct phases in which optimisation of protective measures should be considered:

- In the phase of planning and preparation, prior to accidents, a *generic* optimization of protective actions should be established, based on a *generic* accident scenario calculation. This should result, for each protective measure and each selected scenario, in an optimized *generic* intervention level, which is meant to be the first criterion for action to be used immediately and for a short time after the occurrence of an accident.
- Some time after the beginning of a real accident, specific information on its nature and likely consequences and evolution would be expected to be available. In this case, a more precise and *specific* optimization analysis should be carried out on the basis of actual data and the actual efficiency of protective measures. This should result in a *specific* intervention level for each protective measure, to be used as criteria in the medium and long term. However, in many cases the optimization will be constrained by socio-political factors, which may make it difficult to alter the generic intervention levels unless there are overriding reasons.

3.3 *Protective measures*

With regard to protecting against the deterministic and stochastic health effects associated with radiation exposure, three major principles have evolved, and they appear to have almost universal acceptance.

- All possible efforts should be made to prevent serious deterministic health effects.
- The intervention should be justified, in the sense that introduction of the protective measure 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 measure will produce a maximum net benefit.

In practice, agricultural countermeasures normally address stochastic health effects in the human population although the more immediate impact of radiation exposure on plant and animal life should be considered.

The protective measures that are available to avert or limit radiation doses via the exposure pathways concerned (see Figure 1) are presented in Table 1. The risks, difficulties, disruption and financial costs that these various protective measures entail differ widely and depend on many factors, including the location of the site and the meteorological conditions at the time of the accident. Consideration is generally limited to the major protective measures: sheltering, relocation, restriction, decontamination, treatment and control of soils and feedstuffs.

4. Generic intervention levels for foods

There are a number of advantages in using internationally recognised intervention levels:

1. maintaining credibility, confidence and trust in the authorities;
2. preventing anomalies that might otherwise exist along borders of neighbouring countries; strong arguments can be made to adopt international values as national intervention levels for control of food.

The FAO/WHO Codex Alimentarius Commission addressed the situation of international standards in order to maintain widespread international trading in food. Guideline levels for radionuclides in international trade following accidental nuclear contamination have been agreed. It should be recognised that these levels are a compromise between what is appropriate on radiological protection grounds (which would give rise to higher values) and the natural wish of countries unaffected by an accident to avoid importing produce with any contamination at all, no matter how small, even compared with natural radiation. These values are reproduced in Table 2.

Figure 1. Human exposure pathways

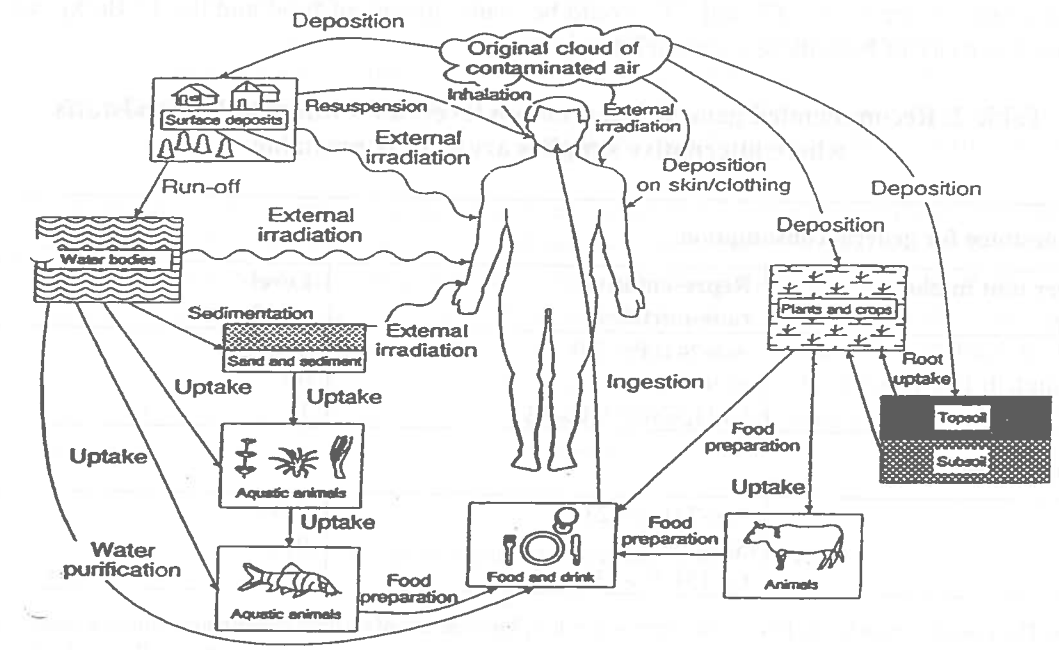


Table 1. Protective measures for averting radiation exposures via various pathways

Protective measures	Main exposure pathways
Sheltering[1,2]	External irradiation from facility, plume and ground deposits Inhalation of radioactive material in plume Deposition on skin and clothes
Temporary relocation[1,2] and permanent resettlement[1]	External irradiation from ground deposits Ingestion of contaminated food and water Inhalation of resuspended radionuclides
Restriction of access into contaminated area[1,2]	External irradiation from ground deposits Inhalation of resuspended radionuclides
Decontamination of land[3], buildings and roads, vehicles and 'removal' of radionuclides from soil through scraping and deep ploughing	External irradiation from ground deposition of radionuclides Inhalation of resuspended radionuclides
Restriction of feedstuffs (*e.g.* transfer from pasture to indoor feeding) or substitution with 'clean' feed[2]	Ingestion of radionuclides
Treatment with chemicals which reduce uptake of radionuclides (*e.g.* lime, K fertilizers, Prussian Blue)[1,2,3]	Ingestion of radionuclides through forage and feed by meat and milk producing livestock
Processing of food or withdrawal from sale[1]	Ingestion of radionuclides

1. human consumption,
2. livestock,
3. land.

As the proposed levels were derived using extensive conservative assumptions, there is no need to add contributions from each of the three groups of radionuclides; each group should be treated independently. However, if more than one radionuclide is present, the activities of the different accidentally contaminating radionuclides within a group should be added together. For example, following a reactor accident, ^{134}Cs and ^{137}Cs could be contaminants of food and the 1 kBq/kg refers to the summed activity of both these radionuclides.

Table 2. Recommended generic intervention levels for withdrawal of foodstuffs where alternative supplies are readily available

Foods destined for general consumption		
Dose per unit intake (Sv/Bq)	**Representative radionuclides**	**Level kBq/kg**
10^{-6}	Am-241, Pu-239	0.01
10^{-7}	Sr-90	0.1
10^{-8}	I-131, Cs-134, Cs-137	1
Milk and infant foods		
10^{-6}	Am-241, Pu-239	0.001
10^{-7}	Sr-90, I-131	0.1
10^{-8}	Cs-134, Cs-137	1

Notes: The generic action levels have been expressed in kBq/kg so as to reflect their lesser underlying precision.
These levels apply to situations where alternative food supplies are readily available. Where food supplies arescarce, higher levels can apply.
These levels are intended to be applied to food prepared for consumption, and would be unnecessarily restrictive if applied to dried or concentrated food prior to dilution or reconstitution.
The Codex Alimentarius Guideline Levels remain applicable for one year following a nuclear accident.

Both FAO and WHO have called attention to the special consideration that might apply to certain classes of food which are consumed in small quantities. Some of the foods grown in the areas affected by the Chernobyl accident fallout contained very high levels of radionuclides following the accident. Because they normally represent a very small percentage of total diet and hence would make very small additions to the total dose, application of the Guideline Levels to products of this type may be unnecessarily restrictive. FAO and WHO are aware that policies vary at present in different countries regarding such classes of food.

The generic intervention levels are specified as activity concentrations of a particular radionuclide (or group of radionuclides) in the foodstuff (*e.g.* Bq/kg, Bq/L), and countermeasures should normally be taken to achieve values lower than these. The values selected were also chosen on the basis of ranges of optimized intervention levels specifically for withdrawal and substitution of food, and for the substitution of clean fodder to animals (Table 3), with due account taken of the radiotoxicity of the various radionuclides, the nature of the foodstuff and the cost of simple agricultural countermeasures.

The resulting levels in Table 2 are strictly 'action' levels since they are not for any specific countermeasure, nor are they expressed in terms of an avertable quantity. Consistency and simplicity in application and compatibility with the guidance of the Codex Alimentarius Commission were important considerations in the selection of specific values.

5. Specific intervention levels

It should always be recognised that accident and site specific conditions, as well as political considerations, might lead to different levels, even outside the ranges. In particular, where the numbers of people and area of land potentially affected by a protective action become extremely large, the cost of resources and societal disruption become more and more important in comparison with available national resources, and relaxation of the intervention levels may be necessary. On the other hand, when the numbers of people and area of land potentially affected are very small, additional costs incurred in order to gain public confidence can be more readily absorbed by society.

In practice, the specific intervention levels used in CIS countries differ from the generic levels (see Table 4). Thus, national and local authorities believe there is good reason for lowering the intervention levels for foodstuffs in comparison with generic guidelines in view of the additional contribution of external exposure to the total dose in certain localities. The overall impact of this on the agricultural community is variable; for instance, milk and meat may be deemed to be more "contaminated" than necessary so causing concern among consumers, both local and distant. On the other hand, producers will continue to receive subsidy payments for longer in view of the fact that their milk and meat produce is above nationally acceptable TPLs.

Table 3. Optimized intervention levels for food

Radionuclide group (*e*(50))	**Optimized intervention level (Bq/kg)**				
	Specifically for withdrawal of food-stuff		Specifically for substitution of clean fodder		
	Food category 1	Food category 2	Milk		Meat
Group I (10^{-8} Sv/Bq)	About a thousand to about ten thousand	About ten thousand to about a hundred thousand	About a hundred to about a thousand or so	Cs-137	A few hundred to several thousand
				I-131	A hundred or so to a thousand or so
Group 2 (10^{-7} Sv/Bq)	About a hundred to about a thousand	About a thousand to about ten thousand	About ten to about a hundred	Sr-90	Several tens to several thousands
Group 3 (10^{-6} Sv/Bq)	About ten to about a hundred	About a hundred to about a thousand	About one to about ten	Pu-239	A few hundred to a few thousand

Table 4. Specific intervention levels (or temporary permissible levels) currently employed in contaminated areas[1] of CIS countries (1995) for withholding foods from human consumption

	^{137}Cs in milk Bq/L	^{137}Cs in meat Bq/kg
Belarus	111[2]	600
Ukraine	370	740
Russian Federation	370	740

1. Defined as areas where deposition of ^{137}Cs, ^{90}Sr and ^{239}Pu fallout still exceed 1, 0.15 and 0.01 Ci/km^2 respectively.
2. Some contaminated districts use lower levels (*e.g.* Gomel region uses 37 Bq/L milk and 370 Bq/kg meat).

6. Future activities

There will be a need for authorities to develop secondary reference levels (so-called 'operational intervention levels') for quantities such as animal feeds and levels of contamination of pasture on which animals should normally graze. These working quantities should be specified in their own appropriate units (*e.g.* Bq/kg).

A range of agricultural countermeasures is currently available to reduce the impact of radiocesium contamination in the food chain. The same cannot be said for radiostrontium contamination. Considerable laboratory and field research will be required to address this major contaminant; a field laboratory has been provided by the Chernobyl accident and the opportunity should not be missed.

Also, whereas parameter values for the prediction of radionuclide transfers exist for the soil-plant system in temperate environments [18], such values are not currently available for warmer climates and sub-tropical soils and plants. In view of the fact that over 30 nuclear power reactors are found within the tropical belt, the IAEA has recently initiated a Co-ordinated Research Programme to predict radionuclide transfer under tropical conditions.

The IAEA in conjunction with FAO continues to be involved in promoting agricultural countermeasures and other Chernobyl related activities in CIS countries. These include the supervision of Technical Co-operation projects and Co-ordinated Research Programmes, and the publication of relevant technical documents (Table 5).

Despite the fact that the health and environmental effects attributed to the Chernobyl accident have been subject to extensive scientific examination, there still remain widely differing perspectives of the radiological consequences. Ten years after the accident, the European Commission (EC), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) will jointly sponsor, from 8 to 12 April 1996, an International Conference to seek a common and conclusive understanding of the nature and magnitude of the accident's consequences. The Conference, "One Decade after Chernobyl: Summing Up the Radiological Consequences of the Accident", will be organized in co-operation with the United Nations through the UN Department of Humanitarian Affairs (UNDHA), as well as with the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the United Nation Environment Programme (UNEP), the NEA/OECD and FAO.

Table 5. Publications Concerning Agricultural Countermeasures and Other Chernobyl-Related Activities in the Commonwealth of Independent States

Type of Activity	Country	Project Title	Duration	Budget US $
Technical Co-operation	Belarus	i) Rapeseed cultivation on soils contaminated by radionuclides	2 years/continuing	} 600 K
	Belarus	ii) Migration of radionuclides in contaminated soils	2 years	} for } equipment,
	Belarus	iii) Establishing regulatory procedures and standards laboratory	2 years/continuing	} expert } services
	Ukraine	iv) Reduction of radionuclides in human food and environment	2 years	} and } training
Co-ordinated Research Programmes	Tropical & sub-tropical countries	i) Transfer of radionuclides from air, soil and freshwater to the food chain of man in tropical and sub-tropical environments	1993-1997	150 K
	S.E. Asia	ii) Efficacy in tropical crops of countermeasures to reduce the uptake of radionuclides	1996-1999	150 K to be secured
	Europe & CIS	iii) Methods to reduce the uptake of ^{90}Sr by Animals consuming contaminated fodder	1996-1999	150 K to be secured
Publications	CIS	i) FAO/IAEA technical document on the Use of caesium binders to reduce radiocaesium contamination of farm products from the territories of Ukraine, Belarus and the Russian Federation, (results of a 5-year UN Project sponsored by the Norwegian Government (US $150 K), involving 6 institutes in the CIS, Norway and the U.K.)	1995	20 K

REFERENCES

1. International Atomic Energy Agency, Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency, Safety Series No. 72, IAEA, Vienna (1985).

2. Commission of the European Communities, *Derived Emergency Reference Levels in Widely Distributed Foodstuffs*, Report to the Group of Experts Set up under Article 31 of the Euratom Treaty, CEC, Brussels, 29 July 1986.

3. International Atomic Energy Agency, Derived Intervention Levels for Application in Controlling Radiation Doses to the Public in the Event of a Nuclear Accident or Radiological Emergency, Safety Series No. 81, IAEA, Vienna (1986).

4. Food and Agriculture Organization of the United Nations, *Report of the Expert Consultation on Recommended Limits for Radionuclide Contamination of Foods*, Rome, 1-5 December 1986, FAO, Rome (1987).

5. World Health Organization, Derived Intervention Levels for Radionuclides in Food, WHO, Geneva (1988).

6. International Atomic Energy Agency, Revised Guidance on the Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency, IAEA-TECDOC-473, Vienna (1988).

7. United Nations, Sources, Effects and Risks of Ionizing Radiation (Report to the General Assembly), Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UN, New York (1988).

8. *Environmental Contamination Following a Major Nuclear Accident*, Proceedings – Joint FAO/IAEA/UNEP/WHO Symposium Vienna 1989, Vol. 2, IAEA, Vienna (1990).

9. Nuclear Energy Agency of the Organisation for Economic Co-Operation and Development, *Protection of the Population in the Event of a Nuclear Accident: A Basis for Intervention*, OECD/NEA, Paris (1990).

10. International Commission on Radiological Protection, 1990 *Recommendations of the International Commission on Radiological Protection*, Publication No. 60, Annals of the ICRP 21 1–3, Pergamon Press, Oxford and New York (1991).

11. Food and Agriculture Organization of the United Nations/World Health Organization, Codex Alimentarius, General Requirements, Section 6.1, *Guideline Levels for Radionuclides in Foods Following Accidental Nuclear Contamination*, Joint FAO/WHO Food Standards Programme, Rome (1991).

12. International Advisory Committee, The International Chernobyl Project: Assessment of Radiological Consequences and Evaluation of Protective Measures, Technical Report, Section G, IAEA, Vienna (1991).

13. International Atomic Energy Agency, *Modelling of Resuspension, Seasonality and Losses during Food Processing*, First report of the VAMP Terrestrial Working Group, IAEA-TECDOC-647, IAEA, Vienna (1992).

14. Howard, B.J., Desmet, G. (Eds), *Relative Effectiveness of Agricultural Countermeasure Techniques (REACT)*, Proceedings, CEC Workshop, Sci. Total Environ. 137 1–3 (1993).

15. International Commission on Radiological Protection, *Principles for Intervention for Protection of the Public in a Radiological Emergency*, Publication No. 63, Pergamon Press, Oxford and New York (1993).

16. International Atomic Energy Agency, Generic Intervention Levels for Protecting the Public in the Event of a Nuclear Accident or Radiological Emergency, Interim Report, IAEA-TECDOC-698, Vienna (1993).

17. International Atomic Energy Agency/Food and Agriculture Organization of the United Nations, *Guidelines for Agricultural Countermeasures Following an Accidental Release of Radionuclides*, Technical Reports Series No. 363, IAEA, Vienna (1994).

18. International Atomic Energy Agency, Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments, produced in collaboration with the International Union of Radioecologists, Technical Reports Series No. 364, IAEA, Vienna (1994).

19. International Atomic Energy Agency, *Intervention Criteria in a Nuclear or Radiation Emergency*, Safety Series No. 109, IAEA, Vienna (1994).

20. Joint Secretariat for the Basic Safety Standards, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, jointly sponsored by the Food and Agriculture Organization of the United Nations, the International Atomic Energy Agency, the International Labour Organisation, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, the Pan American Health Organization and the World Health Organization, IAEA, Vienna (to be published).

SESSION II

ASSESSMENT AND MANAGEMENT OF AGRICULTURAL ISSUES

Chairperson : Frances Fry, United Kingdom

DIFFICULTIES LIKELY TO BE ENCOUNTERED IN ESTABLISHING A FOOD RESTRICTION STRATEGY IN THE EARLY STAGES OF AN EMERGENCY

by

Paul Naylor
United Kingdom

Introduction

In the event of a major nuclear accident, the Ministry of Agriculture, Fisheries and Food (MAFF), in keeping with its role in consumer protection with regard to food, would be responsible for protecting the population from radiation received via the food chain. MAFF's objectives would be to:

1. ensure that the public are protected from unacceptable exposure to contaminated foodstuffs;
2. ensure that alternative food supplies are available where necessary;
3. provide advice on the safe removal and disposal of contaminated food;
4. minimise the effects of the accident on the agriculture, fisheries and food industries, as consistent with the over-riding need to protect human health.

This paper is concerned only with the first objective, which would be achieved by prohibiting the supply and movement of contaminated food from the affected area by the imposition of emergency orders. Orders would be made under the Food and Environment Protection Act, 1985 (FEPA). The criteria for such restrictions would be the Maximum Permitted Levels (MPLs) of radionuclides in foodstuffs as laid down by the European Union, for use in the event of any future accident.

Staff from different parts of MAFF will have specific roles in an emergency. Under the current arrangements, Policy Division staff will be responsible for the Ministry's overall strategy and for issuing the restriction orders under FEPA, while staff from the relevant MAFF regional office will co-ordinate the local response. Scientists from the Food Safety (Radiation) Unit (FSRU) will gather information on the accident in order to determine its likely effect on food and agriculture. Specifically, their first priority will be to assess whether foodstuff restrictions are necessary and, if so, the area over which they need to be applied in order to provide effective advice to policy and regional staff.

Formulation of FSRU advice

Initial predictions of the extent of contamination will have to be based on basic meteorological data and the site operators' estimates of the magnitude and nature of the release. Simple measurements of radionuclide concentrations in air close to the site, or of dose rates, may also be available. At the same time as these initial predictions are being made, a monitoring strategy must also be established. Indeed, a major function of the predictions will be to maximise the effective utilisation of potentially limited monitoring resources. When measurements of deposited activity become available, more accurate predictions of the extent of contamination can be provided. The whole process is likely to be iterative, as incoming results of monitoring should be used to continually refine the monitoring strategy. It is important that time is not wasted taking large numbers of samples from areas that are well within the severe contamination zone or those where there is no significant contamination. In other words, most effort must be concentrated in the zone of uncertainty.

Potential obstacles to the formulation of effective advice

The requirement for advice to be accurate, comprehensive, unequivocal, and adequately (though not excessively) conservative will have to be considered alongside the need for rapid action. Potential obstacles to achieving this objective, and the way in which emergency plans are adapted to overcome them, are discussed below.

Monitoring resources will be concentrated in areas close to the accident site, where there may be an immediate risk to public health. Studies of potential accident scenarios show that the area over which food restrictions may need to be applied are much greater than those affected by other countermeasures. The large-scale releases of radionuclides envisaged in emergency exercises typically produce decisions to evacuate the public out to approximately 1 km from the site, but restrict milk out to several tens of kilometres. Initial monitoring, undertaken by the operators and others, will be focussed on the areas close to the site. Such measurements will have to be used to infer contamination levels at much greater distances from the site, in order to provide a first indication of the area over which food restrictions may be necessary. In order to minimise these problems, it is important that all nuclear site operators are aware of MAFF's monitoring requirements. This is achieved by various levels of liaison, particularly when planning, playing and analysing the outcome of national emergency exercises. It is also necessary for MAFF to have its own monitoring capabilities. Samples of grass (to estimate total radionuclide deposition) and crops will be collected by MAFF regional staff and analysed at MAFF laboratories or at conveniently situated universities and research institutes with the relevant expertise. Any monitoring results collected by other agencies will also be utilised.

Atmospheric dispersion models may prove unreliable when confronted by real releases and real dispersion conditions. Inferring distant contamination levels from close-to-site measurements will be performed using atmospheric dispersion models. Shifts of wind direction, particularly when combined with a prolonged release, can "smear" the plume over a wide area which cannot be accurately predicted by a simple dispersion model. The area affected by deposited material from the Windscale fire in 1957 was a good example of this effect. Variable terrain, plume buoyancy (potentially very significant in the case of major fires) and patchy rainfall may dramatically reduce the effectiveness of models. Coastal fringe meteorology can be particularly unpredictable, and it is worth noting that almost all major nuclear sites in the United Kingdom are close to the coast. Appropriate caution must therefore be applied in using atmospheric dispersion models. Data points may need to be filtered before entry and, at any one stage, the model may need to be run a few times with different parameters used on each occasion. The iterative process of using monitoring results to plan further monitoring activities is intended to avoid over-reliance on models.

Measurements of radionuclide concentrations in air, or on the ground, will have to be extrapolated to levels in foodstuffs, with associated uncertainties. Real or inferred monitoring results, whether they be air concentrations or ground deposition measurements, will have to be

converted into estimated peak contamination levels in foodstuffs, for comparison with the European Union MPLs. If sufficient time was available, monitoring results could be inserted into an environmental transfer model, with appropriate parameters selected to reflect the agricultural environment close to the accident site. It is the selection of these parameters, rather than the actual running of the model, that would make this a fairly time-consuming process. Where rapid decisions are needed, monitoring results would be compared with pre-prepared sets of values obtained from the model. These data sets will have been produced using worst-case modelling assumptions so, in the majority of instances, they will tend to produce a conservative estimate of the extent of contamination.

The following list compares the deposition of Iodine-131 calculated (or measured) to result in the Maximum Permitted Level (500 Bq/litre) in milk.

MAFF emergency model, worst-case assumptions	4.2 kBq/sq. metre
NRPB accident study results, using transfer model [1]	6.6 kBq/sq. metre
Windscale fire, actual measurements [2]	10 kBq/ sq. metre

Given the large number of variables and assumptions involved, the consistency between the two models and a real situation is encouraging.

Where deposition measurements are not available, air concentrations have to be used and levels of deposited activity are calculated using an assumed deposition velocity for each radionuclide. The deposition velocity of iodine isotopes is taken to be 0.01 metres/second in the MAFF emergency response model, a widespread assumption when more certain information is unavailable. After the Windscale fire, iodine-131 deposition velocities of approximately 0.003 to 0.005 metres/second were recorded close to the site. This figure dropped to 0.001 metres/second further from the source, as larger proportions of the more reactive components of the plume had already been lost by deposition. In extrapolating air concentrations of radionuclides through to levels of contamination in foodstuffs, the deposition velocities of materials in the release are amongst the most important uncertainties.

Deposition measurements are difficult to interpret until the release of radionuclides has ceased and the resultant plume has travelled beyond the monitoring site. The use of deposited activity measurements is preferable to that of air concentrations, not only because uncertainties associated with deposition velocities are avoided, but because the measurements are effectively integrated over the duration of the release rather than being "snap-shots" in time. For this to be entirely true, the rear edge of the plume has to have left the location concerned, so that deposition has been completed. Plume travel can therefore impose a significant delay in the realistic evaluation of contamination spread if the area of concern is a long distance from the accident site. If a release occurs between 0900 and 1200 Hours, in a light wind of 2 metres/second, the rear edge of the plume will not leave a location 30 km downwind of the accident until 1600 Hours.

There will be a significant delay in most foodstuffs reaching their peak radionuclide concentrations. The delay involved depends on both the radionuclide and foodstuff involved. A list of examples of the time taken for radionuclides to reach peak concentrations in foodstuffs, following deposition, is given below:

Iodine-131	Leafy vegetables	Instantaneous
Iodine-131	Milk	3 days
Caesium-137	Milk	6 days
Caesium-137	Beef	20 days

In theory, such delays could be seen to ease the emergency situation as for most foodstuffs large-scale food restrictions would not be necessary immediately. In practice, the expansion of the area where food restrictions are applied as time proceeded following the emergency should be avoided if at all possible. Direct measurements on affected crops and foodstuffs are obviously ideal in that they avoid the need for converting air and deposition data into food contamination levels. However, the delays in the foodstuffs reaching peak concentrations means that such measurements must be interpreted with care and that their reliability will increase with time. It can be concluded that all types of monitoring results have advantages and disadvantages associated with their use, in terms of speed, reliability and ease of interpretation. Overall, an emergency response strategy must be flexible so that at any given time the most appropriate measurements are used. In practice, this will probably mean that air concentrations are used in the very early stages of the emergency, followed by deposition measurements in the medium term and crop and foodstuff measurements in the longer term.

Public perception of the risk from contaminated food

The pressure on MAFF scientists to produce rapid and accurate advice on which a food restriction strategy can be based will tend to be increased by the following aspects of public perception.

- As discussed previously, food restrictions will almost certainly need to cover a much larger area than other countermeasures. This will tend to exaggerate the apparent hazard of contaminated food.
- The European Union food criteria are set so that long-term consumption of food at the MPL represents a minimal additional risk to the consumer. The public may perceive that the inadvertent consumption of any food, even a single item of food, exceeding an MPL represents a severe health risk. Their concern will tend to be enhanced by the general perception of radioactivity as being more dangerous than other food contaminants.

Conclusions

In the immediate aftermath of a major nuclear accident, the public will expect rapid and unequivocal action to be taken, in order to ensure that they are not subjected to the risk of eating contaminated food. The first priority for MAFF scientists will be to quickly establish the area over which foodstuff restrictions should apply. Various obstacles to this objective can be envisaged and the following recommendations can be made:

- Over-reliance on atmospheric dispersion models should be avoided, especially if they have not been successfully validated against data from real dispersion situations.
- Monitoring results should be used to continually refine both the predictions of affected areas and the monitoring strategy as they become available.
- All types of monitoring information that may be available in an emergency have their advantages and drawbacks. Response plans should therefore cater for utilising the maximum possible range of measurement types.
- The most efficient strategy will probably involve using different types of monitoring at different stages in the emergency.
- The public's perception of large-scale food restrictions, and their association with other countermeasures, needs to be considered in all stages of emergency planning.

REFERENCES

1. *Likely Extent of Contamination Following a Design Basis Accident.* Document prepared by the National Radiological Protection Board under contract for NII and DTI.

2. M.J. Crick and G.S. Lindsay, *An Assessment of the Radiological Impact of the Windscale Reactor Fire, October 1957.* National Radiological Protection Board Publication R135, 1982.

AGRICULTURAL ASPECTS OF NUCLEAR AND/OR RADIOLOGICAL EMERGENCY SITUATIONS

by

Gérard Griperay
France

Introduction

Paradoxically, after the negative outcome of the first 50 years of atomic research – the explosion of the world's first atomic bombs on 6 and 9 August 1945 – the public's attitude towards nuclear energy, while not entirely positive, at least remained fairly neutral.

The atomic test conducted by the United States on Bikini Atoll on 1 March 1954, for example, gave its name – in France at any rate – to a new item of "two-piece" ladies' swimwear.

As a result of the series of nuclear tests conducted by the major powers until the signing of the Nuclear Test-Ban Treaty in 1963, all countries had access to sample of agricultural produce taken from the vicinity of test sites and, at meeting after meeting (Guyaquil 1972, Canberra 1973, etc.), the experts concluded that the resultant level of radioactive contamination was not significant.

Incidents at Three Mile Island (USA) and Sellafield (UK) did nothing to shake the (comparative) complacency of farmers, who were aware that the use of nuclear technology had resulted in technology was responsible for a slight increase in background radioactivity which had been checked and cleared by the health authorities.

Then came the Chernobyl incident which shocked the agricultural sector into nothing short of a cultural revolution.

1. What Chernobyl taught us about farm management in France

Consumers' total ignorance of both production conditions and contamination cost farmers an estimated FF 150 million in lost agricultural produce sales in 1986 alone.

The products most affected were strawberries, asparagus, and mushrooms and, later, herbs (particularly thyme) and hay in the south-east.

A typical emotional reaction to the incident and to pressure from neighbouring countries, was the ban on spinach consumption in the Haut-Rhin area for which there was no real medical justification given that an individual would have to eat two tonnes of spinach in a week before running any health risk.

There was also a marked decline in milk sales in east and south-east France.

A number of conclusions can be drawn from these developments:

1.1 Information

Information is crucial and must be ready **BEFORE** a crisis develops but cannot be managed effectively **DURING** a crisis.

1.2 International standards

While the media must take some of the blame for misleading the public, the real culprits are the international organisations:

The WHO, the EEC, the FAO/CODEX Experts (31 in total) EURATOM have all issued their own standards. Furthermore, the EEC has amended its standards on no fewer than four separate occasions!

The recommendations adopted by different countries (end of 1986) also vary according to type of produce, and the period of time over which it is consumed. How can journalists, and consumers and food producers possibly know what to make of the situation when nuclear and health scientists have to bow to pressure from the scare-mongers and from politicians?

Standards set by the EURATOM directive apply to normal plant operating conditions and were not intended for accident conditions, when intervention levels can be substantially higher. In the end, they were dictated by economic, not health, criteria with the aim of standardising import terms for consumer products.

It is hardly surprising that the public did not know what to believe and that it proved necessary to put alarmist reports – released by some of the media and by non-government-approved associations or independent laboratories – into perspective.

Practical examples are:

1. For hay or silage with a contamination level of 6 700 Bq per kilogram, the maximum daily intake that ensures that levels will not exceed 600 Bq per day in meat and 370 Bq per day in milk can be calculated from the transfer coefficients: the maximum intake for cows should be no more than 30 000 Bq/day, for,sheep, no more than 7 500 Bq/day and, for goats, no more than 3 000 Bq/day. In other words, to remain within the authorised limits, cows should be fed no more than 5 kg/day of the most highly contaminated silage (INRA study).
2. Drinking one litre of milk containing 60 Bq of caesium/litre per day for a year (60 Bq x 365) would give an intake of 20 000 Bq/year, *i.e.* 20% of the maximum limit specified in Articles 30 and 31 of the Treaty of Rome, which are themselves based on the annual limits of intake (ALI) given in the 1977 recommendations of the International Commission on Radiological Protection (ICRP).

The intake would have to be 5 tonnes/year, to reach the ALI.

3. Eating 1g of thyme with a radiation level of 3 000 Bq/kg (caesium) per day for a year would give an annual intake of only 1 000 Bq/year, *i.e.* 1/300th of the ALI. An individual would have to consume 100 kg/year before reaching the ALI.

ALI caesium 134-137 = 300 000 Bq/year

ALI iodine 131 = 100 000 Bq/year.

Concluding remarks: current standards will have to be revised again.

Recommendation "ICRP 60", published in 1990, is clearly based on the state of our scientific knowledge in 1988, but significant advances were made between then and 1994. Comprehensive references are given in reports by UNSCEAR (1994), BEIR-V (1990) and the US-Japanese RERF (1994).

EC decision-makers should base their regulations on the proposals put forward by these scientists, since they ensure adequate protection of workers in the nuclear industry and of the population at large but avoid barriers to trade and forestall any move towards prescribing an optimum "zero level" that is in fact lower than the level of background radiation.

1.3 Questions the agricultural sector could not answer

In the aftermath of Chernobyl, we found that we had no answers to the questions farmers put to us:

- What happened to soil contaminants?
  - Did they sink into the soil?
  - Were they absorbed by crops?
- Could crops be harvested or should they by left in the ground, buried, turned into silage, burned. What were the health risks?
- Should farmers evacuate, stable or slaughter livestock?
  - What water could livestock drink?
- Could farmers sell contaminated animals, spread manure from contaminated animals?
  - What was to be done with milk production?

It emerged that, while France did have Off-Site Emergency Plans and On-Site Emergency Plans for Basic Nuclear Installations, its only Post-Accident Plans were either sketchy or non-existent.

Drafting Post-Accident Plans is a difficult exercise. General plans do not suffice, they have to be tailored to local circumstances.

Example 1 **In the Haut-Rhin** area, the plan provides for animal slaughter, but the problem of quartering and incinerating carcasses remains unresolved due to the lack of incinerators. Burial is a problem, too, due to the lack of suitable geological survey maps on which to base the location of disposal sites.

Example 2 **In the Manche** area, where there are approximately 1 million head of livestock, farmers and the local authorities have opted to keep cattle in pens and evacuate only beef cattle from the three calf-breeding areas around La Hague.

PAPs can arrange for emergency evacuation or quarantine, but their chief purpose is to ensure **a return to normal living.**

In the short term this entails:

- immediate and on-going management of wastes and landfills for the disposal of up to 100 000 t each of crops, confiscated or contaminated animal products and milk.

In the long term, it will entail management of:

- the land,
- types of crops,
- the impact on the food chain,
- etc.

On this last point, depending on the cause of the incident and its severity, alternative solutions might be to delay consumption (*e.g.* production of tinned or powdered milk, slow-maturing cheeses, etc.), to produce less-contaminated products (*e.g.* butter) or to re-use contaminated produce for fodder, since transfer coefficients and time-to-slaughter would reduce initial contamination levels.

Concluding remarks. It was in an attempt to answer the above questions that the FNSEA worked with the CEA/IPSN for four years on the production of an information pamphlet which lays the technical groundwork for a Post-Accident Plan for the agricultural sector (first published by the FNSEA in 1990, and later republished by the CEA/IPSN).

2. What remains to be done – a broad outline

2.1 Compensation

If a nuclear and/or radiological incident occurs in one of the signatory countries to the Paris Convention, the government, or international reinsurers, pay a certain amount of compensation depending on the scale of the damage.

As the former Soviet Union was not a signatory to the Convention, French farmers received no compensation for the FF 150 million in lost sales.

German farmers, however, received compensation of DM 260 million.

In view of the above, it is time to consider:

- whether current compensation scales are adequate for potential incidents in signatory countries, and the terms under which compensation would be paid;
- whether, given that Western financial and technical assistance is alleviating the problems of obsolescent nuclear plants in Eastern Europe, it would be feasible, in the event of another Chernobyl, to extend the convention to countries which are not currently signatories.

2.2 Research and dissemination of findings

Areas in which further research which should be undertaken include:

- transfer (animal and vegetable);
- deposition of aerosols on crops, soils and forest;
- rehabilitation programmes (RESSAC) (CAPTATIO);
- comparative studies by laboratories (government and private sector) (GERMON network) (CONRAD cross-border system with Germany);
- concentrations in sediments (SERE/Rhône).

Above all, farmers want results. They also want to see better co-ordination on programmes and more information on the practical feasibility of measures.

2.3 Post-accident plans

An exercise conducted at Cadarache in 1991 provided a basis on which to assess the impact of emergencies on the food chain and to draw up an outline a a post-accident plan (see IPSN report 1993). *"Once the nature of the contamination has been established, experts can advise the Prefect. Tables and maps can be drafted to show contaminated areas in which countermeasures can be implemented.*

"In order to diagnose problems and recommend a course of action, experts must have access to socio-economic as well as radiological data.

"Information on livestock production practices (forage schedules, how often silage is cut and when) can help to establish livestock feeding patterns – which vary greatly from one region to another – and to assess current and future levels of contamination in milk and meat.

"Information on crop farming practices (types of crop, how often they are harvested and when, sources of water used for spraying and irrigation) can provide a realistic basis for assessing the current and future contamination levels of vegetable produce.

"Information on the above aspects would enable experts to advise the Prefect, who is ultimately responsible for deciding which crops should be destroyed, which animals should be slaughtered and which produce should be banned from sale or declared unfit for human consumption".

2.4 Exercises

This field exercise was the follow-up to a series of desk-top exercises in which farmers were asked to take part.

We would strongly advise all those attending this OECD workshop to organise similar exercises and to involve farmers, journalists, mayors, etc.

Such exercises have many advantages:

- They can **break down barriers** between public authorities, scientists, politicians, users (the public) and neighbouring countries.
- Those involved **get to know each other** as well as the desired objectives, the resources available, the limitations and the weaknesses of the system, particularly from the logistics standpoint, and what needs to be done to correct them.
- They promote the **exchange of information**, based on transparency, and create a climate of trust, laying the foundation for a new era of consensus between the parties involved.
- They ensure that workers in the nuclear field, laboratories, emergency services and government personnel receive **support and recognition** for the job they do, rather than constant opposition.

Lastly, in the agricultural sector as in other sectors of society, first-hand "involvement" with the problems is a valuable **"learning"** experience.

2.5 *Information*

The point was made earlier in this paper that information has to be available **BEFORE** a crisis if it is to be effective **DURING** a crisis.

It is extremely difficult to do this.

It is now 10 years since Chernobyl.

- In 1990, the French farmers' federation produced a technical reference manual jointly with the IPSN – it has long since been forgotten.
- French veterinary surgeons produced several scientific pamphlets aimed at professionals and, presumably, at dispensing chemists in rural areas.
- The French Parliament published a number of reports on security and safety. How many were actually read?
- Organisations such as the IPSN also publish annual reports on their work. How many are reported in the press?

But, in France, there is still no official Post-Accident Plan, and informative articles for the layman are few and far between. Unless memories are "jogged", people forget and they are now no better informed of the basics than in 1986.

After all the "scare-mongering", the general public's attitude to nuclear power, now, may well be rather more negative than before.

The public has weather bulletins, and even air quality bulletins, but no information from France's Téleray or MAGNUC phone-lines.

What it needs are (regular) programmes on crisis management, involving all sectors of society.

Conclusion

What is needed at present, at least with regard to the French agricultural sector, is better co-ordination in general, and up-to-date information in particular, and the provision of resources to ensure that:

1. A proper presentation is made of the case for a new definition of **EC threshold limits**.
2. Up-to-date information – with due regard for the Common Agricultural Policy (CAP) – is available on food production and the agri-food industry activities in the vicinity of basic nuclear installation, so that decisions can be taken in real time on the basis of accurate **statistics**.
3. In cases where no Post-Accident Plan has been drawn up, the public authorities can act swiftly to ensure that agricultural produce reaching local and export markets can be **certified as complying** with health standards.

Besides OPRI inspections, such measures could require nuclear facilities which have a responsibility in this area to maintain radioactivity **detectors** and, in the event of a major incident, to install them at **key points** for the food industry in the vicinity of the plant (dairy and wine co-operatives, fruit and vegetable and other packaging plants). These sites should be determined in advance and should be ready to to into operation at short notice. The detectors would be automatic or operated by trained personnel so that the results could not be subsequently challenged (by consumers or by conflicting expert appraisals).

On the contrary, the above proposal assumes, that **compensation** for produce that has to be withdrawn, confiscated or destroyed, particularly perishable produce, would be decided **BEFORE** any incident occurs, to avoid "haggling" by the experts and disputes with **insurance companies** (samples) three months after the fact.

4. Sending samples solely to public or private **sector laboratories** which have been **approved by the government** and which are required to ensure the comparability of results (to avoid panic and the release of misleading information).
5. Implementing a **training and information plan** at all levels so that the public will be capable of seeing the information in perspective and will not panic or be misled by the prophets of doom.
6. Finally, with recent developments such as chemical terrorism (*e.g.* the release of Sarin in Tokyo) and food terrorism (poisoned yoghurt) in mind, we must be on our guard against nuclear terrorism.

This is why it is absolutely vital to keep existing radiological stations in operation and to continue the present level of funding to safeguard facilities whose personnel are trained and ready to respond in the event of an emergency.

At a time when the size of armed forces are becoming smaller, in relative terms, more money must be ploughed into civil defence forces.

It is equally essential to encourage co-ordination between government services (and governments) and professional representatives, to ensure that there will be an on-going technology watch ready to step into action at the slightest incident.

CONSEQUENCES OF RADIOACTIVE FALLOUT
POST-CHERNOBYL EXPERIENCE

by

Alexandre Lutsko
Belarus

Both the experience gained in the first post Chernobyl years and the decision making of officials have been extensively argued. Leaving out analysis of the events, I would like to make some observations on the nature of protective measures.

The protective measures, which had been taken at least in the first four post Chernobyl years, largely reflected experience obtained in the South Urals. By the time of the accident the USSR had gained considerable experience in agro-technical usage of contaminated farm lands. After Chernobyl, however, its direct implementation was polemical. Obviously, measures which were valid in the 1950s and 1960s might turn out inappropriate in the 1980s. For instance acceptable dose levels were frequently revised and notably reduced. And this time the accident took place in the populous area with highly developed agricultural sector. Also one must admit that a major reason for low efficiency of the protective measures was the lack of appropriately trained personnel and equipment, which were in demand after the accident of such a scale. To exemplify that I am quoting the decree of the Ministry of Health and the Ministry of Agriculture issued May 12, 1986.

Status: *Confidential*
To: *Minsk Executive Committee*
Regional Executive Committees
Ministries and Federal Organisations Public Protection Headquarters
Date: *12.05.86 #H 7/375*

For the period of coping with consequences of the Chernobyl accident, the following acceptable dose levels are introduced:

	Category	Acceptable Level per kg		Category	Acceptable Level per kg
1.	Drinking water	3700 Bq	8.	Vegetables, fruits, concentrated fodder:	
2.	Milk	3700 Bq		Dairy cattle	37 MBq
3.	Sour-cream	18500 Bq		Beef cattle	740 MBq
4.	Cottage cheese	3700 Bq	9.	Coarse fodder:	
5.	Butter	74000 Bq		Dairy cattle	11.1 MBq
6.	Meat	1.48 MBq		Beef cattle	370 MBq
7.	Fish	37000 Bq	10.	Rich fodder:	
				Dairy cattle	2.59 MBq
				Beef cattle	74 MBq

In the case of exceeding the acceptable dose levels the products must be diluted with non contaminated counterparts or recycled. The State Committee of Agriculture and Industry must provide local medical control services with appropriate dosimeters to secure that radioactive contamination of drinking water and food is below the above levels. Trade of milk products is authorised with indication "For Adults Only". Food trade in the streets must be strictly forbidden. Briefing on food control matters must be put on a daily basis.

Y. M. Husainov
President,
State Committee of Agriculture and Industry

N. E. Savchenko
Minister of Health

However these acceptable dose levels, which were rather high, could not be observed as there were no equipment to do it at that moment in the country. There is no need in arguing that authentic data should constitute the basis for decision making. Only by 1990, that is four years after, high sensitive dosimeters and radiometers had been designed and produced in abundance. Nowadays Belarus rates among top states as far as the quality and diversity of environmental and soil monitoring, measuring, for gamma-radiating nuclides in particular, equipment is concerned.

In the last 9 years since Chernobyl various experimental data has been accumulated. At last the time of chaotic measurement has ceased. The experience obtained has being evaluated. Sound models of radionuclides behaviour in the environment and effective protection measures have being designed. Unfortunately, in the period of 1989-91 some statements of political nature, which notably reduced the number of opportunities for international scientific co-operation in the field of Chernobyl aftermath, were made. As a result, research in the field is not supported with modern technologies, and our international counterparts are not familiar with the better part of highly valuable results and databases. To make it worse, current situation in the economy of the country economy gives no reason to think that that will not be the case in the nearest future.

Now, maps of contaminated farm lands are built and corrected on regular basis. Farms and villages receive reports on radiological situation in their neighbourhoods. Behaviour patterns of Cs-137 and Sr-90 is under control. Data on Plutonium isotopes and Am-241 are less reliable. It is recognised that the pool of Americium isotopes has been increasing and can cause a major problem in forthcoming years owing to the isotopes mobile and toxic properties.

As far as Strontium and Plutonium radionuclides are concerned, fortunately, they exist in hard to dissolve forms. That counts for low horizontal circulation of the radioactivity. However soil vertical profiles have been undergoing temporary changes. It is known that the radionuclides in question remained in the upper 5 cm layer. That was the justification of the 5 cm deep ring sampling method. At the moment, the radionuclides can be found as deep as 15 cm, and in case of peat bog, sandstone and sub-sandstone soils as deep as 60 cm. That is why new sampling devices and methods have being introduced. Hence the term "surface concentration of radioactivity" is inaccurate, and leads to confusion in the end. In our opinion, it is reasonable to introduce two terms; integral and differential concentrations of radioactivity. In the case of the latter, concentration of radionuclides in layers of different depth is meant.

In Belarus almost all advised methods to diminish radionuclides concentration in soil were employed. Below a short analysis of their actual efficiency is given:

1. **Ploughing**: 5 cm deep ploughing diminished the concentration of radionuclides in the root layer right after the accident. Also it enabled to diminish the exposure up to 3-4 times by autumn '86. Next year, however, plant roots absorbed the radionuclides back. As a result, though this method involved huge costs, it proved to be of low efficiency. Deep ploughing was inefficient as well, and endangered futility of the soils

2. **Liming of soils**: This method diminishes transition ratio of radionuclides. It is greatly recommended for the soils with low pH.

3. **Potash-Phosphoric Fertilisation**: Besides it diminishes radioactive Cs-isotopes transition it increases the crop capacity of the fields.

4. **Re-profiling of Plant-growing**: It is widely employed in the country. Crops absorbing Potassium are grown on the contaminated areas.

5. **Ploughing and Fertilisation of Natural Pastures**: It makes sense only where natural pastures are in use.

6. Boluses for Livestock

7. All these measures enabled to have diminished 1.5–2 times levels of contamination of various agricultural products already in 1986.

Table 1. Quantitative decrease in production of meat and milk products exceeding the acceptable dose levels.

Year	Meat (x 10^6 kg)	Milk(x 10^6 kg)
1986	21.1	580.8
1987	6.9	388.6
1988	1.45	238.9
1989	0.6	91.4
1990	0.7	8.7
1991 (10 months)	0.0288 (0.03%)	27.4 (0.74%)

However, Table 1 requires commenting. For one thing, the data collected during the period of 1986-87 is not reliable. For another, the figures are not comparable as different acceptable dose levels were enacted in the indicated period. (See Table 2.)

Notwithstanding the private agricultural sector annually yields meat and milk products which exceed the acceptable dose levels. In 1994 the amount of contaminated food products produced in both the public and private sectors slightly increased owing to the decline in investments into agriculture and growth of transition ratios by reason of the unusually hot summer.

As far as exceeding acceptable dose levels contamination of cereals is concerned it has not been recorded in recent years. As a matter of fact cereals with the contamination of that kind amounted to 312.1 x 10^6 kg in 1986.

Recently forest biocoenosises in contaminated areas have become an increasing interests of scientists. Forests are in abundance in the republic. They play an important role in the country economy. Locals pick wild berries, mushrooms, herbs. Hence the forests largely contribute to the dose accumulation for the population in surrounding villages. However it can make a topic for a separate meeting. Reports on this issue and forests ecosystems modelling, which are developed at the Sakharov Institute, were made in Vienna not long ago.

And finally general observations. Huge sums were spent on decontamination measures in Belarus. AZ measures like removal of upper soil layer and its disposal proved inadequate. Now contents of dozens of temporary disposal sites have being washed out by rain and ground water. Apparently this method is more appropriate in case of the contamination of small rather than large areas.

Table 2. Radionuclide Content Acceptable Level in Food

Kind of food	Temporary acceptable level in 1986 Bq/kg	Temporary acceptable level in 1988 Bq/kg	Temporary acceptable level in 1990/92 Bq/kg
For caesium radionuclides			
Drinking water	370	18.5	18.5
Milk	370	370	185
Sourcream, cottage cheese	3 700	370	185
Vegetable oil, grease, margarine	7 400	370	185
Butter, concentrated milk	7 400	1100	370
Pork, mutton, poultry	3 700	1850	592
Beef	3 700	2960	592
Powder milk	18 500	1850	740
Potatoes and root-crops	3 700	740	592
Vegetables, fruits	3 700	740	592
Wild berries			185
Mushrooms			185
Dried mushrooms		11 100	3700
Herb, tea			1850
Baby food		1 850	37
Bread & Grain products		370	370
Honey, juice, canned food		740	185
Other food			592
For strontium-90			
Drinking water			0.37
Milk and milk products			3.7
Powder milk			18.5
Bread and grain products			1.85
Meat, fish, eggs			18.5
Concentrated milk			3.7
Baby food			1.85

Recently the National Committee on Radiation Protection (NCRP) adopted new conception on social protection of the population, which suffered after the Chernobyl accident. It contains two very important points. Firstly, it states that Belarus is at rehabilitation phase. Secondly, radiation protection measures will be taken purely on the grounds of dose approach. Not long ago that would depend on extent of surface contamination in a region. Now no protective measures are taken as long as the annual dose accumulation is less then 1 mSv.

The NCRP passed the document to the Council of Ministers. However the point of enacting it is uncertain because of the parliamentary crisis. However the NCRP is concerned with negative consequences as a result of some articles of the conception. Thus some of the agricultural land will be denied fertilisers. Agro-technical protective measures will be terminated on them. Some farms will not get boluses. All that will inevitably result in growth of annual doses, which in turn would entitle the areas again to what it was denied before. These fading oscillations seem to be unavoidable. The NCRP would be very grateful to be consulted on the matter.

In conclusion, should we forget of the natural decay for a moment radioactivity seems never to cease to exist. I admit its intensity can be artificially lessened. That, however, requires reasonable optimisation, which is possible on the grounds of international experience only.

THE SWEDISH SYSTEM FOR MANAGING AGRICULTURAL PROBLEMS FOLLOWING A NUCLEAR ACCIDENT

by

Jan Preuthun
Sweden

1. Responsibility

The one who is normally in charge of a certain activity keeps this responsibility even in the case of a nuclear accident.

Sweden is divided into 24 administrative regions (counties). The size of these regions varies considerably. Their share of the land area varies between 0.7 per cent to 24.0 per cent, and their share of the population between 0.6 per cent to 19.2 per cent.

In each county, there is a County Administration Board, which is directly subordinated to the Government. The County Administration Boards are, in general, responsible for the governmental administration of the region, and also for leading emergency relief and rescue operations in connection with nuclear accidents. They are also responsible for clean-up operations after accidents involving radioactive material.

Not only County Administration Boards but also central authorities are directly subordinated to the Government. The area of responsibility of these central authorities is the whole nation. They are responsible for separate sectors, which in the case of nuclear accidents means that:

- The Nuclear Power Inspectorate, SKI, analyzes the accident causes and estimates the source term of a possible radioactive release.
- The Meteorological and Hydrological Institute, SMHI, is responsible for relaying alarms from abroad and for weather forecasts to indicate the likely pattern of dispersion of radioactive material after an accident.
- The Radiation Protection Institute, SSI, leads and coordinates measurements of radiation on the national level and advises both county administrations and central authorities concerned such as the National Food Administration, the Board of Agriculture and the National Board of Health and Welfare regarding measures to minimize the radiation dose received by the population.
- The National Food Administration, SLV, is the central administrative authority concerning foodstuffs. It is responsible for issuing rules and recommendations regarding this sector. In the case of a nuclear accident, the SLV is responsible for adopting measures necessary in order to acertain that a certain individual dose is not exceeded through food consumption. The SLV may fix maximum limits for the content of radioactive substances in individual foodstuffs, give diet advice and issue recommendations on the handling of foodstuffs. Furthermore, the European Union has decided on a procedure for the fixing of marginal values for radioactivity in foodstuffs and animal feedingstuff.
- The Board of Agriculture, SJV, is the expert authority on agriculture, horticulture and reindeer farming. The SJV is responsible for issuing rules and recommendations

concerning these sectors. In the case of a nuclear accident, the SJV is responsible for adopting measures necessary for limiting the absorption of radioactive substances into agricultural products. The SJV may fix maximum values for radioactive substances in animal feedingstuffs and give advice on appropriate measures for the agricultural sector etc. In addition, the SJV will probably, within its sphere of activity, administrate any financial compensation for additional costs and losses due to prohibition of placing foodstuffs with a large content of radioactive substances on the market. Within the Board's sphere of activity, the Chernobyl disaster has, until 1993/94, caused payments of appr. SEK 680 million. Approximately two thirds of this amount relates to reindeer farming.

The central authorities are also responsible for keeping the Cabinet Office abreast of developments. The Swedish Government and the responsible authorities have realized the importance of training and periodic exercises in maintaining the country's preparedness for possible nuclear emergencies. The Rescue Services Agency, SRV, supervises regional planning and coordinates contingency planning for rescue services and clean-up operations. The SRV sees to it that all decision-makers and personnel in the county administrations are trained and regularly take part in emergency response exercises. The SRV organizes courses for the staff of the regional emergency organizations each year.

2. The Central Organization

In the case of a nuclear accident, the Radiation Protection Institutes tasks are councelling and coordination.

The Board of Agriculture remains the expert authority within the sectors of agriculture, horticulture and reindeer farming. Its tasks are partly to support the county administrations and partly to be the sector authority of the Government.

The central emergency organization is based within the SSI and has a staff of roughly 175, who serve in two shifts. Its prime task is to provide the county administrations with data and advice so that they can determine how best to limit the consequences of a nuclear accident in their respective counties.

The central organization includes an administrative reference group consisting of representatives of authorities and organizations such as the National Food Administration and the Board of Agriculture. These representatives serve as a link between the central emergency organization and the emergency organization of each authority. They shall also, on the basis of the SSI's assessment of the situation at hand, decide on appropriate measures within their respective spheres of responsibility.

Furthermore, the Board of Agriculture is represented in the national expert group on decontamination, which is attached to the central emergency organization. The prime task of the group is to provide an operational and economic frame of reference for decisions concerning clean-up operations and to advise the county administrations on related matters.

3. Organization of the Board of Agriculture

On an early stage, a "disaster group" is appointed and an information centre is organized. The "disaster group" is lead by the Deputy Director General, who decides on questions regarding the nuclear accident and its consequenses.

Even an accident which does not have any serious consequenses may result in a considerable work load for the Board of Agriculture, and may demand a very flexible co-operation between the Board's departments. The demand for information and advice on measures to be taken by individual farmers could be considerable, even if the radioactive fall-out is rather small.

By appointing a "disaster group", the possibilities for complying with the demand for quick decisions in an emergency situation are improved. It also makes possible the continued necessary management of regular tasks. By appointing the group at an early stage, changes in organization will not be necessary during a later, more hectic stage. The group includes, among others, representatives of the following departments of the Board of Agriculture: the Department for Animal Production and Health, the Department for Crop Production and Environment, the Information Division, the Division for Economic Analysis, the Division for Legal Affairs and the Division for Emergency Planning.

4. Objectives

Before and after a fall-out, measures are taken in order to, firstly:

- *limit the maximum individual dose, in order to:*
  - *avoid acute injuries (deterministic injuries);*
  - *reduce the risks for diseases later in life (stochastic injuries) to an acceptable level;*
- *limit the collective dose in order to reduce the number of stochastic injuries to an acceptable level.*

In order to limit the radiation dose that the body is exposed to through contaminated food, the Board of Agriculture will issue recommendations for limiting the presence of radioactive substances in agricultural products. Possibly the National Food Administration will give maximum permissible levels of radionuclids in foodstuffs, and the Board of Agriculture for animal feedingstuffs, but probably the European Union will fix maximum levels for both foodstuffs and animal feedingstuffs.

When designing its recommendations, the Board of Agriculture also considers:

- the radiation dose that the agricultural worker is exposed to during agricultural work,
- animal welfare legislation,
- financial and social aspects,
- etc.

5. Ambitions and Preparatory Measures of the Board of Agriculture

Create an emergency organization adaptable to various accidents and other emergencies, and give this organization the means to take all necessary steps quickly and effectively.

The actions taken in connection with the Chernobyl disaster did not fulfill the demand on an emergency organization that quickly and effectively can take the necessary steps. The Government was of the opinion that the Board of Agriculture should formalize its planning in order to increase its preparedness for serious accidents.

That is the reason why a "disaster manual" is being written. This manual includes such events as may constitute a threat to the agricultural, horticultural and reindeer farming sectors, for instance epizootic diseases, radioactive fall-out and war. Particular attention is given to radioactive fall-out, since radioactive substances and ionizing radiation are unknown territory for most people at the Board of Agriculture.

Knowledge accumulation is an important method to improve in advance the preparedness and thereby increase the chances of succeeding in adapting the necessary measures quickly and effectively. The knowledge is now being improved about the transmission of radioactive substances through different food chains and about the effectiveness of different measures.

Education of the personnel is in progress, and, in addition, excercises are planned every third year. Also planned are studies on the handling of animals during evacuation and on the consequenses of different systems and scope for financial compensation. The preparedness for testing and measuring is being improved in co-operation with the Radiation Protection Institute.

6. "Disaster Manual"

The "disaster manual" contains exact information on which immediate measures are to be taken in the case of an alarm.

Since each event is unique, the final choice of preparedness increasing and damage limiting measures is not made until an accident/emergency has occurred or threatens to occur.

The manual mentions possibilities regarding this. It shows how action could be taken – not how action must be taken.

The manual shall include not only data on the organization, immediate measures in the case of an alarm and preparedness increasing measures, but also, to a high extent, illumination of consequenses and systematic presentations of different damage limiting measures that can be adopted, *i.e.* the advantages and disadvantages of the various alternatives.

The outline of the manual:

Preparatory measures:	1.	The preparedness of the Board of Agriculture.
Measures if an alarm might occur:	2.	Own initiatives.
Measures after an alarm about	3.	War/danger of war.accidents etc.
	4.	Radioactive fall-out.
	5.	Epizootic disease.
	6.	Other major accidents and emergencies.
General issues:	7.	Role of other authorities and of the EuropeanUnion.
	8.	Role, organization and authorization of the Board of Agriculture.
	9.	Information activities.
	10.	Evacuation.
	11.	Compensation issues.
	12.	Phone, fax and telex numbers.

Chapter 1 explains why the Board of Agriculture must have an emergency preparedness for accidents/emergencies, in which situations it may be activated and how the preparatory activities are to be conducted.

Chapter 2 stresses the demand for own initiatives – that it is not always enough to await Government demands or some kind of "alarms".

For each event respectively, **Chapters 3-6** discuss which immediate measures that are to be taken in the case of "alarm", the objectives of the activities and which preparedness increasing and damage limiting measures that may be brought to the fore.

Chapters 7-12 give the common background for the actions taken. They describe the role and authorizations of the Board of Agriculture and the "basic view" of the Board concerning organization, information activities, treatment of animals during evacuation and compensation issues. In chapter 12, phone, telefax and telex numbers that might be needed are given.

The manual will never be completely finished. As new knowledge is obtained and i. a. personal particulars become obsolete, it is the intention that new versions of separate chapters, parts or annexes shall be produced and the old ones replaced.

7. Facing a Possible Fall-Out

Advice on general and comprehensive measures, and later limit the measures when knowledge of the radiation situation increases.

When a radioactive release has occurred or may be about to occur, the insecurity is likely to be large, both as regards the range of the release and whether Sweden will be affected and, if so, to what extent.

If the cows are grazing outdoors, radioactive iodine may reach the milk within 24 hours after the fall-out. A news broadcast on radio/TV that the farmers usually listen to should therefore urge them to keep the animals indoors after the next milking. The alternative, to bring the animals in when they do not expect milking could both take a lot of time and be difficult to manage. The animal owners will also be urged to minimize ventilation, bring feedingstuffs indoors and to use uncontaminated feedingstuffs.

The crop producer is urged to postpone planned operations (earth preparation, sowing and harvesting) until more detailed instructions are given, and to, if possible, cover or move indoors input goods (*e.g.* seed) and harvested products.

8. Damage limiting measures within animal and crop production

Choose the set of measures that best fits the situation at hand.

Each event is unique. Since the manual systematically lists various measures, a suitable combination of some of, for instance, the following measures may be chosen:

Within animal production

1. Reduce the exposure of cattle to radiation:
   - external (housing, decontamination of stable roofs),
   - internal (housing, other feedingstuffs, other pastures).
2. Reduce the adoption into the product:
   - feed ration (more fibres, calcium additives),
   - type of production (meat production, other animals),
   - slaughter (time, sanitary feeding).
3. Not using the products for human consumtion:
   - as animal feedingstuffs,
   - condemn.

Within crop production

1. Postpone field work.
2. Not grow agricultural products:
   - other products (energy crops, industrial crops),
   - no growing.
3. Remove the radioactive covering:
   - remove material (snow cover, grass and root system, earth layer),
   - plowing (conventional plowing, trench plowing).
4. Reduce the adoption into the crops:
   - agrochemical methods (fertilization, liming),
   - grow other crops (other varieties, equivalent crops *e.g.* other fodder crops, other crops).
5. Reduce the use of the crops:
   - condemn,
   - means of harvesting.

The area in which the dairy cows even onwards should be kept indoors should be limited as, gradually, the ground contamination becomes known. As soon as after a few days it should be possible to name areas in which hardly any fall-out has happened. After a month, the knowledge concerning ground coverage of Cesium 137 should be so detailed that the dairy cows can be released in areas where the coverage is below a certain level. Continuos measurings will decide when the dairy cows may be released in areas with a higher ground contamination. The grazing restrictions can be lifted successively as gradually the radioactive substances disintegrate and new, fresh grass grows.

In order to determine when grazing can be permitted, measurings must be performed of radioactive substances on the ground, in the grass and in the milk. This can be done at certain farms where some dairy cows are kept grazing outdoors. The Government will then pay for the milk that must be condemned.

In this way, hypotheses on the connection between ground contamination and the content of radioactive substances in the grass and finally in the milk, can be tested. A more secure basis will be obtained in order to assess whether the dairy cows of other holdings can be released with the ground coverage of that area taken into account.

AGRICULTURAL COUNTERMEASURES – PROBLEMS ASSOCIATED WITH THEIR IMPLEMENTATION

by

S. Bittner, R. Stapel
Germany

1. Introduction

In a nuclear event involving significant potential radiological consequences measures have to be taken to keep the exposure of humans as low as possible. Such measures can be divided into agricultural and non-agricultural ones. The latter – except in cases of very high soil contamination – are of short-lived character when applied before or during the passage of the airborne plume. Agricultural measures, however, can often be initiated not earlier than after the plume has passed. The necessity of such partially very costly late actions could be prevented by the early initiation of other measures, thus minimizing economic and ecological damages. Therefore, the recommendation of countermeasures in the agricultural area obviously has a multitude of aspects to be considered when preparing for a nuclear emergency. There is a need for:

- measures to be appropriate for the actual situation,
- economic considerations to be taken into account, and
- possible ecological consequences to be analysed.

With such aspects in mind, agricultural countermeasures will be discussed in the course of the following passages.

2. Time phases

In case of an airborne radioactive release, it has proved sensible to differentiate between three time stages in reference to the passage of an airborne plume:

Phase I: Measures before passage of an airborne plume;
Phase II: Measures during and immediately after passage of an airborne plume;
Phase III: Measures after passage of an airborne plume.

2.1 *Phase I (before passage of an airborne plume)*

In this phase, the radioactive cloud is expected. The time available for preparation for the passage of an airborne plume might be a matter of hours or days. The recommendation of measures before passage of an airborne plume is based on results from a radioecological evaluation of the expected contamination on the basis of a potential source term and corresponding to dispersion calculations. Such predictions are still subject to considerable error due to the uncertainties between estimation and the actual course of event.

The measures recommended in this stage are short-termed and designed to avoid contamination. They include, for instance:

- immediate gathering of all products ready for harvest,
- closing of green houses and cold frames,
- covering of fruit cultures as well as of open feed – and food depots and prepare for stabling and prevent livestock from grazing.

The advantage of such measures is their cost efficiency and also their preventive nature. The ecological consequences of such measures are relatively low, if any at all.

As a result it is necessary to establish reference values during the planning stage before a nuclear contamination occurs which, when exceeded, demand initiation of the above recommended measures. Since the available data base includes predicted values marked with great uncertainties and since the measures are cost efficient, it will be sufficient when reference values represent certain magnitudes of quantities beyond which measures are recommended to be initiated.

2.2 *Phase II (during and immediately after passage of an airborne plume)*

The data base for this stage has still not changed considerably. The recommendation of measures will primarily still rest on predictions since sufficient measurement data on the contamination of agricultural products will only be available during this stage if the time of passage of the airborne plume is of longer duration.

Measures taken before passage of the airborne plume still largely apply also during this stage. The goal continues to be the prevention of agricultural products from contamination, while a possible human radiation exposure, particularly from inhalation, must be taken into consideration, *i.e.* animals remain stabled but products ready for harvest should not be gathered during passage of an airborne plume. An additional example for an appropriate measure is:

Avoidance of using contaminated surface water to irrigate agricultural fields or cattle trough.

2.3 *Phase III (after passage of an airborne plume)*

In this stage the contamination of various environmental areas by direct deposition has been concluded. With some delay, further relevant environmental areas will be contaminated which were not or only little exposed by direct deposition. Now it is important to gain a long-term view of the process of activity concentration in relevant environmental areas.

After passage of an airborne plume, the general question is whether intervention levels were exceeded. Should this be the case, it is necessary to examine whether agricultural products can still be brought to market. Is this not possible, it must be determined whether, by appropriate measures, for example, storage until short-lived radionuclides have worn off or industrial processing, products could be processed to reduce their activity to a level conforming with the limits established by EU. If this is not possible, the products must be discarded.

As a data base for announcing recommendations, measurement values covering agricultural areas are now available (*e.g* soil contamination, specific activities in milk, plants, etc.).

Measures applied after radioactive contamination, for example the disposal of agricultural products, are more costly and, in part, more complicated than the measures applied for the two preceding phases. For this reason, the measures applied during this stage are no longer based on predicted but on measured values. Predictions are now only used to identify possible critical agricultural products and affected areas, particularly in view of the future development of radioactive contamination.

Measures that now are available can be divided into two groups:

1. Measures reducing the contamination in feed – and food products;
   - delay of harvesting time, higher cutting level when harvesting, etc.;
   - feeding of uncontaminated fodder, additional feeding of Cs – and Sr-binders;
   - industrial processing (production of canned vegetables, fruit juices, wine, butter, full grinding of cereals storage;
   - alternative use or disposal of highly contaminated feed – and food products (discarding).

2. Measures reducing or preventing the transfer of radionuclides into feed – and food products after deposition, for example by:
   - decontamination and processing of agricultural soils (clearing/removal of upper soil, deep ploughing, adding fertilizing agents, etc.);
   - cultivation of alternative crops (flax, rape instead of grain, sugar beets instead of potatoes etc.);
   - abandonment of agricultural areas (afforestation of highly contaminated areas).

The individual measures may have greater ecological than economical consequences because of partially grave interferences with nature and a thus permanent disruption of the ecological system (*e.g.* clearance of upper soils) which, among others, will only be regenerated in the far future.

3. Problems

3.1 *General*

Before any measure can be recommended, its utility in each actual situation must be weighed while considering also all of the economical consequences (cost-benefit-analysis). For example, there is a difference whether individual measures should be used in small areas or in the entire country.

Precondition for the implementation of a specific countermeasure is that the competent authorities ascertain already in the planning stage, *i.e.* prior to nuclear contamination, the availability of personnel, as well as of consumption and use related materials for implementing the action. In any practical application, problems may nevertheless occur.

3.2 *Problems with short-term measures*

With short-term measures before the passage of an airborne plume, the available time is playing a particularly important role. Furthermore and as mentioned above, there is again the capacity problem, *i.e.* whether materials needed for the implementation (*e.g.* harvesting machines, storage space, sheets of covering material, sufficient amount of uncontaminated fodder) and personnel are available in sufficient number.

3.3 *Problems with medium – and long-term measures*

The heaviest ecological damages occur within the range of measures concerning the abandonment of agricultural use. For instance, when clearing a forest area, the side effect will be a dry surface with the hazard of whirling up the deposited radioactive particles. This re-suspension may lead to an increased inhalation dose , particularly by whirled-up alpha-particles.

A further consequence within the abandonment of agricultural use could be a complete change in land utilization. This is connected with at times massive financial losses for parts of the population. A change in land utilization can also mean a necessary change in nutritional habits of the locally affected population, depending on the size of the affected area. The problems are even larger when highly contaminated areas are destined to a piece of fallow land, *i.e.* completely non-arable. In such case, financial compensation or the supply of substitute land for further utilization should be offered.

Decontamination problems: Several approaches to decontamination with different requirements and consequences are possible. One possibility of decontaminating agricultural soils is to clear off the upper soil level by using street sweeping machines. Next to the accumulating high amounts of waste needing to be disposed, this measure disrupts the ecological soil balance and decreases the fertility of the soil. A further possibility would be a shifting of upper soil to a deeper level or deep ploughing. The equipment needed for both measures is lacking.

The problem of waste disposal: A difficult problem is the disposal of cleared vegetation and the discarding of highly contaminated food products. In a small and spatially limited area, the implementation of this measure may perhaps be relatively uncomplicated. The corresponding damage claims will have to be paid but the compensation by alternative and not contaminated food products should be relatively simple. It is more difficult if, for instance, the entire country is affected by the measure.

In both cases, however, the question of how the waste products should be disposed will arise. This problem originates from all decontamination measures and not only in the agricultural area.

Problems with industrial processing: Problems will also emerge concerning industrial processing. An example is the processing of milk into butter. Aside from the processing costs, the problem of what to do with additional butter, beyond an already existing excessive amount of butter, needs to be solved. In the light of this, would it not be more sensible to discard the milk? Would the storage of new butter not create additional costs?

4. Conclusion

From all of these considerations evolves the necessity that already during the planning stage the individual measures must be thoroughly examined. It would seem to be practical to have measures with corresponding limiting values available for each single stage, and particularly for the first two, in excess of which values the implementation of measures is recommended. They should be compiled and ready for use for the respective agricultural products and also for alternative quantities (*e.g.* time integrated activity concentration in air, soil contamination, etc.).

For this purpose, a first compilation of countermeasures was done in Germany, the so-called Catalogue of Countermeasures [1]. An easily viewed tabulation in form of a poster would also be of benefit.

In France, too, a compilation of agricultural measures with corresponding reference values already exists [2].

Among others, the problem of waste arising from decontamination needs to be clarified as well as the disposal of waste from discarded agricultural products.

REFERENCES

1. Karthein, R.; Schnadt, H.; Willrodt, C, "Übersicht über Maßnahmen zur Verringerung der Strahlenexposition nach Ereignissen mit nicht unerheblichen radiologischen Auswirkungen" TÜV Rheinland, Köln, 30. Juni 1992 (überarbeitet am 22.03.1993).

2. Association Nationale pour le Développement Agricole, 1990 Agriculture, environnement et nucléaire, Comment réagir en cas d'accident.

CHANGING CROP AND LIVESTOCK FARMING PRACTICES TO MINIMISE CONTAMINATION IN THE FOOD CHAIN

by

Henri Maubert and Philippe Renaud
France

Abstract

Following a nuclear accident, it is important to minimise human exposure to land and surface deposits of radioactive aerosols. Agricultural countermeasures are protective actions designed to achieve this objective in the farming and agri-food sectors. We now have a better understanding of their effectiveness when used individually or in combinations and also of how and why they should be implemented, notably as a result of their widespread use after the Chernobyl accident.

Based on a wide-ranging study of the literature, this report provides statistical information on agricultural countermeasures.

1. Introduction

Since the Chernobyl accident, much research has been given over to agricultural countermeasures. These are protective actions directed towards the farming sector and the agri-food industry and aimed at reducing the potential for human absorption of radionuclides, primarily through ingestion.

This report takes stock of such measures and provides statistics to demonstrate how effective they are in reducing radioactivity.

2. Changing Agricultural Practices

2.1 Rehabilitation techniques

These techniques are used to bind some of the radioactive deposits and remove them from the soil. In the case of farmland with little or no plant cover (ploughed earth, stubble or recently sown fields) and few stones, there are two possible techniques. They both involve binding, then removing, the first few centimetres of topsoil which contain virtually all the radioactivity.

Binding is carried out using either **polyurethane foam** [1], spread over the ground to polymerise or "trap" soil particles or by means of natural or seeded **plant cover** with a running root system that has the same effect. Tests conducted in 1992 around Chernobyl showed that peeling-off some types of plant-cover could remove between 95 and 99 per cent of the contamination, depending on the radionuclide and the depth of soil removed.

Such techniques are particularly effective when used in the first few years after the accident. During this period, the land must be left fallow. If the land is worked and the radioactivity allowed to penetrate into the soil, the effectiveness of these techniques will rapidly be reduced.

The disadvantage of such techniques is that their deployment requires special resources which still require further development.

Another method is **deep ploughing**, using special implements to bury the radioactivity below the root horizon (-1 metre), more or less beyond the reach of crop root systems. This is not strictly a site decontamination technique since, unlike the previous method, it does not remove radioactivity. Experiments have shown it to improve on normal ploughing by a factor of 2 to 3 [2].

With this technique, however, there is a risk that the radioactivity will migrate upwards to the arable topsoil or downwards to the water table, into an environment conducive to its release [3]. Tests are under way on a method that uses chemicals to block radioactive surface deposits in the topsoil, then buries them – without turning the soil over – 30 to 40 cm below the surface [4].

Finally, for perennial crops like grapes and fruit, one solution is **defoliation**, which does not kill off the plants but prevents the migration of radioactive deposits from leaf surfaces to woody stems and fruit. This technique is still at the early trial stage.

2.2 *Use of additives*

The addition of stable isotopes to the soil via **fertilisers**, a method similar to isotopic dilution, will reduce plant uptake. This is a particularly effective countermeasure in soils which have a high capacity to absorb a particular isotope. It was widely used after the Chernobyl accident and improvements ranging from a factor of 1.5 to 2.5 were achieved with different crops [5, 6, 7, 8]. However, the sandy soils around Chernobyl are not ideal for this kind of countermeasure. In permeable soils, there is a risk that excessive doses of fertiliser (over 1g per kg or 3t per ha) may have the opposite effect and increase the transfer factor as a result of the displacement of caesium at binding sites by potassium ions. In all cases, the use of fertilisers containing ammonium is to be avoided [5] because the ammonium ion causes the desorption of cations bound to soil particles, thereby enhancing the bio-availability of pollutants.

Adsorbents or **complexants** (sequestering agents) are used to increase the soil's capacity to hold and hence bind radionuclides. The use of zeolites on the contaminated land around Chernobyl reduced the soil-to-plant transfer of caesium by a factor of 1.5 to 2 [6]. However, this countermeasure is apparently less effective when used in combination with fertiliser [7]. Reducing soil acidity will also reduce transfer factors. Lime can therefore be added to acid soil. In Ukraine, liming reduced caesium levels by a factor of 1.5 to 2 [8]. A combination of lime and fertiliser on pasture, for instance, reduced caesium levels in milk by a factor of 3.5 [9].

3. Changes in Livestock Farming Practices

3.1 *Livestock farming*

Milk production, which is of particular importance to children's health, is the activity that is the most sensitive to post-accident conditions, and will be affected within a few hours of the deposition of radioactivity. In the short term, the transfer of radioactive iodine into milk is a major contamination pathway, particularly in the case of cows allowed to graze freely and thus directly exposed to the deposits. In the medium and long term, the transfer of radiostrontium and radiocaesium into milk may still give cause for concern even when the transfer to crops is no longer a problem.

As a rule, all free-grazing dairy and beef cattle should be rapidly withdrawn from pasture; suckling calves, in particular, concentrate high levels of radioactivity. However, suckling is increasingly rare as calves are now fed reconstituted milk. Pig and poultry farms are often safer in the months following an accident, since feeding takes place in indoor pens or battery sheds.

Possible countermeasures for livestock which has been left to graze on the land after an accident, or which for economic reasons (to use up fodder or cereal crops) or because of the difficulty of procuring feed from outside suppliers, must be fed contaminated fodder, include deferring the date of slaughter, clean-feed diets and the use of techniques designed to reduce the rate of metabolic transfer (cf.§ 3.3).

3.2 *Withdrawal from pasture*

The earlier this countermeasure is taken, the more effective it will be, particularly in the week following the accident. The ensuing decrease in milk activity will directly determine the length of any ban on consumption (Figure 1). Reducing the radioactivity in cow's milk by a factor of 2 once there is metabolic equilibrium will take 7-10 days for caesium, 40 hours for strontium and 20 hours for iodine [10]. As well as withdrawing the stock from pasture, care must be taken to ensure that drinking water is as free as possible from contamination.

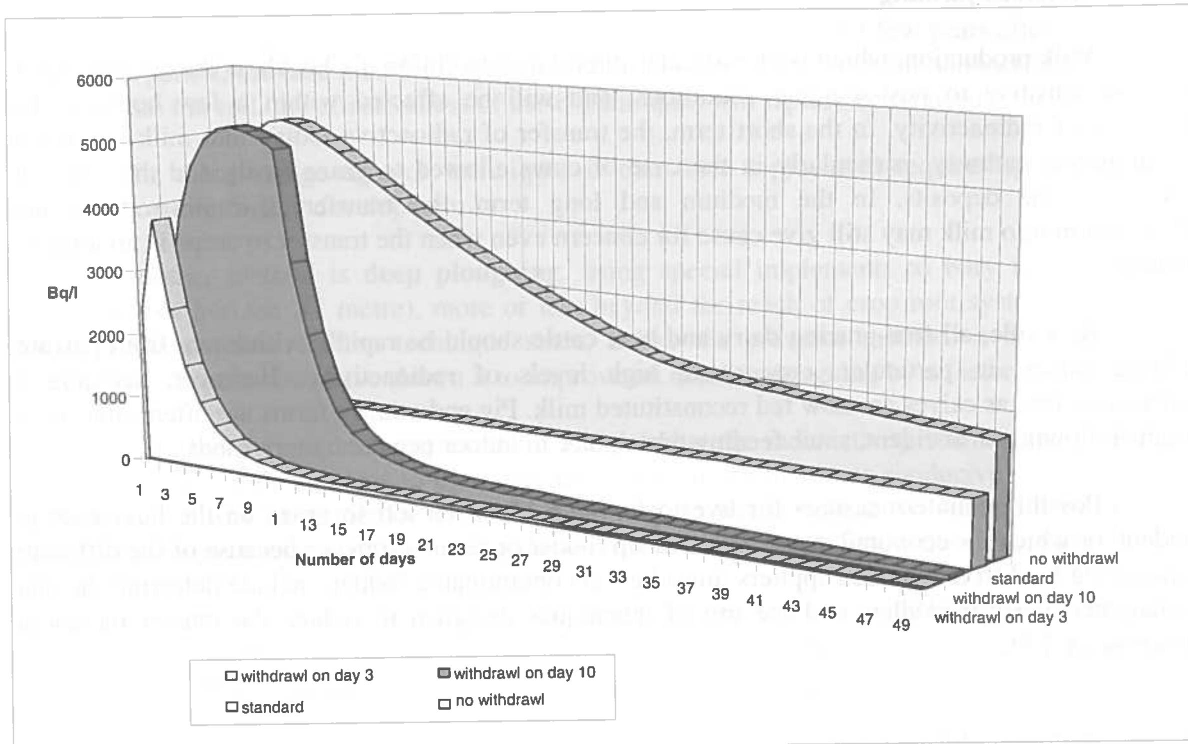
Its effectiveness as a countermeasure can also be assessed by calculating the ratio of the radioactivity in milk, over a period of 100 days, without withdrawal from pasture to the radioactivity following withdrawal after a given number of days.

Table 1. Examples of the effectiveness of "withdrawal from pasture", based on caesium levels in milk over a period of 100 days (Bq without withdrawal/Bq after withdrawal on Day x)

X (days)	2	5	8	10	30
Effectiveness	14	6	4	3	1.5

The findings for strontium 90 are comparable.

Figure 1: Effectiveness of withdrawal from pasture in reducing caesium-137 levels in milk from cows grazing freely on land carrying a deposit of 1E5 Bq.m^{-2}



The standard indicated is 1 000 Bq/kg (EEC). The metabolic model used for this graph is the German model ECOSYS [14].

This countermeasure raises the problem of feed supply, in particular on extensive dairy farms following an accident in the spring or the early months of the year. The equivalent of 13 kg of dry matter must be available per day and per cow. This is a production ration, which can be cut back to a subsistence ration of 8-10 kg of dry matter per day and per cow. If confinement proves difficult or impossible for the whole herd on a sustainable basis, the stock can be kept on small paddocks of previously mown pasture; subsequently, when there is adequate regrowth, the paddocks can be extended and the cattle gradually returned to free grazing.

A series of countermeasures aimed at achieving this objective and referred to collectively as the "radical improvement of grassland and natural pasture" was applied in the Pripet Marshes area in Belarus [11, 12] after the Chernobyl accident. The countermeasures consisted in the deep-ploughing of pastureland, treatment with complexants and fertilisers and then re-seeding. The use of this technique reduced caesium levels in cow's milk by a factor of 3 (on podzol or peat) to 16 (on more fertile land), without any other measures being taken with regard to the cattle. It also helps to reduce external exposure by a factor of 2 to 3. In the case of contamination by "hot particles", however, it apparently has the opposite effect, probably due to deterioration of the matrix enclosing the fission products.

As a rule, the radioactive content of milk from cows grazing on natural pasture is 3 to 14 times higher than for cows grazing on seeded pasture, assuming deposits are identical and no other countermeasures are used.

3.3 *Postponing the time of slaughter and decontamination diets*

In the case of free-grazing cattle that cannot be brought inside within eight days, the time of slaughter should be postponed to allow the elimination of contaminants from the metabolism, during which time they should be given clean fodder. To reduce radioactivity by a factor of 2 in cattle and sheep takes from five to seven days for iodine, 20 to 40 days for caesium and 60 to 100 days for strontium [10]. R.G. Iliazov et al [12] found that biological elimination periods ranging from 14 to 30 days were needed depending on the feed ration. These findings are in line with the metabolic periods used in dynamic models of radioactivity transfer to animal produce [13, 14].

Decontamination diets can be used to treat cattle which have been fed, in part, on contaminated feed and which thus fail to comply with meat marketing standards. Since the biological elimination periods listed above can be shortened by giving clean fodder to livestock, maintaining animals on clean feeds for a period of time prior to slaughter offers an effective means of reducing contamination to an acceptable level. N.P. Astacheva et al [15] note that some livestock fattening diets, mostly barley-based, can bring down overall radioactivity levels in meat by a factor of 8 to 12 within two to three months.

3.4 *Decrease in metabolic transfer to milk and meat*

The administration of **iodine** is based on the well-known principle of isotopic dilution, also used in treating humans. Iodine activity in milk can be reduced by a factor of 2 to 4 by administering a daily dose of around 10g of potassium or sodium iodide [16].

The countermeasures for caesium and strontium consist in adding to animal feeds substances which can adsorb radionuclides in the gastro-intestinal tract. This allows a greater proportion of contaminants to be excreted, thus reducing the transfer of radioactivity to milk and meat.

Incorporating **clays** (bentonite, vermiculite) in animal feeds will reduce radiocaesium levels in milk (cow's or ewe's) and meat (beef, mutton or pork) by a factor of 2, based an a daily dose of around 300g. Stock can be given up to 500g per day without suffering any ill effects. More than 800g per day of clay will cause loss of weight, and from 700g per day upwards animals will gradually start to refuse to feed. Finally, supplementing feed with 5 per cent doses of humolite, a mixture of zeolite and humus, will reduce radioactivity by a factor of 3 [17].

Doses of **hexacyanoferrate (Prussian Blue)** reduces caesium levels by a factor of 3 to 5 in cow's or ewe's milk, and by a factor of 4 in beef, 6 in chicken, and 10 in veal or pork [18][19][20]. It is administered simply by adding it to animals' diet (1g.kg^{-1}), either in the form of salt licks or by means of boli that gradually release the substance into the rumen [21]. This treatment, routinely used in Norway and Ireland, was used on some private farms affected by radioactivity from Chernobyl as early as the 1993 grazing season [22].

4. Simple Food Processing and Culinary Preparation

When farm produce has been contaminated, the amount of radioactivity ingested can be reduced by, for instance, certain types of agri-food processing and culinary preparation. The radioactive content of the food can be modified in various ways:

- Discarding part of the raw product, *e.g.* fruit and vegetable skins or animal bones and fat, will reduce radioactivity.

- Some forms of cooking *e.g.* boiling vegetables, will dilute radioactivity.
- Some forms of processing may, on the contrary, concentrate radioactivity *e.g.* crisps (potato chips).

The transfer factors associated with the main types of agri-food processing are given in Table 2.

Table 2: Transfer factor from raw produce to finished product in certain forms of food processing or culinary preparations: [Bq/kg fresh processed/Bq/kg fresh raw] [23, 24, 25, 26, 27]

Produce		Cs	Sr	I
meat	→boiled	0.4	0.5	0.6
	→roasted or fried	0.8	0.8	
	→marinated	0.1 – 0.6	0.5	
	→cured	0.2 – 0.4		
milk→derived products				
cottage cheese		0.01 – 0.05	0.08	0.25
whey from cottage cheese		0.70 – 0.95		
cheese, soft or hard (rennet)		0.05 – 0.10	0.5 – 0.6	0.15 – 0.30
whey cheese		0.10 – 0.12	0.08	0.21 – 0.27
yoghurt		0.34		
skimmed milk		0.90 – 0.95	0.90 – 0.95	0.85
cream		0.05 – 0.10	0.05 – 0.10	0.15
butter		0.01 – 0.05	0.005 – 0.008	0.04
wheat	→ white flour	0.40	0.20	
potatoes→	peeled, boiled	0.90	0.75	
	fried		0.60	
	crisps (potato chips)	2.00	5.00	
mushrooms	→boiled	0.80	0.50	
leafy vegetables*	→washed	0.90	0.50 – 0.80	
(lettuce, cabbage, spinach)	blanched	0.10 – 0.50	0.50	
fruit vegetables*→	boiled	0.30 – 0.50	0.30	0.20

* Vegetables contaminated by airborne deposits

5. Comments

A few comments are called for with regard to the limitations of the countermeasures described above in terms of their effectiveness and the way in which they must be applied.

As we saw with regard to changes in production, the use of **countermeasures in combinations** can sometimes prove more effective than the sum of the effects of the individual measures involved. A good example is provided by a set of countermeasures known as the "radical improvement of grassland and natural pasture" which was used in the Pripet Marshes area in

Belarus [11, 12] and which successfully reduced radiocaesium levels in cow's milk by a factor of 3 (on podzol or peat) to 16 (on more fertile ground), without any other measures being taken regarding the cattle.

Although rehabilitation techniques can significantly reduce activity levels and improve the morale of the population, they pose major problems in terms of their implementation (special machinery still under development) and the subsequent disposal of waste. Their costs in both financial and radiological terms (dose received by those applying the techniques) also need to be assessed in order to determine whether the size or economic value of the land concerned justifies the use of such techniques. They are mainly worthwhile for rehabilitating small areas of urban or suburban land (*e.g.* gardens, lawns, clay paths).

With respect to additives, their proven effectiveness in reducing contamination is actually lower than the variations normally observed in the amount of radioactivity transferred. This makes it difficult to impose them as part of a countermeasure management plan for use in emergencies. We would therefore suggest that they be used to support and make safe decisions to authorise the sale of specific agricultural products, rather than as a justification for extending such authorisations. For instance, they should be recommended for products which already meet the requirements of health standards and should not be used to bring products whose level of contamination is two or three times over the specified limit up to marketable standard (depending on the countermeasure in question). It should also be borne in mind that such countermeasures require special forms of treatment which need to be maintained permanently in place, in particular where animals are concerned, and which may in the long term become both tedious and onerous.

Changes in production require a radical shift in agri-food practices, the introduction of special arrangements on a vast scale (new forms of trade) and the presence of an adequate agri-food infrastructure. However, such changes are not incompatible with traditional practices and may very well fit in with existing systems of production. For example, switching from forage or row crops to cereals is routine practice in crop-rotation and allows the land to maintain its full yield capacity. Similarly, the development of farm produce collection and distribution channels, and their expansion as agri-food processing structures consolidate, should, with some adjustment, enable the recommendations on food-processing to be put into practice. From a radiological standpoint, changes in production practices should make it possible, by intervening at different stages, in the food chain, to cumulate the effects of the individual countermeasures envisaged and thus enable agricultural products that fall well within the requirements of basic standards to be produced in contaminated areas.

6. Conclusion

Research into ways of reducing the transfer of radioactivity throughout the terrestrial food chain has led to the development of a wide range of countermeasures for use in post-accident situations whose effectiveness has been tested in field trials and through subsequent use in various CIS countries.

Most of the tests have confirmed the effectiveness of the more widely studied countermeasures, namely the use of additives to reduce transfers of radioactivity into farm produce (lime, fertilisers and zeolites for transfers to crops, and iodine, clay, and cyanoferrates for transfers to livestock). The same is true of rehabilitation techniques (soil removal, deep ploughing, etc.), also tested in situ on contaminated land.

These "full-scale" applications of countermeasures have also revealed the limitations of such measures when used on extensive areas of land (in the case of rehabilitation techniques) or over long periods of time (additives). The decision as to whether they should be applied must clearly be based on their effectiveness in terms of their ability to cope with variations in initial deposits and the actual transfer of radioactivity; the basic protection factors weighing on any decision; the constraints, costs and problems generated by implementation; and above all the psychological impact of countermeasures.

In addition to or in support of these countermeasures, other measures involving changes in agri-food practices have been proposed. Some have been tested and introduced by the authorities in various parts of the CIS. Their effectiveness, their suitability for large-scale applications, their compatibility with existing agri-food structures and their sustainability would appear to make these countermeasures an appropriate response to the major long-term concern, which is to minimise the impact of an accident.

REFERENCES

1. H. Maubert, A. Jouve, N. Mary and R. Millan-Gomez; *Agricultural soil decontamination techniques: methods and results of tests released near Chernobyl.* Environmental impact of nuclear installations. Seminar, Fribourg, (Switzerland) 15-18 September 1992. SFR February 1993.

2. H. Loensjoe, K. Rosen. Effects of remedial measures on long term transfer of radiocaesium from soil to agricultural products as calculated from Swedish field experimental data. International Symposium on Environmental Contamination following a Major Nuclear Accident. Vienna, 16-20 October 1989.

3. V.S. Davidtchouk. *Analyse écologique des conséquences des contre-mesures dans la zone de Tchernobyl.* UIR/CIS Seminar on Radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

4. V.P. Koukhar, V.V. Blagoev, AN Liachenko, Bilanzet; Perspectives des travaux de l'Institut de chimie bio-organique et pétrolière de l'Académie des Sciences de l'Ukraine dans le domaine de la réhabilitation de zones contaminées suite à l'accident de Tchernobyl. UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April – 4 May 1991.

5. A. Grauby, A. Jouve, B. Legrand: Study of the possibility of attempting soil-plant transfer after an accident, by application of manure to the soil and by foliar spraying. Workshop on the transfer of radionuclides in natural and semi-natural environments. Udine (Italy), 11-15 September 1989. Desmet, 707 pp., p.403, 1990.

6. R.M. Alexakhin. *Countermeasures in agricultural protection as a powerful factor in liquidation of the Chernobyl accident consequences.* Workshop on "Relative Effectiveness of Agricultural Countermeasury Techniques" (REACT). Brussels, 2-4 October 1991.

7. A.G. Tischenko, V.I. Kounovsky. *Accumulation du ^{137}Cs dans les tubercules de pommes de terre suite à l'introduction d'engrais et d'agents améliorants.* UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

8. P.F. Bondar, A.I. Doutov. Influence des engrais minéraux et autres agents améliorants sur l'accumulation du césium dans la récolte d'avoine sur les sols chaulés. UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

9. B. Prister, G.P. Perepeliatnikova, L.V. Perepeliatnikova. Countermeasures used in the Ukraine to produce forage and animal food products with radionuclide levels below intervention limits after the Chernobyl accident. The Science of the Total Environment. vol. 137, p.183, 1993.

10. B.EV. Jones. Management methods of reducing radionuclide contmaination of animal food products. The Science of the Total Environment. vol. 137, p.227, 1993.

11. S.K. Firsakova, N.V. Grebenschikova, S.F. Timofeev, A.A. Nivik. *Efficacité des contre–mesures d'amélioration des sols appliquées en Polésie biélorusse pour diminuer les transferts du radiocésium dans les plantes.* UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

12. R.G. Iliazov *et al. Utilisations possibles de différentes préparations de ferrocyanides pour diminuer le transfert du radiocésium dans la production de l'élévage du territoir contaminé par Tchernobyl.* UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

13. *Radioactivity transfer to animal products.* Radiation protection of the Commission of the European Communities. Report EURO 12608 EN – 1991.

14. H. Müller, G. Pröhl. ECOSYS-87: *A dynamic model for assessing radiological consequences of nuclear accidents.* Health Physics, vol. 64, No. 3, p. 232, 1993.

15. N.P. Astacheva, L.M. Romanov. *Possibilité de diminution de la pénétration des radionucléides dans la production de l'élevage.* UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

16. G. Voigt. The reduction of radioactive contamination in animals and their products by chemicals in agricultural ecosystems. GSF. Forschungszentrum für Umwelt und Gesundheit. Institut für Strahlenschutz. Neuhaberg. 1991.

17. B. Prister, N. Coschchilov, L. Perepeliatnikova. Efficiency of measures aimed at decreasing the contamination of agricultural products in areas contaminated by the Chernobyl NPP accident. The Science of the Total Environment. vol. 112(l), p.79, February 1992.

18. G. Voigt. The reduction of radioactive contamination in animals and their products by chemicals in agricultural ecosystems. GSF. Forschungszentrum für Umwelt und Gesundheit. Institut für Strahlenschutz. Neuhaberg. 1991.

19. R.G. Iliazov, S.K. Firsakova, A.F Karpenko. *Problèmes radioécologiques de l'élevage en Bélarus après l'accident de Tchernobyl.* UIR/CIS Seminar on radio-ecology and countermeasures, Kiev, 27 April to 4 May 1991.

20. N.I. Burov, P. Arhkipov, S.P. Gaschak, M.S. Roudtchenko. *Influence des ferrocyanides sur la teneur en ^{137}Cs de la production de l'élevage après Tchernobyl.* UIR/CIS Seminar on Radioecology and Countermeasures, Kiev, 27 April to 4 May 1991.

21. K. Hove. Chemical methods for reduction of the transfer of radionuclides to farm animals in a semi-natural environment. The Science of the Total Environment, vol. 137, p. 235, 1993.

22. Reducing caesium contamination of food products in the Chernobyl area. AIEA Bulletin, 1/1993. p. 18.

23. A. Grauby, J. Miribel. *Les techniques agro-alimentaires et culinaires, rôle et importance sur les niveaux radiologiques des aliments.* Seminar on Radioactivity Transfer during Food Processing and Culinary Preparation. Cadarache (France), 18-21 September 1989. p. 3.

24. H. Noordjik. A literature review on radionuclide behaviour during food processing. *Les techniques agro-alimentaires et culinaires, rôle et importance sur les niveaux radiologiques des aliments.* Seminar on Radioactivity Transfer during Food Processing and Culinary Preparation. Cadarache (France), 18-21 September 1989. p. 29.

25. G. Voigt, H. Müller, G. Pröhl, N.G. Paretzke. *Caesium activity distribution in cereals after milling processes.* Seminar on Radioactivity Transfer during Food Processing and Culinary Preparation. Cadarache (France), 18-21 September 1989. p. 351.

26. R. Kirchmann. Rétrospective des études sur la décontamination du lait et la répartition des produits de fission majeurs dans les dérivés. *Les techniques agro-alimentaires et culinaires, rôle et importance sur les niveaux radiologiques des aliments.* Seminar on Radioactivity Transfer during Food Processing and Culinary Preparation. Cadarache (France), 18-21 September 1989. p. 231.

27. A.H. Rantavarra. *Transfer of radionuclides during processing and preparation of foods.* Finnish studies since 1986. Seminar on Radioactivity Transfer during Food Processing and Culinary Preparation. Cadarache (France), 18-21 September 1989. p.69.

AGRICULTURAL ASPECTS OF CONSEQUENCES OF THE ACCIDENT ON CHERNOBYL NPP IN THE UKRAINE

by

B.S. Prister, L.V. Perepelyatnikova and V.A. Pronevich
Ukraine

Abstract

Sequence of application and Mectiveness of countermeasures, applied in agriculture after nuclear accidents, is shown on the example of the territories of Ukraine, contaminated after the accident on Chernobyl NPP. High effectiveness of chemical ameliorations, especially on acid soddy-podzolic and peaty soils is demonstrated. The important aspect of radiation protection of the population is application of countermeasures on private farms, which use for production critical landscapes – forest and swampy pastures. The necessity of not only radiation monitoring, but also ecological and hygienical monitoring in order to discover critical landscapes and products, is shown.

The importance of agricultural aspects of the consequences of environmental radioactive contamination is determined not only by its scale, but also by its complex character: together with the problem of population radiation protection it includes social-psychological problems, employment of people, the necessity to change life habits and ways of using nature communities. In this connection the decision on countermeasures application in agriculture and intervention levels should be done immediately after the decision on evacuation or other urgent measures of human protection from external irradiation, inhalation intake of radionuclides or surface contamination.

The sequence of measures application and characteristics of the basic agricultural countermeasures are presented in Table 1. Irradiation of the population in biologically significant doses is the most probable in the first period after the accident, before the monitoring of radiation situation. Therefore, initial measures are prohibitive or restrictive, in order to exclude uncontrolled transfer of radionuclides to the organism of people and agricultural animals and prevent radiological effects on the cattle. These measures include: immediate ceasing of field works, pasturing of animals and poultry, feeding of fresh forage, consumption of fresh vegetables by people. Unfortunately, late application of the above mentioned measures greatly aggravated the consequences of Chernobyl accident.

As the radiation monitoring is carried out, the prediction of radiation effects on plants and animals should be done.

Table 1. Radiological measures carried out in agricultural areas after a major radiation accident

Type of measure	Principal characteristics	Period of application
Interdictions	• Cease the consumption and sale of vegetables, especially leafy ones • Cease cattle pasturing and feading fresh fodder	Before the specification of the radiation situation
Prediction of effects for plants and animals, its differentiation	• Measurement of gamma-radiation dose rate on the surface of animals body • Clinical observations for the condition of animals	After the end of fallouts and during 10-14 days after the accident
Study radiation situation and degree of plant contamination	• Survey the area by measurement of the gamma-dose rate	Immediately after the accident
Plant contamination	• Determine the radionuclide composition of contaminated soils and plants. • Assess the expected areal deposition on, and root contamination of plants, taking into account the season and soil condition. • Determine the critical radionuclides and products • Approximate the radionuclide binding capacity of soils Organize the radiological control of agricultural production	After obtaining data on the nuclide composition of the contamination
Specifying the contamination situation	• Compile farmland contamination maps; collect data and specify the agrochemical properties of soils	Immediately after the gamma-survey, before the extent of radioactive contamination is specified
Change land-use structure	• Exclude from crop rotation the fields that are most contaminated. • Allocate pasture and hay product to areas least contaminated. • Differentiate between dairy and meat cattle. • Differentiate between fodder with different levels of contamination during storage	As the radiation situation specifies
Land-reclamation and agrotechnical	• Determine the main soil parameters governing the transfer of radionuclides to plants and determine ways of influencing them. Cultivate soils, improve meadows and pastures by applying ameliorators and fertilizers, or change the agrotechniques	Constantly until the radiation situation is normalized

Radiation damage of crops can happen at contamination density of fallouts of fission products young mixture above 2 GBq/m^2 [1]. Plants contamination is determined both by their specific radiosensitivity, and feasibility to contamination. At equal density of contamination, value of the dose, received by plant critical organ, depends on physical-chemical characteristics of released radioactive substance, phase of development at the moment of acute irradiation, etc.

Application of measures on plants protection is unreasonable, as it is connected with considerable economical and dose expenses, and usage of saved harvest will be practically impossible due to high level of contamination with radionuclides. For the prediction of damage the plants can cause the data of experiments with plants irradiation by contaminating with young mixture of fission products and ittrium 90 [2].

Consumption of fresh fodder on the pasture and in stalls is most dangerous for animals. Main factor of radiation danger is the intake of iodine radionuclides. Thyroid irradiation in thyreoectomical doses (above 200 Sv) is possible at intake of more than 5 GBq of I-131 to the organism [2]. Blood-forming and gastrointestinal systems can be affected at much lower irradiation doses – above 10 and 0.2 Sv respectively. In case of animals contamination they should be differentiated by the expected degree of their contamination in accordance with recommendations, developed by us [2].

Unfortunately, in acute period after the Chernobyl accident, contaminated animals were not differentiated and a considerable amount of animals (more than 15 thousand cows only in Ukraine) were slaughtered in the first days after the accident. Utilization of corpses caused great hygienic and economical difficulties, and storage of meat in refrigerators, naturally, did not provide self-decontamination from long living radionuclides as a result of decay. The problem of utilization of this meat and bone powder is not solved to the end, even 9 years after the accident. At the same time, feeding of animals with "clean" fodder could provide radiocaesium removal from the organism within 1-2 months.

Prohibitive and restrictive countermeasures are the most effective in small private farms, where most of products are used fresh without processing. At the same time, urban population has centralized supply with milk and other food, which allows to restrict radionuclides-transfer to human organism. For instance, in Kiev in 1986 differentiated usage of milk after detecting its contamination levels and processing to butter allowed to reduce the concentration of I-131 in milk up to 10 times and to prevent the exceeding of maximum permissible concentrations.

Planning of the second period countermeasures requires the monitoring, tasks of which change, as the situation develops and information is specified (see Table 1). In the second period radiation monitoring should be supplemented by ***Ecological Monitoring***, which allows to discover critical landscapes and objects. For example, the territory of Ukrainian Polessye, contaminated after the accident on Chernobyl NPP, is characterized by great geochemical contrast. The range of mineral soils includes leached chernozems with pH of salt extract 6.6 to 7.5, grey forest soils with pH 5.6-6.5 and acid soddy-podzolic soils with pH 4.5-5.5.

Transfer factors of Cs-137, main dose-forming radionuclide, from soil to forage crops, vary from 2.5 to 13 times. Specific peculiarities in radionuclides accumulation by crops on similar soils determine the differences of TF up to 30-40 times (Table 2).

Table 2. Cs^{137} transfer factor from soil to forage crops (average for 1987-1990), (Bq/km) / (kBq/m² soil)

Crop	Soil type, pH salt extract			Diferences, time
	soddy-podzolic sandy, 4.5 – 5.5	grey forest 5.6 – 6.5	chernozems 6.6 – 7.2	
Hay of natural grasses	10.00	4.00	1.80	5.5
Hay of sown grasses	4.00	3.00	1.60	2.5
Vetch	2.70	0.45	0.20	13.0
Cover	1.80	0.30	0.30	6.0
Lupin	1.50	0.40	0.15	10.0
Lucerne	0.80	0.40	0.20	4.0
Maize for silage	0.40	0.20	0.08	5.0
Root beet	0.50	0.35	0.20	2.5
Potatoes	0.25	0.13	0.045	5.5
Winter grain crops	0.50	0.20	0.05	10.0
Rye	0.40	0.10	0.04	10.0
Barley	0.30	0.10	0.06	5.0
Differences, time	40	40	30	

Differences of soils and climate characteristics are displayed along whole trophic chain. As a result, considerable differences are observed in different zones in contamination of meat and milk, which provide 70–90 per cent of Cs-137 intake, in different zones (Table 3). On chernozems, characterized by higher absorption capacity and content of clay minerals, strength of Cs-137 fixation increases with time and TF of the nuclide to milk and meat decreased since 1987 to 1993 by 4-5 times. On acid soils within the same period TF value decreased only by 1.5-2.0 times.

Table 3. Dynamic of transfer coefficient of Cs^{137} to milk and meat of cattle in Ukraine (Bq/km) / (kBq/m² soil)

$\sigma \leq \pm 20\%$

Product	Group of soil, pH salt	1987	1988	1989	1990	1991	1992	1993
Milk	4.5 – 5.5	1.2	1.2	1.2	0.9	0.8	1.1	0.8
	5.6 – 6.5	0.5	0.6	0.3	0.2	0.2	0.3	0.2
	6.6 – 7.2	0.2	0.2	0.1	0.1	0.1	0.05	0.05
Meat	4.5 – 5.5	2.0	2.4	2.0	1.7	1.5	1.6	1.4
	5.6 – 6.5	0.6	0.7	0.6	0.7	0.5	0.6	0.4
	6.6 – 7.2	0.5	0.3	0.2	0.2	0.2	0.1	0.1

Critical soils are peaty soils, distributed in Polessye: peaty, peatygley, peatboggy. Due to high content of organic matter (from 20 to 60 per cent), acid reaction (pH salt from 4.2 to 5.4) and extremely low content of clay minerals and silt fraction, content of Cs-137 in mobile form in these soils is up to 40-72 per cent, and factors of nuclide transfer for the link soil-plant are 3.7-30 Bq/kg per 1kBq/sq.m of soil, while on soddy-podzolic soil they vary within the range of 0.2-7.6, depending on growing technology. Radioecological monitoring demonstrated that natural and seminatural ecosystems – forests, meadows and cultivated pastures – are critical landscapes in contaminated zone. In the conditions of Polessye they are presented mainly by peaty soils and peatbogs with various degree of gley content. TF in the system soil-meadow vegetation is much higher there, than on arable soils (Table 4).

Table 4. Cs^{137} content in the turf and grass of natural meadows at soils contamination density kBq/m² (1988–1989)

Soil	Meadow Type	Cs^{137}, Bq/kg of air-dry mass	
		Turf	Grass
Meadow-chernozem loamy	Floodland humid	3.0	0.6
Meadow sandy-loam	Waterless normal	10-14	2.0-3.0
Meadow sandy-loam	Floodland humid	12-15	8.0-11
Soddy-podsolic loamy	Waterless normal	4.0-14	1.0-4.0
Soddy-podsolic sandy	Waterless normal	40-63	5.0-9.0
Soddy-podsolic sandy	Waterless overmoisturized	45-69	13-22
Soddy-podsolic sandy	Floodland humid	53-75	25-39
Peaty-gley	Drained peaty	77-90	30-45
Peaty-gley	Peaty floodland	123-172	58-82
Peaty-gley	Peaty lowland	170-198	135-189

As the data of Table 4 demonstrate, Cs-137 accumulation in the biomass of meadow grasses depends on water regime and significantly increases on lowland and floodland pastures.

As a result of these soil peculiarities, total dose of human-internal and external irradiation of 1 mSv can be received onpeaty soils at Cs137 contamination density 0.3-0.6 Ci/sq.km, as compared to 6-8 Ci/sq.km on chernozems (Table 5).

Table 5. Limit level contamination of soil surface, Cu Cs^{137} per km² at which internal irradiation dose from radionuclide intake is mSv/y

Type of soil	Meadow	Arable
Peaty-turf	0.3-0.6	0.6-2.5
Podzolic sandy sod “ash soil”	2	3.5
Light grey podzolic	4	5
Chernozem loam	6	8

Special attention in the second period should be paid to ***Ecological-Hygienic Monitoring***, the task of which is to discover critical products of human diet and trophic chains of their formation. Investigations, carried out on the territory of five regions (Volyn, Rovno, Zhitomir, Kiev and Chernigov) demonstrated, that critical trophic chains are connected with the use of forest and meadow swampy pastures. The monitoring allows to discover pasture and hay fields with high levels of contamination or TF values.

In Milyachy village, Rovno region, Cs-137 concentration in hay and soil in 20 private farms was investigated. As it is seen from the data of Table 6, at differences in pastures contamination by 2.2 times, the farms can be divided into 4 groups by the concentration of Cs-137 in grass and milk differences between the groups exceeding 100 times. Marked differences are preserved during the whole grazing period. Critical pastures should be improved, cultivated or excluded from usage, as the contamination of rough forage on Polessye private farms determines milk contamination.

Table 6. Cs^{137} content in soil and vegetation in grass pastures grazed by privately owned cows v. Miliatchy, Rovno Region

Family no.	Deposition	Vegetation		Milk	
	kBq/m²	kBq/kg dw	TF* x 10^{-3} m²/kg	kBq/l	TF* x 10^{-3} m²/l
0-5	197 ± 27	7500 ± 650	38 ± 15	340 ± 110	1.72 ± 0.5
6-10 (+ countermeasures)	150 ± 58	818 ± 60	6.1 ± 2.8	190 ± 80	1.25 ± 0.4
11-15	420 ± 215	87 ± 10	0.15 ± 0.05	18 ± 9	0.04 ± 0.02
16-20	342 ± 78	145 ± 15	0.46 ± 0.29	19 ± 7	0.05 ± 0.02

* TF = Transferred Factors

Critical character of natural pastures can be illustrated on the example of comparison of Cs-137 concentration in meat of domestic and wild animals (Table 7). During summer 1993, nuclide concentration in the meat of cows from collective farms, where fodder is produced on arable soils, was 20-44 Bq/kg. Meat of cows from private farms contained at the same time 75–500 Bq/kg, and meat of wild animals – 500-1540 Bq/kg.

Table 7. Cs^{137} content of meat from various animals in the Rovno Region

Product	Place of sample	Date	Contamination of soil kBq/m²	Concentration Cs-137 Bq/kg	Transfer Coefficient m²/kg
Meat of cows from colkhoz	Scarny region	25.08.93	129	43	0.33
	c. New life	25.08.93	166	35	0.21
	Polessye Goryn	25.08.93	74	44	0.59
	1 May	25.08.93	74	20	0.27
Meat of cows from private farms		25.08.93	74	75	1.00
		25.08.93	55	110	2.00
		25.08.93	55	95	1.70
Meat of elk	Klesov forests	21.06.93	185	1540	8.30
	farm	25.08.93	185	990	5.30
Meat of wild boar	Krichilsk	12.06.93	74	484	6.80
	forests farm	13.06.93	74	504	6.80
Meat of cows from colkhoz	Dubrovitsa region c. Chapaev	15.08.93	277	43	0.16
		15.08.93	222	62	0.28
		15.08.93	222	71	0.32
		15.08.93	222	38	0.17
Meat of cows from private farms	Dubrovitsa region c. Chapaev	12.07.93	333	500	1.70
		12.07.93	333	520	1.60
		12.07.93	333	470	1.50
		12.07.93	333	330	0.99

Berries and mushrooms from natural ecosystems can provide significant contribution to annual intake of Cs-137 to the organism of inhabitants in Polessye.

For example in 1994, in the settlement Dubrovitsa, Rovno region, average concentration of nuclide in plant products was 17-78 Bq/kg, in berries was 223 Bq/kg, and in mushrooms was 7000 Bq/kg.

Countermeasures in agriculture have been developed within the whole period after the accident on Chernobyl NPP, using the experience, accumulated during the elimination of consequences of 1957 Kyshtym accident in South Ural. In Tables 8 and 9 the results of field experiments, carried out in Rovno region in 1992 on soddy-podzolic and peaty arable soils, are presented as an example. As it is seen from Table 8, separate application of nitric and phosphorus fertilizers is of low efficiency and can even cause the increase of TF. Application of potassium fertilizers, especially in combination with other nutrition elements in the ratio Nitrogen: Phosphorus: Potassium as 1: 1.5: 2, increases the yield and significantly – to 2-14 times – decreases radiocaesium accumulation in products.

Table 8. Efficiency of chemical melioration on the turf-podzol soil (Rovno region, 1992 year)

Variation	Hay, concentration/ha		Cs^{137} in biomass at kBq/m²			
			cereals		vegetables	
	cereals	pulse	Bq/kg	decrease times	Bq/kg	decrease times
Monitoring	24.8	44.3	0.82	1.00	7.60	1.00
N 60	25.6	31.2	1.40	+1.70	5.60	1.40
P 90	33.4	51.0	1.40	+1.70	3.90	1.90
K 120	41.7	58.3	0.25	3.30	0.42	1.80
P 90 K 120	37.5	67.6	0.11	7.50	0.58	13.0
N 60 P 90 K 120	50.8	63.3	0.38	2.20	0.54	14.0
N 60 P 90 K 180	39.9	46.3	-	-	0.78	9.70
Lime with microfertilizers	34.4	41.3	1.60	+2.00	2.40	3.20
Manure, 60 t/ha	45.7	45.9	0.30	2.70	0.32	24.0
Sapropel, 100 t/ha (year of applying)	53.5	50.9	2.08	+2.50	2.10	3.60
Lime + microfertilizers + N 60	35.6	47.6	0.71	1.20	0.26	29.0
P 90 K 120	43.3	55.5	0.20	4.10	0.25	30.0
The same + manure	46.9	40.4	0.70	1.20	0.57	13.0
The same + sapropel						

* the experiment is done in 4 replicates, $\sigma \leq \pm 10\%$

On soddy-podzolic soils lime in combination with manure and mineral fertilizers is specially effective, which provides 30-fold reduction of Cs-137 accumulation in grain of cereals and leguminous crops.

On peaty soils, apart from chemical amelioration, sanding and claying is very effective. Application of sand and clay increases the strength of radionuclide fixation in soil and reduces its transfer to plants by 2.5-5.2 times [3].

When the countermeasures are applied on large areas in working conditions, their efficiency is lower mainly due to the fact that the technology is not observed to a full extent, and is 1.5-2.7 times on mineral soils and 2.7-5.2 times on peaty soils (Table 10).

Table 9. Efficiency of chemical melioration on the peat soil (Rovno region, 1992 year)

Variation	Hay concentration/ha		Cs^{137} in biomass at kBq/m^2			
			cereals		pulse	
	cereals	pulse	Bq/kg	decrease times	Bq/kg	decrease times
Monitoring	43.5	50.8	13	1.0	30	1.0
P 90	68.6	56.5	21	+0.62	20	1.5
K 120	72.9	67.9	14	+1.1	7.6	3.9
P 90 K 120	62.4	66.3	12	1.1	9.2	3.3
K 180	73.3	63.5	12	1.1	8.2	3.7
Lime	64.2	69.8	6.5	2.0	15	2.0
Lime + P90 K120	44.6	60.2	4.1	3.2	6.2	4.6
Manure, 60 t/ha	75.5	60.9	3.9	3.3	5.5	5.5
Manure + P90 K120 +Lime	68.6	66.6	3.8	3.4	4.4	6.8
Sanding, 100 t/ha	51.5	59.5	3.7	3.5	12	2.5
Sanding +P90 +K12 + Lime	71.3	68.3	6	2.2	5.8	5.2
Claying, 100 t/ha	78.2	71.2	9	1.4	11	2.7

* the experiment is done in 4 replicates σ ≤ ± 10%

Table 10. Efficiency of countermeasures on the various soil in the working conditions during 1987-1992 (reducing of Cs^{137} concentration in the products of plant-growing, times)

Countermesures	Types of soil		
	Chernozem, usual and grey, wood podzoled (Kiev region)	Turf-podzol sandy soild (Kiev region)	Turf podzol, claying and meadow-swampy soils (Volyn region)
Drying of ground		2.7	2.7
Radical improvement of meadows	1.7 – 2.6	1.7 – 2.6	16.0
Surface improvement of meadows	1.5 – 2.0	1.5 – 2.0	4.0
Grounding	1.1	–	1.1
Cutting of the upper layer of soil	–	–	10.0
Applying: sapropel, 80t/hectare	1.7 – 2.7	1.7 – 2.7	–
Clay, 200t/hectare	–	2.0 – 2.3	–
Lime 1,5t/hectare	2.0 – 2.7	1.8 – 2.7	–
Manure, 50t/hectare	2.0 – 2.7	–	–

Application of chemical meliorantse increases the yield of agricultural crops and decreases products contamination, and, thus, is economically profitable countermeasure. Its application reduces individual irradiation dose of people, who consume these products. Total amount of radionuclide

intaken and collective irradiation dose in this case decreases to lower extent or even increases. Control of collective dose is possible by means of maximum use of contaminated products for feeding meat cattle on early stages of fattening [4].

Organisation of three-stage fattening of meat cattle with successive reduction of Cs-137 content in the diet as animals approach marketable weight, and with additional feeding of "clean" fodder during 4-10 weeks before slaughter, is one of the most effective countermeasures on contaminated territories.

In animal-breeding various entorosorbents and fodderadditives on the base of clinoptilolite and other minerals can be successfully used. It allows to reduce milk contamination up to 5 times and meat contamination – to 2.9 times in working conditions (Table 11).

Table 11. Efficiency of ferrocyne and fodder additives on the base of Zeolytes

Fodder additives	Reducing of Cs^{137} concentration, times	
	Milk	Meat of cattle
Zeolites Hymolite (Clinoptilolit) Indoor maintenance Pasture maintenance	2 – 4 1.2 – 4 1.5 – 3	1.5 – 2.9 1.6 – 1.75
Ferrocines Briquettes for licking Applying to a mixed food 0.6% Inducing to rumen of bolis	2 – 5 2.4 – 2.7 4 – 5	1.7 – 2.9

Change of land-use structure by location of critical food production on the cleanest and most productive areas is one of the most effective organizational countermeasures [5]. Its application should be combined with differentiated storage and usage offodderwith different levels of radioactive contamination.

Countermeasures, applied in agriculture of Ukraine, allowed to prevent the production of food with radionuclides content exceeding set norms by 1992. At the same time, in private sector radiation situation is more complicated. This is connected to the difficulty of excluding from usage of natural and seminatural ecosystems, especially in the regions with peatbogs.

At organisation of countermeasures one should distinctly note two tasks – organisation of supply with clean products of urban population and rural population, which produces this food. If for the first category the countemeasures are directed mainly to the reduction of collective doser at least in the second period, for separate critical groups of rural people even 10 years after the accident the problem of preventing the exceeding of permissible individual irradiation dose still exists.

REFERENCES

1. B.S.Prister, V.A.Shevchenko~V.A.Kalchenko *Genetic effects of radionuclides on agricultural plants: Successes of modern genetics*, Moscow, USSR Academy of Sciences, 1982, V.10, pp. 27-60.

2. B.S.Prister *et al.*, *The principles of agricultural radiology*. Kiev, Urozhay, 1991, p. 383.

3. S. Prister, L.J.Gramok, I.P.Los *et al.*, *Problems of rehabilitation of the territories contaminated after Chernobyl NPP accident,* Proceedings International Symposium Remediation and Restoration of Radioactive-contaminated sites in Europe, Antwerp, 11-15 October 1993. Vol. 1, pp.351-368. Doc. XI-5827/94.

4. B.S.Prister, G.P.Perepelyatnikov, L.V.Perepelyatnikova. Countermeasures used in the Ukraine to produce forage and animal food products with radionuclide levels below intervention limits after the Chernobyl accident. Sci. of Tot.Environ.137(1993), pp. 183-198.

5. Manual on countermeasures application in agriculture in case of radionuclides accidental release in the environment. IAEA-TEC DOC-745, mat.1994.

AGRICULTURAL REMEDIAL ACTIONS: ECOLOGICAL BASES AND PROBLEMS ASSOCIATED WITH THEIR IMPLEMENTATION

by

C.M. Vandecasteele[1], O. Burton[2] and R. Kirchmann[3]
Belgium

Introduction

In the event of a major nuclear accident, involving the dispersion of radioactive material and a widespread contamination of the environment, the first concern of the responsible authorities will be to assess the radiological consequences for the population living in the affected areas, so that essential protective measures can be taken without delay. The main purpose of these measures is to limit the doses received from external and internal radiation to an acceptable level.

If the estimations carried out lead to the conclusion that acceptable levels could be exceeded, several actions can already be taken before (if sufficient time is available between the notification of the release and the arrival of the plume to allow for preventive actions) or during the passage of the radioactive cloud. These actions, reviewed and discussed by Willrodt [1993], aim to prevent or limit:

- the direct external exposure and contamination of populations to the radioactivity transported by the plume and the internal contamination by inhalation,
- the direct contamination of farm animals, and
- the direct deposition of radionuclides on vulnerable plant products to be consumed in a near future by man or cattle.

They mainly consist in:

- evacuation or sheltering of inhabitants,
- housing of grazing cattle, sheep and goats, which will be fed store foods and watered with well-water (no rain nor surface water),
- closing of greenhouses windows and hotbeds,
- harvesting promptly all ripe crops, fruits and vegetables,
- covering with polyethylene foils uncovered feed and food store (hay, heaps of potatoes or beet roots on the field, silos, ...) as well as valuable vegetables and fruits to be harvested soon.

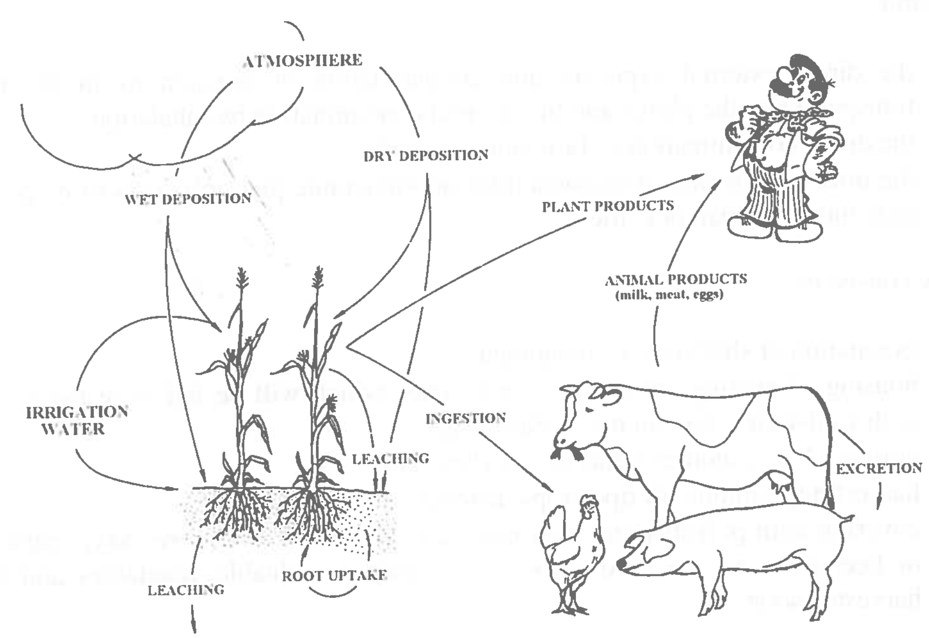
Other remedial actions can be applied after the passage of the radioactive plume, in order to limit the exposure of populations *via* external irradiation from the radionuclides deposited on the ground, inhalation of resuspended contaminated particles and ingestion of contaminated food products. There are two time-scales on which such interventions can be envisaged [Segal, 1993]: in the short-term when the radioactivity is still present on the surface of exposed material (plants, soil, roads, buildings), and in the long-term when radionuclides become distributed over the different compartments of the ecosystems.

- Short-term remedial actions consist essentially in removing the radionuclides from contaminated surfaces (washing of buildings, roofs, roads, ...) or eliminating contaminated material (vegetation, top soil and building materials). These techniques are generally very efficient and may reduce or prevent long-term problems, but they also generate huge volumes of radioactive waste.
- Long-term countermeasures are carried out once the radioactivity has become incorporated into soil, plant and animal components of the ecosystems. They aim to reduce the transferability of radionuclides between the various compartments of food chains, to increase the decorporation in contaminated living organisms or to process contaminated plant and animal products into cleaner by-products.

The decision on whether or not countermeasures must be applied and the choice of particular remedial action(s) depend on radiological considerations, taking into account economic, ecological and social aspects [ICRP, 1991]. The selection of potential remedial actions to be applied depends, however, greatly on the characteristics of the deposit (composition and speciation) and of the ecosystem considered. An adequate understanding of transfer paths and mechanisms is thus essential to intervene the most efficiently, on the most critical pathways.

The most important pathways of radionuclides in agricultural systems, reviewed by Vandecasteele *et al.*, [1991], are shown in Figure 1.

Figure 1. Main pathways for radionuclides to man in continental agricultural food chains



The contamination of vegetation by most radioactive elements injected and dispersed into the atmosphere arises from two main processes: by direct deposition on aerial parts of plants or by indirect contamination when radionuclides, deposited onto the soil, are absorbed by the root systems together with water and nutrients. In a similar way, radionuclides present in irrigation water reach plants by direct deposition on aerial parts (sprinkling) or via soil and root absorption. Gaseous

elements like ^{14}C and ^{3}H (as water vapour) penetrate the plants through the stomata and are incorporated into organic constituents by photosynthesis and other metabolic processes. Contamination of animals and animal products results from lung absorption of soluble, inhaled radionuclides and from ingestion of contaminated soil, feed and water.

The following sections will consider the main steps of the radionuclides pathways and discuss for each possible remedial actions.

Direct contamination of the vegetation

During the growing season, direct contamination of the plant aerial parts by dry and wet deposition is the first step in food chain contamination. It generally gives rise to higher contamination levels in plant products that indirect contamination (root uptake). In the case of short-lived isotope like ^{131}I, a sufficient delay before consumption will provide clean products. Waiting is not a problem if the release happens in the early season; however, when radioactivity is deposited close to harvesting, storing as dry, frozen or sterilised by-products can be envisaged. For long-lived radionuclides, elimination of plant material by harvesting as soon as possible after the deposit (to avoid leaching by rain and other field loss mechanisms) is relatively straightforward and may be a very efficient way of decontaminating the environment, specially if the fraction of the deposit intercepted by the green mass is important. The harvested biomass must be considered as a radioactive waste and burning it into *ad hoc* designed installations can be recommended. Use of this material for production of bio-methane or ethanol can also be envisaged but will be restricted to a small proportion of the material to be treated due to the probably limited capacity of available fermentors. Due to the problem raised by the huge volume of waste produced by harvesting, ploughing in contaminated plant material appears as a very simple way to get rid of it, ensuring that radioactivity does not immediately enter the food chains and reducing by the way external radiation from soil surface; but, this countermeasure may increase the long-term problems.

It is, however, not always recommended to eliminate the contaminated vegetation. If the accident happens in Spring, when stored feed for cattle is exhausted, the only forage available may be the contaminated standing grass. In these conditions, it should be recommended to house the animals and feed them with forage cut above the usual cutting level, since pasture grass exhibit a higher accumulation of deposited radioactivity in their lower parts than in the upper ones. Also some radionuclides are very poorly translocated from organs contaminated by a deposit early in the growth season to edible parts harvested later in the year; the edible parts (*e.g.* grains of crops) could be expected to exhibit contamination levels below the intervention levels. For instance, translocation of ^{90}Sr, ^{144}Ce and ^{106}Ru into the grains of cereals is minimal if deposition takes place in the early stage of development, while other nuclides such as ^{65}Zn, ^{55}Fe, ^{137}Cs, ^{60}Co and ^{54}Mn are easily translocated in the plant [Aarkrog, 1975]. Middleton [1959] reported that up to 50 per cent of the caesium deposited on the leaves of potato plants may be transferred to the tubers but only 0.01 per cent of the strontium applied to aerial parts of the same plants migrates from the leaves into the tubers. Similarly, in wheat plants contaminated before ear emergence, 5 to 10 per cent of the caesium and only 0.1 per cent of the strontium initially retained by the plant was found in the grain at maturity.

Finally, if the culture has to be maintained, sprinkling irrigation, when available, can help to leached out a fraction of the radioactivity intercepted by the aerial organs. The leaching efficiency is highest if irrigation is started immediately after the deposit and decreases as the time before washing increases [Kirchmann *et al.*, 1966]. Monovalent radionuclides also appear to be more susceptible to leaching than di- or polyvalent elements more easily sorbed on leaf surfaces. Moreover, a light continuous drizzle, could be more efficient in leaching than a large quantity of water spread over a shorter period [Tukey, 1970].

Indirect contamination of the vegetation

Indirect contamination occurs after radionuclides have been deposited on the ground. These processes require the passage of the radionuclides from the soil into the plant by root absorption. They depend not only on the element characteristics, but also on the physiological properties of the plant roots and on soil processes.

One of the key properties of soils is their ability to adsorb ions and to immobilise them, to different extents, on the solid phase. The soil colloids (clay minerals and organic matter), that adsorb ions from the soil solution, contain a high specific density of predominantly negative charges. They attract mostly positive ions from the soil solution to their surfaces, where those ions exchange with others, already present at exchange sites. The ability of a soil to adsorb ions is proportional to the density of exchange sites and is expressed by its cation exchange capacity or CEC (in meq/100 g of soil or of a specific fraction of the soil solids). Values reported for the CEC vary depending on the clay type, ranging from 3 to 15 for kaolinite, 10 to 40 for illite, 80 to 150 for montmorillonite; the CEC of humic compounds is even higher, from 300 to 500 meq/100 g. Adsorption of anions, although limited, also occurs on the fewer positive sites present on the surface of clay minerals (especially illite and kaolinite clay types), on iron and aluminium hydroxide colloids bound to clay or on clay and organic matter by calcium bridges.

The affinity of ions for binding sites depends on their physico-chemical properties. It is higher for trivalent cations than for monovalent cations; divalent cations are intermediate. For cations of the same valence state, binding affinity is inversely proportional to the hydrated radius of the ion. Adsorption of ions is a reversible process and an equilibrium tends to be achieved between the concentration in the soil solution and on the sorption complex.

Binding of ions on the soil solid phase delays or prevents their leaching in percolation water to below the rooting zone. Thorium and some of the light rare-earth elements are so tightly bound to the solid matrix (clay and iron oxides) that they only leach at a rate as low as 10^{-9} per year [Eisenbud *et al.*, 1984]. Caesium deposited by the weapon test fallout in the early sixties, disappears from the agricultural sandy soil in the vicinity of Mol (Belgium) at a rate of about 1 to 5 per cent per year, both by leaching and removal by harvesting [Vandecasteele *et al.*, 1988].

The soil is also a dynamic system. Its properties are acquired and modified with time due to the joint actions of natural factors (variations of temperature and humidity, erosion, ...) and farming practices. Hence, through these mechanisms, the chemical form of radioelements, their sorption on exchange sites and their localisation in the soil profile, may change with time.

When soluble radionuclides are deposited on the ground, they will be dissolved by rain, irrigation water or soil moisture and will migrate into the soil. They can adsorb on the sorption complex by exchange processes, precipitate as hydroxides, sulphides, carbonates or insoluble oxides, form complex with organic molecules or remain in the water phase in ionic form [Schulz, 1965]. For example, in neutral and alkaline soils, rare-earth's elements and others like yttrium, thorium, zirconium or niobium are precipitated as hydroxides and carbonates while strontium precipitates as carbonate. Elements like K and Cs may be trapped and immobilised between the lattices of illite type

clay minerals. The reversibility of such a binding is very poor and the elements bound at these sites can only be removed by alternations of drying and re-wetting or of freezing and thawing.

How radionuclides behave and how they are partitioned between the different pools, largely determines their availability to plants and how long they will remain in the rooting zone.

Roots absorb their nutrients from the soil solution. The soil solution is thus continuously depleted from its solutes by root uptake, but it is also continually replenished from the soil solid phase. The solid phase constitutes a reservoir of nutrients (as well as of pollutants introduced in the system) which are made available through exchange reactions between the solid and liquid phases.

The main physical factors affecting the absorption of nutrients by the roots are:

- ionic concentration in the water solution: at low concentrations (< 1 meq/l), as is the case for fission products released into the environment, the absorption rate is generally proportional to the concentration in the water phase;
- chemical properties of ions: ions with low valence are in general more easily absorbed than those with higher valences; the relative rate of absorption of several elements is the following:
  89-90Sr >> 131I > 140Ba > 134-137Cs, 106Ru > 144Ce, 91Y, 147Pm, 65Zn, 95Nb > 239Pu [Nishita *et al.*, 1961];
- pH and Eh which effect the solubility of some elements (precipitation and dissolution reaction) and strongly influence the Kd values [Baes & Sharp, 1983];
- ionic interactions, antagonisms and competition between elements, both for adsorption on soil sorption complexes and for root uptake.

A reduction of indirect contamination of the vegetation can be obtained by several means [Baes *et al.*, 1986; Nisbet *et al.*, 1993]:

- removal of the contaminated soil surface layer;
- (deep) – ploughing to reduce the contamination of the upper soil layers and subsequently reduce the uptake by shallow – rooted plants such as grass and legumes;
- addition of fertilisers: phosphorus to insolubilise strontium as phosphates, calcium (lime) to compete with strontium for plant uptake, potassium (potash) to compete with caesium;
- addition of chelating agents to bind the radionuclides in a form unavailable for plant uptake or in soluble forms that will be leached below the rooting zone;
- cropping deep-rooted plants that exploit the soil below the contaminated layers (*e.g.* alfalfa, corn);
- cropping plants used for grain production (grains generally exhibit lower transfer factors than other plant organs), seed production, fibre or oil production, for cattle feeding;
- use of agricultural lands for alternative purposes: planting forest for timber production.

Among the various countermeasures aiming to reduce the indirect contamination of plants, removal of a more or less thin layer of top soil, as long as the deposited radioactivity is still concentrated at the surface, appears as a very effective method to prevent the entry of radioactivity into food chains. It has also the advantage to reduce the resuspension of radioactive particles and the long-term aftermath. Different methods have been developed and, for some of them, tested under real conditions: removal of top soil by scrappers, bulldozers, manual excavation or vacuum cleaners [Marti *et al.*, 1990], trapping of surface soil particles in polyurethane foams spread on the soil surface

[Legrand *et al.*, 1990] or by the roots of turfing plants [Jouve *et al.*, 1993]. However one main drawback of these techniques, in particular the first ones, is that they generate impressive volumes of waste (*e.g.* removing only 5 cm of surface soil on 1 km^2 produces 50 000 m^3 of contaminated waste) and therefore should be restricted to small areas. An alternative to removing the waste from the site would be to place it in self-shielding piles on the field (the top 5 cm accumulated on 3 m high flat top pyramid mound would occupy only some 3 per cent of the cleaned area) [Sandalls, 1990]. Lixiviation and resuspension from these mounds could be prevented by the use of water impermeable barriers.

Ploughing, despite of the potential risk of long-term problem, generally appears as the most practical and cost-effective remedial action [Sandalls, 1990]. Normal ploughing (to a depth of 20-30 cm) would immediately suppress any tendency to resuspension and greatly reduce external irradiation and root uptake by many plant species. The use of modified ploughs, with a skimmer attachment, allowing the placement of a discrete surface layer at the bottom of the furrow would be even better. Deep ploughing (to a depth of 1 m) is a much more effective countermeasure than normal ploughing. This technique offers the advantages that the contamination is placed deep enough so as not to be disturbed by subsequent conventional ploughing and out of reach of the roots of many crops; it also greater reduces external radiation but has the drawback that it requires special ploughs and tractors.

Application of extra quantities of potassium and phosphate fertilisers, lime and/or organic matter (straw, dung, green manure) affects the absorption of radioelements by plants: liming acidic soils reduces the absorption of strontium due to a competition with calcium and application of potassium fertilisers may have a similar effect on the caesium uptake. The reduction observed is highest in poor soils but can be negligible in well fertilised farm lands. Also no effect of liming can be expected on highly calcareous soils. It should also be noticed that any measure taken in the Chernobyl contaminated zones to increase the crop productivity generally lowered the transfer of radionuclides into plant products [Kirchmann, 1990].

Increasing the overall soil CEC by addition of zeolites, clay minerals, sapropel (lake sediments with a high organic matter content) or large quantities of organic manure results in a higher proportion of radionuclides associated with the solid phase. Conversely, the radionuclide concentration in the soil solution is lowered, reducing proportionally the uptake by plants. Moreover, the existence on certain clay types (illite, vermiculite, ...) of specific binding sites, on which caesium is *quasi* irreversibly fixed, contributes to the reduction of radiocaesium availability for plant uptake over the long-term. However, the experience in liquidation of Chernobyl accident consequences has shown that these amendments had in practice quite limited efficiency; appreciable effects can be expected only in the very sandy soils, poor in clay minerals and organic matter.

Addition to the soils of binding chemicals that will immobilised the radionuclides appears as an attractive option. Modified alumino-silicate or Prussian blue compounds such as ammonium ferric hexacyanoferrate (AFCF) are envisaged. Application of 1 g AFCF/m^2 on surface contaminated soils, under laboratory conditions, reduces the transfer to rye grass by a factor around 5. Confirmation of the AFCF effect was also reported after fertilising soils with manure from cows treated with this compound (Hove *et al.*, 1995).

Land drainage in water-logged soils has been reported (Segal, 1993) to reduce considerably Cs uptake by plants. The invoked mechanism, although not yet proved, could be the higher ammoniac concentrations found in these soils, due to the prevailing anaerobic conditions. Under other

conditions, decreasing the soil moisture content may increase the caesium uptake, possibly due to concentration effects.

Selection of crops can offer another solution for contaminated land recovery. Differences up to a factor 4.5 were reported between plant varieties (Alexakhin, 1993) so that a sound choice of the cultivated variety can bring a very significant improvement without any disturbance of the farmers' habits. Even higher differences, up to 10, were observed between plant species (Alexakhin, 1993) but replacement of one crop by another can be a more disruptive option, especially if the new proposed crop requests completely different cultural practices and material, and/or is intended to a different use (oil or fibres plants, production of bio-methanol). When agricultural perspectives must be abandoned because of contamination in food products irremediably exceeding reference levels, afforestation can be proposed as an ultimate solution, allowing at least 30 years before exploitation during which the radioactivity will decay.

Transfer to animals

Two main routes of entry of pollutants in animals can be considered:

- first, inhalation of gaseous compounds, aerosols and particles,
- secondly and principally, by ingestion of drinking water, food and soil particles associated with the vegetation grazed by the animal.

Ingestion of contaminated soil is generally neglected as a contamination pathway; however, if we consider that grazing animals commonly ingest up to 20 per cent of their dry matter daily intake, this may represent the predominant contamination source for elements which exhibit high K_d values and low soil-to-plant transfer [Zach & Mayoh, 1984].

The absorption by animals of ingested pollutants depends on their chemical properties and chemical form, on the animal species and on the particular physiological characteristics of the animals [Stara *et al.*, 1971].

Influence of chemical properties of radionuclide

Caesium, like other alkali metals, is up to 100 per cent absorbed through the G.I. tract in monogastric mammals and to a slightly lower extent in ruminants (60-80 per cent). Gastrointestinal absorption after oral administration of alkaline earth's varies depending on the element: in general, absorption is highest for calcium, less for strontium (about 20 per cent) and a few percent for radium. Orally dosed Pu is absorbed to a very low extent (less than 1 per cent) [Stara *et al.*, 1971; Coughtrey *et al.*, 1985].

Influence of speciation

The chemical speciation of a given radionuclide can modify its gastrointestinal absorption. Absorption of technetium as pertechnetate is higher than that of technetium bio-accumulated in plant material [Gerber *et al.*, 1989; Sullivan *et al.*, 1979; Vandecasteele *et al.*, 1986]. In contrast, bio-incorporation of Pu in plants increases its availability for gastrointestinal uptake [Sullivan *et al.*, 1980]. Differences in accumulation rates due to the chemical speciation are also noticeable for ingested tritium depending on whether it is administered as tritiated water or incorporated in various organic molecules which increase the ^3H incorporation [Kirchmann *et al.*, 1975].

Influence of the diet

The character of the diet (fibrous content of diet, presence of clay particles ingested together with the forage) can modify the availability of the radionuclides in the G.I. tract. The crude fibre content of the forage fed to cows were reported to influence the uptake of caesium: transfer coefficients vary from 0.0025 for alfalfa and corn silage to 0.01 for mixed grain [Wilson *et al.*, 1969 *in* Eisenbud, 1987]. Iron-deficiency in food increases the absorption of U, Np, Am and Cm in rats [Sullivan & Ruemmler, 1988]. The same effect has been reported by many investigators for other non-ferrous metals that may share intestinal absorption routes with iron [*in* Sullivan & Ruemmler, 1988].

Species

Food processing in the G.I. tract also differs between animal species. Ruminants are characterised by having four chamber stomachs. The first chamber (rumen) act as a fermentative vat that receives partially chewed vegetation. The aliments are digested by rumen bacteria, yeast's and protozoa. Through fermentation, carbohydrates are broken down into various carboxylic acids. These fermentation products, along with some peptides, amino acids and short-chain fatty acids, are absorbed into the bloodstream from the rumen fluid. The fermented rumen fluid along with symbiotic micro-organisms are then passed, *via* the reticulum, into the omasum and the abomasum and are subject to enzymatic digestion, similar to that observed in monogastric animals. The rumen provides an anaerobic, reducing environment (Eh = -400 mV) that can modify the chemical form of the ingested radionuclides (*e.g.* Tc administered as TcO_4^- is reduced, resulting in a lower bio-availability [Gerber *et al.*, 1989; Jones, 1983]).

Fermentation in the stomach is not limited to ruminating animals. It is also found in other animal species in which the passage of food through the stomach is delayed, allowing the growth of symbiotic micro-organisms such as in the crop of galliform (chickenlike) birds. Fermentation processes are also present in monogastric mammals and take place in the caecum. This organ is more developed in herbivorous species. The activity of the salivary glands and the amount of saliva produced depends on the alimentary regime of the animal species: a high fibre diet promotes a high production of saliva (up to 16 l/d in cow compared with 1 to 2 l/d in horse). Together with minerals excreted in saliva , large amounts of absorbed radionuclides can be recycled into the G.I. tract. This has been shown for technetium [Gerber *et al.*, 1989; Helman *et al.*, 1987; Jones, 1983] but might also apply to caesium and iodine.

Physiological factors

The accumulation of radionuclides in mammals depends to a large extent on the age of the animal: transfer coefficients (ratio of the radionuclide concentration in an organ or in milk at equilibrium to the daily amount of the radionuclide ingested) are higher for young individuals than for adults. This may be explained by a higher permeability of the gastrointestinal tract, especially in new-borns, and by a higher metabolic activity in growing animals than in adults. Lacourly *et al.* [1971] have shown that calves aged six weeks, have transfer rates for radiocaesium 15 to 25 times

higher than cows. Considerably more niobium is absorbed by lambs and piglets receiving ^{95}Nb orally soon after birth than by those receiving it after weaning [Mraz & Eisele, 1977]. A similar observation was reported by Sullivan [1980] for absorption of Pu in new-born swine. Field measurements performed after the Chernobyl accident on the transfer of radiocaesium to sheep showed higher transfer coefficient for lambs than for their dams [Beresford *et al.*, 1989; Howard *et al.*, 1987; Vankerkom *et al.*, 1988]. However, Cs concentration in tissues of foetus and new-borns at birth are lower than the concentrations measured in the corresponding tissues of their dam [Howard & Beresford, 1989; Vandecasteele *et al.*, 1989b].

Limiting contamination of animal products

Available countermeasures applicable at the animal level were reviewed and discussed by Hove *et al.* [1993].

The first possibility to reduce the contamination level in animal products is undoubtedly the reduction of their radiocontaminated feed ingestion. This can be achieved for housed animal by providing them, exclusively or partly, with clean forage, from the previous year, when still available, or from remote, unaffected regions. For grazing animals, supplementing with clean fodder (hay, concentrates, ...) will contribute to reduce their radionuclide intake. Finally, the cattle can be moved to non – or less contaminated pastures.

The reduction of the contamination of animal products can be obtained by reducing the gastro-intestinal availability of the ingested radionuclides. This can be achieved by the incorporation of additives in the animal feed. The same additives can also contribute to enhance the metabolic excretion of absorbed radionuclides.

Depending of the radioelement considered, alumino-silicates like bentonite, zeolite and vermiculite, stable potassium, calcium or iodine, charcoal and Prussian Blue (the most effective for Cs), can be used to reduce the contamination of mammals [Stara *et al.*, 1971].

- The effect of spreading bentonites (single or repeated applications of 80 g/m2) on pastures grazed by sheep has been investigated by Beresford *et al.* [1989]; only the repeated treatment (every 2 d) was found effective in the reduction of the caesium transfer coefficient but was counterbalanced by a loss in animal body weight (18 per cent after 34 d) associated with a decrease in grass intake (39 per cent). It is however that such a technique could be adopted in commercial agricultural practice because of practical difficulties in its application [Beresford *et al.*, 1989].
- One compound of the "Prussian blue's" group, AFCF, has been tested under practical feeding conditions after Chernobyl and proved efficient [Giese, 1988]. This compound can also be used in free ranging and wild animal, in the form of boli or salt licks.
- 5 per cent sodium alginate added to contaminated milk fed to young swine's reduced by a factor of 6 the strontium content in the body [Van der Borght *et al.*, 1966]. The same authors reported a slight reduction in radiocaesium retention in swine's under the same conditions. The transfer of strontium to milk can also be reduced by giving cows a feed containing 5-7 per cent Na-alginate [Thompson *et al.*, 1971]. This compound is however much less efficient in ruminant because of its polysaccharide nature; it is degraded to a large extent by the rumen microflora. Moreover, the proportion of alginates in feed can

not be increased much above 5 per cent, since it then reduce the appetency of the animal for its feed.

- Chelating agents of the group of amino-acetic acids are administered to enhance excretion of Pb, Cd, Mn and Hg in humans and have been experimentally used to enhance the excretion of 65Zn and Pu. In the case of Pu, the best results were obtained with DTPA, followed in efficiency by DDETA. Zirconium citrate and phosphate compounds, among them hexametaphosphate are also efficient when administered immediately [Lauwerys, 1972; Stara *et al.*, 1971].
- Increasing the fibre content of the ruminants diet may also help to limit caesium absorption [Wilson *et al.*, 1969 in Eisenbud, 1987].

When the animals are used for meat production, a transition period could be forseen before they are slaughtered. Feeding during this period uncontaminated or less contaminated feed will allow them to decontaminated by biological processes until an acceptable contamination level is reached. This approach has been applied in the UK for upland sheep: a considerable decrease in the radiocaesium concentration in muscle was obtained when lambs were brought from highly contaminated upland pastures to less (100 to 200 times) contaminated lowland pastures for fattening before being sold [Howard *et al.*, 1987].

Food Processing

When confronted with unacceptably heavily contaminated plant or animal products, industrial or domestic food processing may provide an alternative for reducing the contamination levels in products consumed by humans.

The problem of the ^{131}I contamination in food products may be solved very easily if it is possible to delay consumption to allow physical decay. This can be achieved by production of long shelf life products such as milk powder, cheese, chocolate, tinned foods, deep frozen meat, deep frozen soup concentrates with ^{131}I contaminated vegetables.

Other techniques must be considered for long-lived radionuclides for which physical decay during storage can not be envisaged:

- washing of vegetables can remove a fraction of the external contamination,
- grain, after removal of the external envelopes, can be used for preparation of white floor,
- milk can be treated by passage on exchange resins to remove strontium and possibly caesium,
- milk can also be used for the preparation of storable by-products in which the contamination is lower (butter, cheese, ...); it should be noted that acid precipitation of casein is more efficient than rennet in the case of Sr contaminated milk,
- some culinary methods of food preparation (such as washing and/or peeling vegetables, boiling meat instead of roasting, pickling,) can also be used to limit contamination ingested by man.

Conclusions

Many kinds of possible remedial actions, some scientifically sound, others of more empirical nature, have been developed and used to limit the contamination level in the products consumed by man or animals. Although developed on a scientific basis, many measures may appear impracticable or too expensive to be used in real situations. As a general rule, remedial actions that can be performed with existing, common material and machines should be preferred to those requiring new technology to be especially developed for such applications.

Often combinations of countermeasures can be applied simultaneously or successively to ensure the best result.

The efficiency of countermeasures may vary depending on the specific conditions in which they are used, and sometimes can lead to undesirable side effects. For instance, excessive liming can lead to the precipitation of micro-nutrients and induce deficiencies in plants and animals fed the deficient forage, high fertilisation in semi-natural systems can induce deep ecological modifications of the ecosystems, etc..

It must also be kept in mind that some countermeasures are not or hardly reversible (ploughing, deep-ploughing, etc.) and, when they appear to have been misguided, it is very difficult to remedy the situation.

REFERENCES

1. Aarkrog A. (1975), Radionuclide levels in mature grain related to radiostrontium content and time of direct contamination, Health Phys., 28: 557-562.

2. Alexakhin R.M. (1993), Countermeasures in agricultural production as an effective mean of mitigating the radiological consequences of the Chernobyl accident, Sci. Tot. Environ., 137: 9-20.

3. Baes C.F. III, Garten C.T. Jr, Taylor F.G. and Witherspoon J.P. (1986), *The long-term problems of contaminated land: sources, impacts and countermeasures*, Oak Ridge National Laboratory, Environmental Science Division, Publication 2593, ORNL-6146.

4. Baes C.F III. and Sharp R.D. (1983), A proposal for estimation of soil leaching and leaching constants for use in assessment models, J. Environ. Qual., 12: 17-28.

5. Beresford N.A., Lamb C.S. , Mayes R.W. , Howard B.J. and Colgrove P.M. (1989), *The effect of treating pastures with bentonite on the transfer of Cs-137 from grazed herbage to sheep*, J. Environ. Radioactivity, 9: 251-264.

6. Coughtrey P.J., Jackson D. and Thorne M.C. (1985), Radionuclide distribution and transport in terrestrial and aquatic ecosystems: a compendium of data, A.A. Balkema, Rotterdam – Boston.

7. Eisenbud M. (1987), *Environmental radioactivity from natural, industrial and military sources* 3rd edition, Academic press Inc., Harcourt Brace Jovanovich Publ., New York, 475pp.

8. Eisenbud M., Krauskopf K., Penna Franca E., Lei W., Ballad R., Linsalata P. and Fujimori K. (1984), Natural analogues for the transuranic actinide elements: an investigation in Minas Gerais, Brazil, Environ. Geol. Water Sci., 6: 1-9.

9. Gerber G.B., Van Hees M., Garten C.T. Jr, Vandecasteele C.M., Vankerkom J., Van Bruwaene R., Kirchmann R., Colard J. and Cogneau M. (1989), *Technetium absorption and turnover in monogastric and polygastric animals*, Health Phys., 58: 337-343.

10. Giese W.W. (1988), Ammonium-ferric-cyano-ferrate(II) (AFCF) as an effective antidote against radiocaesium burdens in domestic animals and animal derived foods, Br. Vet. J., 144: 363-369.

11. Helman J., Turner R.J., Fox F.C. and Baum B.J. (1987), *99mTc-pertechnetate uptake in parotid acinar cells by the Na+/K+/Cl- co-transport system*, J. Clin. Invest., 79: 1310-1313.

12. Hove K., Strand P., Salbu B., Oughton D., Astasheva N., Vasiliev A., Ratnikov A., Jigareva T., Averin V., Firsakova S., Crick M.J. & Richards J.I. (1995), *Use of caesium binders to reduce radiocaesium contamination of milk and meat in Ukraine, Belarus and the Russian Federation, Int. Symp. on "Environmental impact of radioactive releases"*, IAEA Vienna 8-12 May 1995, Extended Synopses, IAEA-SM-339/153: 75-76.

13. Hove K., Strand P., Voigt G., Jones B.E.V., Howard B.J., Segal M.G., Pollaris K. & Pearce J. (1993), *Countermeasures for reducing radioactive contamination of farm animals and farm animal products*, Sci. Tot. Environ., 137: 261-271.

14. Howard B.J. and Beresford N.A. (1989), *Chernobyl radiocaesium in upland sheep farm ecosystems*, Br. Vet. J., 145: 212-219.

15. Howard B.J., Beresford N.A., Burrow L., Shaw P.V. and Curtis E.J.C. (1987), A comparison of caesium-137 and 134 activity in sheep remaining on upland areas contaminated by Chernobyl fallout with those removed to less active lowland pasture, J. Soc. Radiol. Prot., 7: 71-73.

16. International Commission on Radiological Protection (1991), *Recommendations of the International Commission on Radiological Protection*, Annals of the ICRP 21: 1-3, Pergamon Press, Oxford.

17. Jones B. (1983), *Metabolism of technetium in goats*, Int. J. Appl. Radiat. Isot., 34: 837-839.

18. Jouve A., Schulte E., Bon P. & Cardot A.L. (1993), Mechanical and physical removing of soil and plants as agricultural mitigation techniques, Sci. Tot. Environ, 137: 65-79.

19. Kirchmann R. (1990), *Agricultural countermeasures taken in the Chernobyl region and evaluation of the results*, International Union of Radioecology, Report for Contract 88-ET-006 with CE/DGXI/A1.

20. Kirchmann R., Charles P., Van Bruwaene R. and Remy J. (1975), *Distribution of tritium in the different organs of calves and pigs after ingestion of various tritiated feeds*, Current Topics in Radiation Research Quaterly, 12: 291-312.

21. Kirchmann R., Fagniart E. and Van Puymbroeck S. (1966), Studies on foliar contamination by radiocaesium and radiostrontium, in Radiological concentration processes, Pergamon Press, Oxford – New York, 475-483.

22. Lacourly G., Savy C., Lehr J. and Kirchmann R. (1971), Relations entre la contamination de la viande de bovin et celle du lait par le radiocesium, Health Phys., 21: 793-802.

23. Legrand B., Fache P., Hamoniaux M., Camus H. & Gauthier D. (1990), Premiers résultats expérimentaux du programme RESSAC sur les essais in situ de décontamination/fixation et études de migration des radionucléides dans les sols, IAEA Vienna, IAEA-SM-316/33: 507.

24. Marti J.M., Arapis G. & Iranzo E. (1990), Evaluación de contremedidas para la recuperación de suelo agricola, in "Environmental contamination following a major nuclear accident" Vol. II, IAEA Vienna, IAEA-SM-306/103: 111-127.

25. Middleton L.J. (1959), Radioactive strontium and caesium in edible parts of crop plants after foliar contamination, Int. J. Rad. Biol., 1: 387-402.

26. Mraz F.R. and Eisele G.R. (1977), Gastrointestinal absorption, tissue distribution and excretion of Nb-95 in newborn and weanling swine and sheep, Radiat. Res., 72: 533-536.

27. Nisbet A.F., Konoplev A.V., Shaw G., Lembrechts J.F., Merckx R., Smolders E., Vandecasteele C.M., Lönsjö H., Carini F. and Burton O. (1993), *Application of fertilisers and ameliorants to reduce soil to plant transfer of radiocaesium and radiostrontium in the medium to long term – a summary*, Sci. Tot. Env., 137: 173-182.

28. Nishita H., Romney E.M. and Larson K.H. (1961), *Uptake of radioactive fission products by crop plants*, J. Agric. Food Chem., 9: 101.

29. Sandalls F.J. (1990), Review of countermeasures used in agriculture following a major nuclear accident, in "Environmental contamination following a major nuclear accident" Vol. II, IAEA Vienna, IAEA-SM-306/44: 129-140.

30. Schulz R.K. (1965), *Soil chemistry of radionuclides*, Health Phys., 11: 1317-1324.

31. Segal M.G. (1993), Agricultural countermeasures following deposition of radioactivity after a nuclear accident, Sci. Tot. Environ, 137: 31-48.

32. Stara J.F., Nelson N.S., Della Rosa R.J. and Bustad L.K. (1971), *Comparative metabolism of radionuclides in mammals: a review*, Health Phys., 20: 113-137.

33. Sullivan M.F. (1980), Absorption of actinide elements from the gastrointestinal tract of neonatal animals, Health Phys., 38: 173-185.

34. Sullivan M.F., Garland T.R., Cataldo D.A. and Schreckhise R.G. (1979), Absorption of plant-incorporated nuclear fuel cycle elements from the gastro-intestinal tract, in Biological implications of radionuclides released from nuclear industries, IAEA Vienna, IAEA-SM-237/58, Vol.I: 447-457.

35. Sullivan M.F., Garland T.R., Cataldo D.A., Wildung R.E. and Drucker H. (1980), Absorption of plutonium from the gastrointestinal tract of rats and guinea pigs after ingestion of alfalfa containing Pu-238, Health Phys., 38: 215-221.

36. Sullivan M.F. and Ruemmler P.S. (1988), Absorption of U-233, Np-237, Pu-238, Am-241 and Cm-244 from the gastrointestinal tracts of rats fed an iron-deficient diet, Health Phys., 54: 311-316.

37. Thompson J.C. Jr, Wentworth R.A. and Comar C.L. (1971), Control of fallout contamination in the post-attack diet: in survival of food crops and livestock in the event of a nuclear war, Proceedings Symposium, Brookhaven National Laboratory, Upton, New York, Sept. 1970, B.W. Benson and A.H. Sparrow Eds., 566-595.

38. Tukey H.B. (1970), *The leaching of substances from plants*, Ann. Rev. Plant Physiol., 21: 305-324.

39. Vandecasteele C.M., Fagniart E., Colard J., Culot J.P. and Kirchmann R. (1988), Transfer of radiocaesium deposited after the Chernobyl accident to agricultural plants, in "Impact des accidents d'origine 9nucléaire sur l'environnement", CEN-CEA Cadarache, Vol. 1: D179-D187).

40. Vandecasteele C.M., Garten C.T. Jr, Van Bruwaene R., Janssens J., Kirchmann R. and Myttenaere C. (1986), Chemical speciation of technetium in soil and plants: impact on soil-plant-animal transfer, in "Speciation of fission and activation products in the environment", R.A. Bulman and J.R. Cooper Eds., Elsevier Applied Science Publishers, London – New York, 368-381.

40. Vandecasteele C.M., Van Hees M., Culot J.P. and Vankerkom J. (1989), *Radiocaesium metabolism in pregnant ewes and their progeny*, Sci. Tot. Environ., 85: 213-223.

41. Vandecasteele C.M., Zeevaert Th. & Kirchmann R. (1991), Factors influencing the transfer of radionuclides in agricultural food chains, in "Anticarcinogenesis and radiation protection" 2nd Ed., O.F. Nygaard & A.C. Upton Eds., Plenum Press, New York.

42. Van der Borght O., Colard J., Van Puymbroeck S. and Kirchmann R. (1966), Radiocontamination from milk in piglets (swine): Influence of sodium alginate on the Sr-85/Cs-134 ratio of the body burden and on the comparative Sr-85/Ca-47 absorption, in Radioecological concentration processes, Pergamon Press, Oxford – New York, 589-593.

43. Vankerkom J., Van Hees M., Vandecasteele C.M., Colard J., Culot J.P. and Kirchmann R. (1988), Transfer to farm animals (ruminants) and their products of Cs-134, Cs-137 and I-131 after the Chernobyl accident, in "Impact des accidents d'origine nucléaire sur l'environnement", CEN-CEA Cadarache, Vol. 2: E111-E119.

44. Willrodt C. (1993), Agrotechnical countermeasures to be applied before and during deposition of radioactive fallout, Sci. Tot. Environ., 137: 21-29.

45. Wilson D.W., Ward G.M. and Johnson J.E. (1969), *A quantitative model of the transport of Cs-137 from fallout to milk*, Environ. Contam. Radioact. Mater., Proc. Semin., Vienna.

46. Zach R. and Mayoh K.R. (1984), *Soil ingestion by cattle: A neglected pathway*, Health Phys., 46: 426-431.

SUMMARY OF SESSION II

by

Frances Fry,
United Kingdom

In the event of an accidental release of radioactive material to the environment, the public will expect the appropriate authorities to take prompt action to prevent the consumption of food containing unacceptable levels of radionuclides. Decisions on early protective measures will need to be taken on the basis of predictions of the consequences of the accident, in particular the extent of the area in which food restrictions will be applied. Such predictions are inevitably uncertain but, nevertheless, early action is required if the public confidence is to be retained.

Food bans are not the only protective action. Measures to prevent radioactive material entering the food chain may be taken if sufficient warning time is available. If preventive measures are practical, they should be taken since they are cost-effective and have low ecological consequences. However, preventive measures, such as sheltering animals and providing clean feed, are feasible only in some situations and at times of the year when stored feed is available. They may not be practical in many countries.

In order to take early countermeasures, the agricultural community must be well informed and a number of countries are now producing manuals which set out the administrative arrangements for responding to emergencies and catalogue the measures that can be taken. For emergency response to be effective, representatives of the agricultural community should be involved in planning protective actions and in exercises to test those plans.

In the longer term after an accident, a number of countermeasures are potentially available to reduce or prevent the transfer of radionuclides to food products. However, an understanding of the mechanisms of transfer of radionuclides through food chains and of the factors that affect transfer is necessary to judge the effectiveness of these measures. For example, the effectiveness of chemical treatment of soils will vary with soil and plant types.

Other measures have disadvantages. For example: industrial processing of food involves cost and the final product may not be acceptable to the public; decontamination by removal of soil generates large volumes of waste; change of use of land may lead to financial loss and may not be acceptable to the agricultural community affected. Skim and burial ploughing may be effective and acceptable. All possible countermeasures need to be evaluated in advance of an accident. Consideration should be given to: effectiveness; costs; availability of staff and equipment; waste disposal; impact on other sectors of the environment; acceptability by the affected community.

Although man-made radioactive materials have been present in the environment for nearly 50 years, it is only since the far-reaching and long-lasting effects of the Chernobyl reactor accident in 1986 that the complexity of the behaviour of radionuclides in the agricultural environment has been fully appreciated. Problems of agricultural countermeasures can be solved only by a combined effort of those with radiological protection knowledge, radioecological and agricultural expertise and an awareness of socio-economic factors.

SESSION III

ECONOMIC AND SOCIAL ASPECTS OF AGRICULTURAL ISSUES

Chairperson: Jan Preuthun, Sweden

ECONOMIC AND SOCIAL ASPECTS OF THE AGRICULTURAL PROBLEMS ASSOCIATED WITH NUCLEAR ACCIDENTS

by

J. Brenot and Ph. Hubert
France

Abstract

The economic and social impacts on the agricultural sector after a large nuclear accident are listed. The associated costs are evaluated by means of methods that are more or less appropriate depending on duration and severity of the post accidental situation. The costs are necessary for farmers, agro-industry, and public authorities to define compensation levels and mitigation efforts. How compensation is done is developed in one section devoted to liability and Chernobyl costs. With regards to mitigation, public authorities are responsible in most cases. Decision aiding is necessary and the methods available differ with the complexity of the situation and the goals assigned. Examples are given which emphasize costs and social impacts.

1. Introduction

Most of the nuclear installations have been built in areas with low population density, in general rural areas. Thus, in case of a nuclear accident with radioactive releases, the agricultural sector is likely to be the first affected more or less severely according to the extent of contaminated areas. Impacts on farmers, agro-industry and food distribution are numerous and diverse, as demonstrated by the Chernobyl catastrophe; they concern health, environment, economy and society. In this text, health impacts and ecological damage which are not particularly specific to the agricultural sector are not considered.

Economic impacts on agriculture are local or regional, and in certain circumstances international. Following the initial shock, disturbances appear also in the other economic sectors because the sectors are in interaction. Costs are associated with the impacts. The monetary assessment is necessary for both the victims and the public authorities in two contexts. One is litigation and compensation and the other is decision aiding in the mitigation process. Regarding social impacts, they are clearly observed for large accidents and they correspond to the disruption of existing family links and communities.

The importance of the role of public authorities in the post-accidental phase is a characteristic of nuclear accidents. It does not reduce to a civil defence mission, but it conveys the exercise of liability in most compensation cases and the responsibility of countermeasure implementation. How compensate and how much is the first question to be solved when authorities are requested to by the claiming victims. Assessment of the total cost, how it is distributed among the different headings help to judge compensation demands. Concerning mitigation, the task of prevention and repair is a difficult one in a complex and disturbed context. Authorities must account for economic constraints and social demands. Actions must be pragmatic and effective, and the associated costs and benefits need to be assessed. In general, one action is not the application of one countermeasure but the association of several ones at the same time, that is a strategy. The problem then is the definition of optimal strategies. The assessment of costs is essential, and also the use of decision aiding methods. Situations as intervention level setting, management of contaminated foodstuffs, search of decontamination strategies, elicitation of priority criterias in dose mitigation are examples where decision makers are searching for optimality.

The possible consequences of a nuclear accident and the available interventions are listed briefly together with costs and methods for their assessment. Some social impacts are pointed out. Next, the compensation system and the way it works in practice are presented. The economic and social considerations are taken into account in the mitigation process; this point is developed in the last section.

2. Economic consequences

The consequences of an off-site radioactive release concern agricultural areas (as meadows and fields), forests, buildings and equipments (in farms and agro-industry plants), stocks, livestocks and people. The situation of the post-accident phase is principally resulting of the interventions made by authorities and the agricultural partners, but other factors may intervene as consumers' behavior. For instance, a loss of production may be due to an evacuation either voluntary or decided by authorities, to a ban for sanitary reasons, or to a rejection of the produce by the consumers. Also in categorizing the costs, a difference will be done between those needed for the strict implementation of the countermeasures (they are always supported by the authorities), and those that follow in the whole economic system. Indeed the latter costs are shared out at the society level on individuals, groups, economic partners, and ministries, etc.

2.1 Costs of countermeasure implementation

Population displacements occur in the emergency phase when people (and possibly cattle) are evacuated, and later when they return or when relocation is decided. Evacuation costs concern the transport, temporary accomodation and food, and they are well estimated. Relocation implies in general new housing and the creation of new public infrastructures, whose costs are supported by the state and as such they are easy to know.

In the domain of decontamination techniques, reliable data and efficient procedures were already obtained from the decontamination experience at the TMI-2 reactor and from other contaminated sites. Moreover, considerable knowledge has been obtained during the last years from interventions and studies developed in the CIS Republics (Belarus, Russia and Ukraine) in decontamination and in agricultural practices also. Indeed, costs and dosimetric efficiencies were necessary to establish cost/dose indicators for the countermeasures. It can be considered also that valuable cost estimates exist now for the changes in cultural practices and for the alternatives in animal feeding. The same applies to decontamination of soil, agricultural surfaces and forests (costs concern heavy equipments, materials, labour, and transport), and to foodstuff processing. The management of waste (disposal, storage, and processing) can be a main component of the cost. Finally the system to put in for the radioactivity control in many places and of many products is costly too.

2.2 Economic activity disruption

The decrease or the interruption of economic activity induce different types of losses. Loss of production bears on the farmers and the agro-industry which transforms the corresponding raw produce. Farmers may also have to buy their own food instead of using their own production, which is a major impact in subsistence economies. Wholetraders and distributors are suffering a loss of sales and then of incomes. At last indirect losses appear when there are disturbances in the economic activity of sectors in relation with the agricultural one.

Losses in the agricultural sector depend on many factors. They are related to the duration of the countermeasure (ie. evacuation, interdiction of farming, or ban of foodstuffs) but it is a complex relation in contrast with the case in many industries and service activities. It can be considered that production losses stay at a low level for a short perturbation period but increase rapidly when such a period extends. However, if losses can increase continuously for restricted areas because of difficult working conditions, it is no longer true in interdicted areas and for a prohibited practice because what is lost here will be produced elsewhere. In addition, for cattle and poultry consequences are not the same for breeding indoors and at the open, and for vegetal produce the period of growth has an essential role.

Methods available for estimating the associated costs depend on the duration of the disruption period which is a valuable characteristic of the importance of the accident [Brenot, 1990]. For a few weeks, a production loss can be estimated by the cost of the product on the market or by the loss in personal income for people working in distribution services. For some months, it is the loss of value-added, *i.e.* the Gross Domestic Product (GDP), which is used to quantify the effect of the disruption in the agricultural sector of the affected region. Cost estimates are based either on the number of people affected and their individual contribution to GDP, or on the land use in contaminated areas and the contribution of each type of land to GDP. For longer disruptions, the input-output methodology that accounts for the interactions between the agricultural sector and the other sectors, both at regional and national levels, should be applied. Indeed it allows to assess the indirect, and often time-delayed, losses in sectors that were not affected initially.

2.3 Loss of capital

The capital of a farmer is made up of the farm and its equipments and materials, the stocks (livestock and raw produce), the land and his private house. For agro-industry, the production plant constitutes the main part of the capital. The capital is depreciating with the duration of an evacuation, or if the necessary maintenance is not provided. The capital is lost if the area is interdicted. Then the problem is to define the wealth. For productive lands and common goods, losses are estimated from the real estate and the market. For agro-industry plants that must shut down following the interdiction, the corresponding loss is the capital of the plant at the closure time and this is known by financial officers. Assessing the loss for rare goods and all collective tangible assets is difficult and not performed; anyway, these assets cannot be identified with nor compared to those needed when displaced populations are relocated.

2.4 Side effects

From Chernobyl experience, agricultural producers in the nation and in foreign countries, other than those affected locally, can be hitten. These side effects appear as shifts in consumption of foodstuffs and barriers to exports. Some products can be rejected temporarily by consumers and also by distributors who fear or anticipate consumers' reactions. The resulting cost of such collective behavior is difficult to assess and only professional unions have informations about what happened.

3. Social consequences

The extreme consequences, evacuation – relocation – restrictions in the every day life, while necessary, contribute to the destabilization of the long lived social network. The social consequences are not a simple function of the size of the affected areas, the number of persons concerned, the duration of the remaining contamination, and of the total cost imposed to society to repair and restore the situation. It is more than that. Confidence in the future and trust in nation relief capacity are modifying factors which amplify or diminish the extent of social effects.

In the contaminated areas where population is allowed to stay, the age of the population increases when young people leave, either because they have no more work or because of concerns about the health of their children. Changes in everyday life are multiple, from the increase of radioactivity controls, the supply of clean food, to advices about agricultural practices and leisure activities. Such a permanent assistance reinforces the feeling of living in abnormal conditions [Lochard and Prêtre, 1995].

In clean areas, when relocated people become members of existing communities, coexistence and insertion are not easy; in fact from historical experience, one can rather say that they have never been easy and the need of land, which is crucial for farmers, makes the problem more acute. When new settlements are created, social identity is missing, and it needs some years to build one.

In the previous situations, authorities are normally assisting individuals, possibly with money compensations. But negative behaviors arise from this situation; they can be justified by the need of state pensions, but they hinder or delay the return to more normal conditions. The assessment of costs for all these social consequences has not been done yet and it stays a matter of methodological research.

4. Compensation

4.1 Liability

As mentioned before, costs are estimated by economists and lawyers upon request of the victims, professional unions, interested groups, plant owners, and state ministries. The interest of their assessment lies in giving to the concerned parties some orders of magnitude. Processes and figures depend on the legal framework of the country. In any case, costs are far from being fully compensated and the setting of compensation amounts is the result of a lengthy litigation process which involves the nuclear operator, the state and its ministries, and the claiming parties.

The first question is, "who should pay", and the second, "is he able to do it". There is a civil liability regime where different bodies intervene successively according to the compensation level, see Table 1 [Nucleonics Week, Sept. 29, 1994]. The first is the owner of the responsible nuclear plant who has liability up to a certain limit. The second is the state where the plant is located and which compensates up to a higher limit. In third, international conventions exist which allow to share the

costs between the signing states up to a limit above the previous one. Nevertheless, the impressive cost of a nuclear disaster, and everybody thinks to Chernobyl, cannot be compensated by civil liability. The only remaining partner is the state where the plant is located which has to fund and guarantee; consequently, those who are responsible for the post-accident management are the public authorities.

Costs and compensations are evolving continuously in all large actual accidents with off-site consequences (Chernobyl for instance, and also at several chemical plants). In each case, a first assessment was done in the few months following the accident, restricted to the costs associated with early consequences corresponding to a short period of time. Thus consequences were underestimated. Reassessment by the interested groups led to new estimates covering an extended scope of consequences and a longer disruption period. Estimates were even updated several times during the post-accidental phase, because repair took time and compensations were increasing with the duration of abnormal conditions.

Table 1. Nuclear Third Party Liability

PARIS CONVENTION July 29, 1960–OECD/NEA 14 parties Operator funding (unit M US $) Floor 7 Ceiling 21		
VIENNA CONVENTION May 21, 1963–IAEA 24 parties Operator funding (unit M US $) Floor 5		
BRUSSELS CONVENTION January 31, 1963 12 parties of the Paris Convention State supplementary funding (unit M US$)		
• Operator	Floor	7
• State	Ceiling	254
• Signing parties	Ceiling	174
Total	Ceiling	435

Source: International Nuclear Liability, Nucleonics Week, Sept. 29, 1994
Unit: Million US$ or SDR (Special Drawing Right, 1 SDR = 1.45 US $ in Sept. 1994)

4.2 Costs and compensations for the Chernobyl accident

In the Chernobyl case, estimating costs and giving compensations is clearly an iterative process. Many countries have been affected by the core melt occurred on April 26, 1986, which led to serious contamination in ex-USSR, mainly Belarus, Russia and Ukraine, and lower contamination accross European countries. Some monetary figures are given in the following. For CIS Republics, it must be underlined that: a) few figures have been published; b) some figures come from officials' and experts' declarations; c) exchange rates for the CIS Republics currencies have tremendously changed during the last 9 years; d) few figures are precise enough to point out the affected sectors or those which are compensated. In the other European countries, figures are better.

Estimates of the costs incurred in ex-USSR are given in Table 2. The first estimate given by Soviet authorities in September 1986 covered the immediate costs in USSR, Rouble 2 billion (around ECU 3 billion). The on-site costs were limited to the loss of the reactor, and cleansing and decontamination of the site; they represented 20 per cent of the total cost. The off-site costs, 80 per cent of the total cost, corresponded to emergency countermeasures, off-site decontamination, ban of agricultural products, and relocation of populations. In 1988, the new estimate Rouble 8 billion (around ECU 12 billion) given by the Soviet authorities included the side effect of the accident on the other nuclear power stations with RBMK technology, that is Rouble 6 billion (around ECU 9 billion). In 1990, a new official estimate is given: Rouble 10 billion (around ECU 14.3 billion) to account for all costs incurred up to 1989 [Bull. Droit Nuc., N°46, 1990]. Interesting percentages are those of agriculture loss (15 per cent), compensations paid to people (18 per cent) and decontamination with relocation expenses (29 per cent). In March 1990, an officious Soviet report estimated that Chernobyl might cost the country Rouble 175 billion to Rouble 215 billion by the year 2000. The average figure Rouble 195 billion (around ECU 275 billion) is 20 times more than the previous official estimate that was primarily concerned by the 3-year period following the accident. Such a large difference may be discussed by official authorities. Nevertheless, losses to agriculture and costs of off-site decontamination and recovery that were underestimated in the short term, seem to be better appreciated in the long term with their respective importance, 40 per cent and 20 per cent of the total respectively. Recent declarations of Ukraine Prime Minister [Nucleonics Week April 28, 1994] set the annual Chernobyl cost at 15 per cent of the State budget ; for Belarus, the annual contribution is estimated to 12 per cent of the national budget [Nucleonics Week, July 7, 1994]. Regarding Chernobyl costs, time is needed to get more precise estimates.

In Europe, the agricultural sector was the main victim of the Chernobyl fallout. The consequences concerned agricultural products with the ban of certain products and a drop of sales for others. Compensations have been paid by national authorities to farmers and stockbreeders. They concerned particular productions and were based on the market price. In that case the logic in action, compensating the economic sector of a product, is a "vertical" one as opposed to the "horizontal" logic which gives priority to area restoration. An initial estimate of losses, ECU 1.4 billion, was proposed in 1986. In 1987 and 1988, they have exceeded ECU 0.36 billion and it was considered that actual losses were very much higher [Smets, 1988]. Indeed from [Nucleonics Week Sept.29, 1994] and [Tweten U., 1995] the bill increased and some numbers are still missing. Figures appear in Table 3.

5. Mitigation

5.1 Interventions

Authorities have responsibility in organizing their interventions. Many possible countermeasures are available, as seen previously. There is agreement that a countermeasure is justified when it achieves greater good than harm. Before implementation, optimisation should be applied in such a way as to maximise the net benefit. In this purpose, all consequences must be considered: first obviously, those related to dose (*i.e.* to health); second, the economic consequences which account for technical interest and financial feasibility; third, the social considerations which introduce people attitudes and behaviors.

Table 2. Chernobyl Consequences in ex-USSR [(1)]

		ECU billion [(2)]
1986 September: first estimates		
On-site [(3)]		0.6
Off-site USSR [(3)]		2.4
1987 March-June		
On-site		1
Off-site USSR		2.4
1988 December [(4)]		
On-site		9.1
Off-site USSR		2.4
1990 July [(5)]		
USSR total cost		13
...	27%	
Food restriction	2%	
Compensation	18%	
Decontamination, relocation	29%	
Agriculture	15%	
Capital loss	9%	
1990 March [(6)]		
USSR total cost		275
Power loss	34%	
Decontamination, evacuation, ...	20%	
Agriculture	40%	
Safety design	2.6%	
Capital loss	2.6%	

1. Core melt at the Chernobyl 4 reactor (RBMK technology) in USSR. April 26, 1986. Large off-site radioactive release. USSR and Europe affected
2. Exchange rate in 1990: 1 ECU = 0.7 Rouble = 1.2 $ = 7 FF.
3. USSR official report Sept. 19, 1986. On site: reactor loss. Off-site: decontamination, health care, loss of agricultural products, loss of exports.
4. USSR official estimate. On site costs concern the reactor and side effects on all other RBMK reactors. Period 1986-1989.
5. Belarus, Russia, and Ukraine delegations, July 1990. Report to United Nations. Costs for the 1986-1989 period.
   In: Bulletin de droit nucléaire, N° 46, Dec. 1990, p.103-104.
6. USSR officious report: by Koryakin Y. (1990), economist at the Research and Development Institute of Power Engeneering. Cited in: Wall Street Journal, March 23, 1990. Costs are direct and indirect; they concern USSR and cover the period 1986-2000. The figure given is an average figure.

Table 3. Chernobyl Consequences in Europe [1]

	US billion [2]
1986 September	
Europe estimate[3]	1.680
1987 March-June	
OECD countries : compensations[4]	0.480
1988 Compensations	
Austria [5]	0.097
Germany [5]	0.227
Italy [5]	0.330
Netherlands [5]	0.480
Norway [6]	0.046
Sweden [6]	0.035
UK [5]	0.007
Finland [6]	0.005
Bulgaria [5]	0.074
Hungary [5]	0.018
Poland [5]	0.035
TOTAL	1.354

1. Core melt at the Chernobyl 4 reactor (RBMK technology) in USSR. April 26, 1986. Large off-site radioactive release. USSR and Europe affected.
2. Exchange rate in 1990: 1 ECU = 0.7 Rouble = 1.2 $ = 7 FF.
3. Estimate by ENVIPACT (an Environmental group) (1986).
4. Flavin (1987), and Smets (1988). Compensations paid to farmers in OECD countries.
5. International Nuclear Liability Special report, Nucleonics Week, Sept. 29, 1994, p.11.
6. Tveten U. Economic consequences of Chernobyl in the Nordic countries. IFE Report, Norway 1995.

The search of optimised countermeasures, or at least the determination of the set which contains the better ones, and the final choice constitute a complex problem. Needless to say, complexity increases when the accident is large. There are differing frames to the decision problem. The basic situation involves one set of countermeasures, two criterias (dose averted and cost), and one decision maker. For example, considering the possible options in cattle feeding, the averted dose and the cost of each option are the criterias, and the veterinary service is deciding about the cost benefit balance. It is a bit more complicated when the number of criterias increases, the rest being unchanged. For the previous example, only adding a feasibility criterion leads to decide in a multiattribute context or to use aggregative methods so as to come back to the previous case. At a higher level, at least two parties are involved in the decision, all the rest being unchanged. In this case conflicts arise from the different importance given to the criterias by the parties; if some are emphasizing costs and others the doses or any other criterion, it is quite uncertain to achieve a common choice. There are methods to make explicit the relative importance of the criterias for each party [French *et al.*, 1992]. The actual problems are unfortunately of the highest complexity. More than two parties are involved : the agricultural sector, technical divisions in state ministries, the political representatives. Criterias are many: collective dose averted, individual dose, cost, feasibility, acceptance level, etc. Options to consider are not related to a single type of countermeasures (as seen for cattle feeding) rather they belong to all different types (as decontamination, food processing, etc.) and they are interdependent.

This is common when the situation concerns not a particular production but the whole rural area. The concept of strategy comes here. Some decision frames of various complexity are described in the following sections.

5.2 *Setting intervention levels*

Authorities have the responsibility for setting the dose levels and derived contamination levels for surface or soil contamination, raw produce, foodstuffs, etc. In this respect, they need to evaluate the implications of such choices on the agricultural sector. This is expressed by the surface of land likely to be affected, the number of cattle heads for which action is needed, the loss of production, and other similar indicators.

Decision aiding requires first the computation of the consequences. Accident Consequences Assessment (ACA) codes may address an extended set of consequences, see for instance MACCS [Ritchie et al, 1987], MECA2 [Alonso et al, 1990; Gallego, 1994], COCO-1 [Haywood et al, 1991], and COSYMA [Hasemann et Jones, 1993; Faude et Meyer, 1994]; or they may detail one action with numerous options as for example decontamination, see DECON [Tawil et al, 1985] or [Robinson et al, 1990]. The codes which cover a large spectrum of consequences allow to compute costs for decontamination, evacuation, temporary housing and transportation, economic activities disruption (milk and crops for agriculture), land and property interdiction, and relocation of displaced populations. They offer the possibility to simulate an intervention policy by changing the intervention levels, imposing temporary limits, varying the period of time covered. But they never consider social activities disruption nor side effects. Inherently they focus on generic situations.

5.3 *Strategies for contaminated foodstuffs*

When food is contaminated, countermeasures are taken for sanitary reasons and international trade requirements. The possible countermeasures can apply to all foodstuffs, as a ban (that means destruction) and animal feeding, or are product specific. The milk can be sterilized and stored for some time, it can be decontaminated, it can be used differently (more skim milk, more butter, cheese making modified). Vegetables, fruit and cereals can be harvested on a slightly different way, and for some they can be processed to delay consumption. Meat consumption is made possible by freezing and storage or by changes in animal feeding. In practice, authorities must define a strategy, which means that several countermeasures are taken or must be taken at the same moment. This decision problem is easier to solve when it is computer aided.

DACFOOD (Decision Aiding for Contaminated Foodstuffs) is an example of a system designed to provide the decision maker with the necessary data for the implementation of an optimised strategy [Despres *et al.*, 1993; Despres et Heymes, 1994]. Consumers are defined by their age and diet structure. The system evaluates the dose due to ingestion without any countermeasure; it calculates the dose reduction after implementation of each countermeasure taken among those possible, and also by combining several countermeasures; it is able to assess several strategies on the basis of their cost-effectiveness ratios. Up to 19 nuclides can contaminate the foodstuffs. Should deposition occur at a period of the year without harvest, the system applies dynamic transfer models to calculate the radionuclide concentrations in future productions. The criterias used are dosimetric, either individual dose (effective, thyroid, and red bone marrow) or collective dose, and technical such as cost, feasibility and efficiency of the basic countermeasures. Public acceptance and self-prohibition are not modelised.

5.4 *Decontamination strategies*

Techniques of decontamination have been intensively studied since 1986 within the CIS Republics, in Europe (the Ressac project), and in collaborative actions CIS-Europe (ECP4). Many scientific and technical data on decontamination of forest, urban areas, foodstuffs, meadows, machines, etc. have been produced, collected and analyzed. When data come from laboratory or small scale experiments, they need to be extrapolated in a sensible scale. Technical feasibility includes the definition of the complete process that is necessary *e.g.* associated facilities or utilities, especially as regards possible management of the wastes, and the availability of associated equipments, or skills, and the indication for use (some techniques are efficient only in given conditions). The economic impacts are either positive (eg. possible by-products, possible return to a production), or negative (workforce, fuel, imported material, local material, reduction of production).

Users are the Ministries of the CIS countries in charge of mitigating the consequences. They have a clear objective for contaminated areas where people are living, it is return to "normality". That means significant decrease in individual doses, hence down to dose thresholds, and then reduction of the compensation payments allocated to the populations living in these territories. To achieve these goals, decontamination strategies must be defined which take into account the legislation in force in the three CIS countries.

On account of the multiform character of the radioactive contamination of large territories, and the complexity of the different pathways contributing to exposures of individuals, a case study methodology is used. The strategies are defined for a set of typical settlements covering a wide range of existing situations. Each settlement is defined as a populated zone comprising a given distribution of forests, meadows, agricultural land, private houses with individual gardens, urban areas, to which is associated a certain level of contamination. Determination of the dose distributions in the reference settlements are based on a number of relevant practices concerning agricultural foodstuffs, possible exploitation of the forest, consumption of vegetables from kitchen gardens, consumption of animals and foodstuffs from semi-natural environments, etc. For all settlements, the possible advantage of performing large-scale decontamination of territories is to be compared with the option of doing nothing over 100 years.

6. Conclusions

Agricultural consequences of large nuclear accidents are well known and most of the costs can be determined with a good level of precision. Actual problems are in optimizing mitigation efforts for rural areas characterized by agricultural practice diversity.

Acknowledgements

The research presented in this paper has received financial support from CEC DGXII under contract FI3P-CT92-0013.

REFERENCES

1. Alonso A., Gallego E., Martin J., (1990), *The modelling of off-site economic consequences of nuclear accidents*. In: CEC Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens 7-11 May 1990, EUR Report 13013, p. 713-732.

2. Brenot J. (1990). *Economic consequences assessment for scenarios and actual accidents. Do the same methods apply?* In: CEC Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens 7-11 May 1990, EUR Report 13013, p.733-751.

3. Despres A. (1993), *Dacfood Reference Guide*, IPSN/DPHD/CERP Note 93/01, 1993.

4. Despres A., Heymes P. (1994). *A Decision Aiding System: DACFOOD*, Portsmouth 94 Proceedings, Nuclear Technology Publishing, p.353-356, 1994.

5. Envipact, 1986, *Tchernobyl: 30 milliards de dégâts*, Energie et Environnement.

6. Faude D., Meyer D. (1994), Extension of the COSYMA-ECONOMICS Module, *Cost Calculations Based on Different Economic Sectors*, Karlsruhe, KFK 5442, Dec.1994.

7. Flavin C. (1987), Reassessing Nuclear Power: the Fallout from Chernobyl, World Watch Paper 75, March 1987.

8. French S., Kelly N., Morrey M. (1992), *Decision conferencing and the International Chernobyl Project*, J. Radiol. Prot. 12, N°1, p.17-28, 1992.

9. Gallego E. (1994), MECA2, A Model for Economic Consequence Assessment. Version 2, Reference Guide, Report CTN-43/92, UPM, Madrid, 1994.

10. Hasemann I., Jones A. (1993), COSYMA User Guide, Version 93/1, *KFK-NRPB Report*, CEC Luxembourg, EUR 13045, August 1993.

11. Haywood S.M., Robinson C.A. (1991), *COCO-1: Model for assessing the economic impact of accidents*, Radio. Prot. Bull., N°118, p.9-14, 1991.

12. Haywood S.M., Robinson C.A. 1991. Model for Assessing the Cost of Off-Site Consequences of Accidental Releases of Radioactivity, Chilton, NRPB-R243, London HMSO, 1991.

13. Koryakin Y., (1990), *Cost of the Chernobyl accident*, In: The Wall Street Journal, March 28, 1990.

14. Lochard J., Pretre S. (1995), *Return to normality after a radiological emergency*, Health Physics, vol 68, n°1, p.21-26, 1995.

15. Ritchie L.T., Chanin D.I., and Sprung D.L., (1987), *MELCOR Accident Consequence Code System* (MACCS Version 1.4). NUREG/ CR-4691.

16. Robinson C.A., Haywood S.M., Brown J., (1990), *The costs and effectiveness of various decontamination procedures*, In: CEC Seminar on methods and codes for assessing the off-site consequences of nuclear accidents, Athens 7-11 May 1990, EUR Report 13013, p.633-650.

17. Smets H., (1988), *The cost of accidental pollution*, UNEP Industry and Environment, November-December 1988, pp. 28-33.

18. Tawil J.J, Bold F.C., Harrer B.J., and Currie J.W., (1985), *Off-Site Consequences of Radiological Accidents: Methods, Costs, and Schedules for Decontamination*, DECON Programme NUREG/ CR-3413.

19. Tveten U. (1995), *Economic consequences of Chernobyl in the Nordic countries*, IFE Report, Norway, 1995.

SESSION IV

MECHANISMS FOR INFORMATION EXCHANGE

Chairperson: Andrea Schenker, Switzerland

AGRICULTURAL ASPECTS OF NUCLEAR AND/OR RADIOLOGICAL EMERGENCY SITUATIONS

by

Laure Berthier and Vincent Pupin
France

Abstract

An expert appraisal was carried out by actors from the nuclear industry and two sensitive agricultural sectors (salad vegetables and sheep production) in the Provence Alpes Côte d'Azur (PACA) region as part of a financial audit sponsored by the Institut de Protection et de Sûreté Nucléaire (IPSN) on the theme of communication in the event of a contamination of the region (radiological emergency situation). In view of the information they provided and the information they asked for, we determined common action fields between the four main types of actors, of a different culture, involved Governmental agricultural administration, professionals of Agriculture, members of the nuclear activities area and elected representatives. We analyzed the actions already performed in these fields and we have noticed that the Tchernobyl accident was a turning point in actor mobilization and awareness. A projection in the future made it possilbe to assess the stakes in relations between the IPSN and the two agricultural sectors, namel;y establishing the conditions for response to a radiological crisis. Thus, we were able to make proposals to the IPSN for a French agricultural-nuclear expert appraisal based on a relation network covering (or even going beyond the studies agricultural sectors.

(Keywords: Nuclear, Agricultural Sectors, Expert Appraisal, Crisis, Actor Network)

This exercise is the result of a partnership between the sponsor, the Nuclear Protection and Safety Institute (Institut de Protection et de Sûreté Nucléaire IPSN), the Ministry of Agriculture and the Institut National Agronomique Paris Grignon (INAPG). It follows on from a general review of the risk of contamination of the environment, and therefore of agricultural produce, by radioactivity. This review had already shown the need for better communication between the agricultural and nuclear sectors. That is why this topic has been chosen: "communication" is understood here as a meaningful dialogue between the actors involved and the search for a possible common sphere of negotiation, and not as media information.

A Radiological Emergency Situation (situation d'urgence radiologique) – RES – covers any occurrence which could lead to any type of contamination, here in the Provence Alpes Côtes d'Azur region (PACA), affecting an agricultural sector and groups of actors (those working in the industry, the authorities, etc.) concerned by the same product "from pitchfork to fork". For us, then, communication means an exchange of expertise, *i.e.* the pooling of different types of knowledge such as technical knowhow, familiarity with the actors or location involved, etc., in order to address a given topic. The "patrimonial audit" technique is based on this approach and, through confidential interviews, capitalises on the expertise of each actor in accordance with a method reflecting the plan of the report.

As a result of these interviews, we found that there are four main groups ("cultures"), for each of which the radiological quality of a given product is defined differently, using differing sensibility thresholds to assess the contamination of agricultural products. For the authorities, the European standards represent the legitimate thresholds, while consumers want "zero Becquerel quality" (Becquerels are the units for measuring radioactivity). The report endeavours to describe the strategies of these different approaches and to learn the lessons from their joint actions, before looking to the future in order to search for pointers to help determine methods of changing the present situation.

In the context of Radiological Emergency Situations, the IPSN, a public body under the joint auspices of the Ministries of Industry, Defence and the Environment, considers it can offer the agricultural sector expertise with regard to expected releases into the environment, the type of contamination of the soil resulting from such releases and the definition of the countermeasures to be taken to reduce contamination of foodstuffs.

If it is to carry out its expert role for the public authorities successfully, the IPSN needs information, both "static" and "dynamic", from the different branches of agriculture about their products and organisation. Those working in the IPSN on studies concerning the impact of a nuclear accident outside the installation are aware that their approach to the environment is defined in terms of cause and effect (fundamental research using models, for example) which results in generic, universalist answers only to the questions raised by an RES, and omits consideration of local aspects.

Thus, given its background of research into nuclear physics, the IPSN measures the quality of a product in an RES in terms of health, the number of Becquerels per kilogram, and by the cost of countermeasures. It measures this quality using its own tools. However, the IPSN knows that in using this generic approach, it takes no account of the credibility or image of the products in question, and this is why it needs to consult agricultural experts.

The branches selected (lettuces and the ovine sector) are not homogeneous entities. We have made a distinction between those actually working in the sector (producers, distributors, etc.), the administrative authorities (Ministry of Agriculture), and inter-professional bodies.

We feel that, as far as the first group is concerned, their concerns can be addressed schematically using the concept of a product's life cycle. Products pass more or less directly through the hands of the producer, the distributor (which covers dealers, dispatching agents, wholesalers, hypermarkets, etc.), the consumer and finally the recycling agent, (*i.e.* managers of the waste and of the markets created by withdrawal of surplus production), who starts up a new cycle. At each successive stage, the quality product of a professional is offered to meet the demand for quality of the following professional within the framework of a more or less explicit contract based on mutual trust. This contract is influenced by the prevailing circumstances: a new Common Agricultural Policy of the European Union, the liberalisation of world trade, media pressure, etc.

In the event of an RES, the radiological quality of a given product has an impact on this process and affects other components of quality such as the product's image. Regardless of norms, the least little Becquerel over and above a product's natural radioactivity represents, according to the actors concerned, a risk of a slump in sales. This may lead to a breaking of the "contract" between professionals and thus to the "dealing a new hand": supplies are then obtained elsewhere.

The concern of those working in the sector thus operates at the level of a depreciation of goods, a depreciation which is not only economic but also relates to how a product is perceived, since the reputation of a product and the pride of its producer are also at stake.

For the authorities, the problem is essentially interministerial in nature: for example, the Direction Générale de la Consommation, de la Concurrence et de la Répression des Fraudes (DGCCRF) of the Finance Ministry is responsible for plant and vegetable inspection. The Direction Générale de l'Alimentation (DGAL) of the Ministry of Agriculture is responsible for animal inspection, while the Office de Protection contres les Rayons Ionisant (OPRI) of the Ministry of Health is responsible for monitoring, amongst other things, the quality of water and the air. The system works on the basis of the distribution of tasks to Ministries, departments and offices which, when roles are defined and regulated by legislation and when the signals are clear (for instance when pollution standards are breached), makes it possible for the necessary measures to be taken.

However, in an RES, all roles are not clearly defined (as regards the management of the economic consequences, for example), and the signals can be very feeble. Rumours of radiological contamination can easily start even though no norms have been exceeded. The standardized responses of the authorities do not always sit easily with the particular constraints of those working in the industry. But the authorities know that they must take action in the event of an RES because it is the State's duty to protect public health and ensure the conditions necessary to the country's economic survival.

Between those working in the industry (the "professionals") and the authorities are inter-professional bodies which ensure the interface between the two. These bodies are the representatives, vis-à-vis the authorities, of those working in the industry and are consulted with respect to government decisions which they then communicate and implement in the industry. They therefore have a foot in each camp, their exact role depending on the type and level of measures concerned. We do not therefore count them as an entirely separate group.

Elected representatives were asked questions in their capacity as defenders of the interests of their agricultural constituents in rural areas, and more generally of the population as a whole, thus including consumers. The legitimacy of these roles stems from the democratic vote which amongst other things makes them responsible for keeping their electorate informed, both in normal circumstances and in an RES.

This assumes that they address the concerns, on the one hand, of consumers, anxious to know of any artificial (or even natural) radioactivity in their food or environment, but also of those working in the industry, fearful for their economic survival should a risk to health be evoked. And they are right to fear a "panic reaction" leading to a loss of sales and lasting damage to the reputation of a product when there is in fact no real risk. In an RES, therefore, the individual legitimacy and credibility of elected representatives are at stake, which may lead some of them to organise, and act within the framework of, municipal task forces.

In the light of the different problems facing each group, as described above, we feel that the IPSN and the two agricultural sectors selected share common interests, be they economic, scientific or concerning health or the media. Let us now then look at examples of past co-operation.

The accident at Chernobyl in 1986 remains the point of reference for those working in this field with regard to possible adverse effects of nuclear origin on the environment.

Before Chernobyl, in the context of the Cold War when nuclear power was closely related to politics, the typical nuclear crisis as envisaged by most actors in this field, whether in a military or energy dependency context, was characterised by: outside aggression, major health risk involving high doses, and planned emergency management for the most part using important on-site resources and emergency task forces within the Administration. Thus, nuclear power plant safety in France is based on Internal Emergency Plans (Plans d'Urgence Interne – PUI) and Specific Intervention Plans (Plans Particuliers d'Interventions – PPI). However, this method of organising emergency response relies on an exchange of expert information, at Préfet-level in particular.

For a number of actors in the nuclear field, including the IPSN, it did not need Chernobyl – even though it represented a new type of emergency – to demonstrate the importance of off-site aspects. Evidence of this may be found in research carried out after nuclear tests in the atmosphere, and in the existence of a water monitoring network, for example.

However, for the other actors involved, it was Chernobyl which really brought home the magnitude of the problem, especially given the prevailing economic and political context: the growing importance of product quality, of the environment and of trade. As emphasized by those interviewed, the agricultural sector felt itself to be concerned since several branches experienced a loss of sales and a state of crisis, sometimes for unexpected reasons. Examples include the economic impact on products, and the consequences for their image, of doses of radioactivity which were low or even not measurable, as a result of rumour, the relative nature of norms and the poor perception of the roles of certain actors which were not only ill-defined but often not included in the framework of emergency management.

We have called this type of situation a "grey emergency": it can, depending on how the actors involved behave, turn into a "black emergency", with serious economic and political consequences, or into a "white emergency", when problems are treated in a concerted manner and thus circumscribed.

In the light of this new approach, expert information was exchanged between the IPSN and those working in agriculture, both during and after the crisis caused by the fallout from Chernobyl over France and the PACA area in particular.

Examples include the collaboration between the IPSN laboratories in Cadarache, the DGCCRF inter-regional laboratory at Marseilles and the laboratory of the Direction des Services Vétérinaires (DSV) of the Bouches–du–Rhône, in applying the results of the foodstuffs controls in 1986 and 1987; also, the replies in the media by nuclear experts such as those from the Commission de Recherche et d'Information Indépendante sur la RADioactivité (CRIIRAD) to questions from consumers, and the drafting of an explanatory guide (1990) about radiological emergency situations for farmers, by the Fédération Nationale des Syndicats d'Exploitants Agricoles (FNSEA), the Centre National Interprofessionnel de l'Économie Laitière (CNEIL) and the IPSN.

There was also an important accident simulation exercise organised in Cadarache in 1991 involving, amongst others, the IPSN, the Préfecture and representatives of central and local agricultural authorities, including instruction on how to deal with contaminated areas.

In order to make the best use of the information gained from these experiments, we asked our respondents to imagine three possible ways in which the present situation might develop over a specified time-scale and geographical area.

All the actors are aware that there are several time-scales involved: for dialogue, for technological process, for changing attitudes etc. They usually think of the territory concerned, on the other hand, with reference to their own duties, which will depend on administrative boundaries, on an area of production or on the extent of the contaminated zone. It was clearly important for them to consider possible developments in relation to their network of actors, which in fact defines the area they administer and which is therefore relevant in the event of an RES.

It seems to us, and also from what we were told by those interviewed, that the likely future scenario, following on naturally from the present situation, is that individual roles will become increasingly compartmentalised though still leaving room for action should the situation become critical. The worst-case scenario is that an insidious accumulation of grey crises will lead to an all-but total and permanent breakdown in relations between the IPSN and the agricultural industry. The best-case scenario would be a gradual build-up of mutual trust, making it possible to consult on the most effective measures to adopt.

There is much at stake, therefore, for both the nuclear and agricultural sectors, the main concern, as revealed by the above possible scenarios, being the degree of reversibility of the relations between actors, something which is linked to the cost of negotiation: the less effort is made by the parties concerned to improve the exchange of expert information between the IPSN and the agricultural sector, the longer the actors have to wait and the more difficult it would seem to us to achieve positive results. Indeed, the present situation is perceived by our respondents as tending rather towards the worst-case scenario.

In order to achieve the best results, we are therefore proposing a change of approach, first endeavouring to respond to the needs of the IPSN.

As far the need for technical information is concerned, thanks to our respondents and to various documents, we have been able to supply the IPSN with statistical references. They are presented as relative since they vary in time, in space and in relation to the resources available. Furthermore, it proved impossible to satisfy part of the demand for information about product flows and the economic repercussions on a particular branch of a decision concerning that branch.

In fact, in order to overcome these difficulties, it would seem important to appoint key interlocutors, providing personal information back-up, and constituting a network of correspondents for the IPSN.

At central government level, we would recommend designating the Ministry of Agriculture for this task, provided it ensures the necessary interface with central inter-professional bodies and that it details its duties as regards the management of nuclear crises. At local level, we have chosen, for each branch, certain inter-professional bodies for their possible role as mediator between the professions concerned and the authorities or the IPSN.

For the green salad sector, we suggest the Association Provençale de Recherche et d'Expérimentation Légumière – Centre Technique Interprofessionnel des Fruits et Légumes (APREL-CITEL), the salad section of the Comité économique, the Services des Nouvelles du Marché (SNM) and the Direction Régionale de l'Agriculture et de la Forêt (DRAF).

For the sheep sector, we propose the Groupement Interprofessionnel de l'Élevage ovin (GIE ovin), the Union Bétail Viande Alpes Méditerranée (UBEVIAM), the Centre d'Études et de

Réalisation Pastorales Alpes Méditerranée (CERPAM) and the Fédération Régionale des Groupements de Défense Sanitaire (FRGDS) in collaboration with the DSV.

Thanks to these special interlocutors, we feel that the IPSN will be able to build up an area of practical shared expertise in which the terminology used will be given the same meaning by all.

Thus, we suggest that the actors concerned get together to agree on how to define certain terms such as "quality" and "pollution", which will constitute the basis for joint action. In particular, they should perhaps work together on emergency scenarios for the purposes of simulation exercises, and agree on their special fields of action and prerogatives in, for example, an agreement between the IPSN and the Ministry of Agriculture. The actors stressed that it was important for such relationships to be developed in a wider context of awareness-training and co-ordinated action going beyond the involvement of the IPSN alone.

In conclusion, we found as a result of our investigations that there is a general desire, on the part of those interviewed, gradually to build up agro-nuclear expertise based on a vigilant network of correspondents. The IPSN was also able, as a result of our work, to clarify certain areas of its field of action and to begin to learn the basic facts about two specific agricultural sectors. Furthermore, given the scope of the duties of the interlocutors selected and the interaction of the sectors in the PACA region, this report should pave the way for future studies.

PROLEGOMENA TO A THEORY ON EXCHANGES OF NUCLEAR KNOWLEDGE

by

Dominique Van Nuffelen
Belgium

"It is necessary to invent a new society which is founded more on research into lucidity than research into efficiency."

A. Jacquard

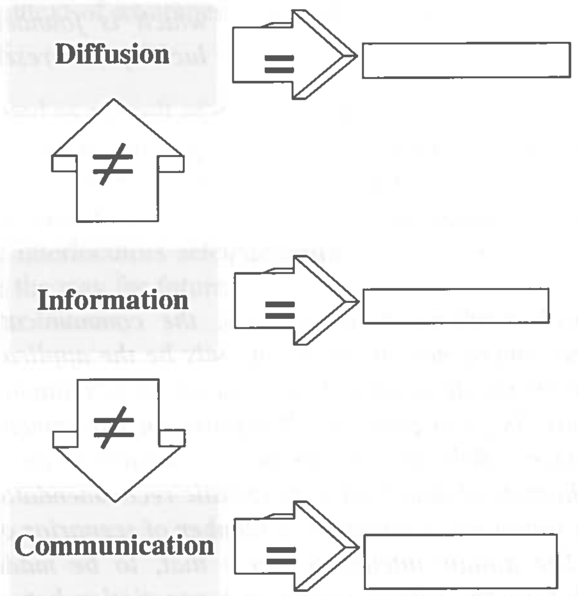
Summary

From the research worker's point of view, the communication with the agricultural population in a radiological emergency situation can only be the application of a theory of nuclear knowledge exchange between social groups. Thus it is absolutely fundamental to conceive such a theory. This paper presents its prolegomenas. It reports an experiment carried out in the SPRI (Radiation Protection Service – Belgium) and proposes a review of the scientific knowledge in the matter. Its empirical and theoretical data lead to pragmatic recommendations, the main being that we must prepare, in a normal radiological situation, a number of scenarios of messages suitable for the agricultural population. The author intends to show that, to be made properly suitable, these scenarios must necessarily form the subject matter of a negotiation between the transmitter and the receiver. On this condition, the nuclear emergency information will really constitute an exchange of knowledge between experts and the agricultural population, in other words a "communication".

I have kindly been asked to say a few words about communication with the farming population in the event of a radiological emergency, and I would like to thank the organisers of this seminar for giving me an opportunity to do so. The scope of my paper will be limited to the communication problems arising at the upstream end of the radiological emergency chain, problems which are of direct relevance to the topic we have gathered here to discuss today. Once a nuclear accident has actually taken place, it is obviously too late to start thinking about how to communicate properly with the population. What we need to have at our disposal is a set of pre-prepared message scenarios specifically tailored to the needs of the farming population. In order to draw up such scenarios, however, we must first carry out the necessary research. What I aim to do in this paper is to describe and comment on our experience in this area. In doing so, I shall review the theoretical basis for an exchange of specific nuclear knowledge, a radiological emergency with a specific population; the farming population.

Before beginning my presentation, however, I would first like to make a brief digression into the realm of etymology, (Figure 1). What exactly does "to communicate" mean? Does it mean the same thing as "to inform" or "to diffuse"? In terms of etymology, no it does not. The verb "to diffuse" derives from the Latin word *diffundere*, which means to spread in all directions [2]. "To inform" comes from the Latin *informare*, meaning to give form [2]. Thus, "to inform" means to give form to a message, whereas "to diffuse" means to spread that message. Again from an etymological standpoint, "to communicate" means something altogether different. To communicate, which is also derived from Latin (*communicare*), means to make common cause or to share [2]. As we shall see later, modern science makes the same etymological distinctions: to communicate does actually mean to share information, or, to anticipate somewhat, to establish a link between discrete systems of knowledge [12].

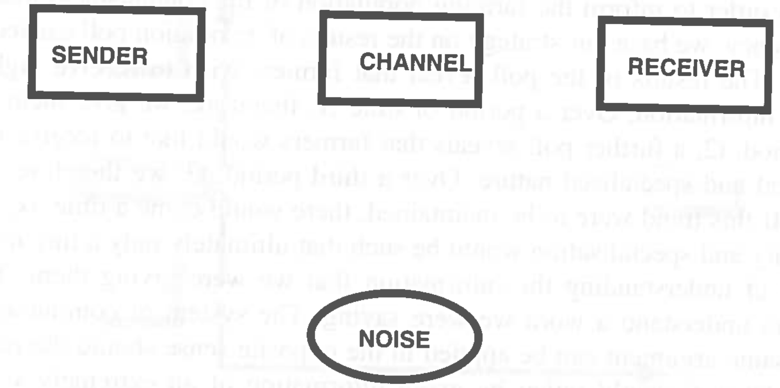
Figure 1. Communication = ?



The first scientific investigations of communication, such as the famous study by Shannon and Weaver on the mathematical basis of communication, addressed the question of how information is transmitted (Figure 2). In the classical model [8], a sender transmits information to a receiver through a channel of communication, and in this process the information may be affected by noise. Shannon defines "noise" as all extraneous physical phenomena which may interfere with the transmission of information. Weaver, on the other hand, gives the concept a semantic dimension and defines noise in terms of the semantic characteristics of the message and the semantic capabilities of the receiver. In other words, communication is a contest between noise and signals [9]. Communication is therefore the act of transmitting a message, without changing the form of that message, from a sender to a receiver, while at the same time ensuring that noise is kept to a minimum.

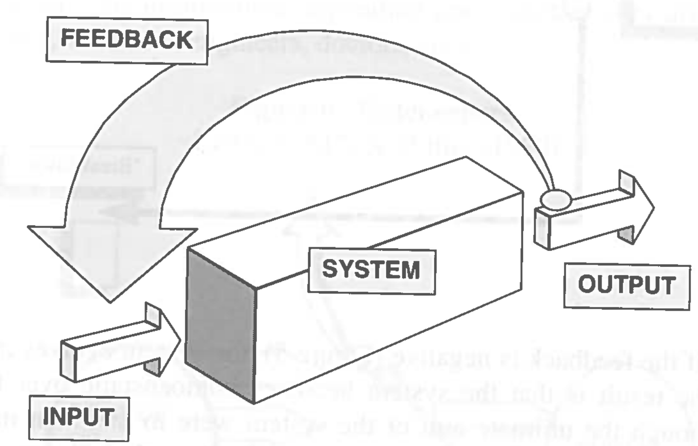
This model is characterised firstly by its simple linear causality, and secondly by its reflection of the well-known behavioural relation of S->R ("stimulus leads to response"). In such a model, cause leads to effect, *i.e.* the receiver reacts necessarily and solely to an action by the sender. As we shall see later, however, such a theory fails to explain several phenomena which are nonetheless observable in communication processes such as the influence of context, exercise of choice, distortion, relays, interaction, etc.

Figure 2. The Transmission of Information
Shannon & Weaver (1949)



The concept of interaction is contemporary with the model developed by Shannon and Weaver (Figure 3). Wiener [17] introduced this concept into cybernetics under the well-known term "feedback". Feedback occurs within a system when the modification of an output affects one of the inputs. Translated into communication systems, the concept of feedback implies that sender and receiver operate interactively. Such systems do not obey the rules of linear causality, therefore, but those of a causality of a quite different order, *i.e.* cybernetic causality or, to put it more simply, circular causality. It would therefore be wrong to assume that a logical causal link exists between the sender and the receiver; in reality, each party "acts" upon the other, and it is this "interaction" which provides the basis for communication [14].

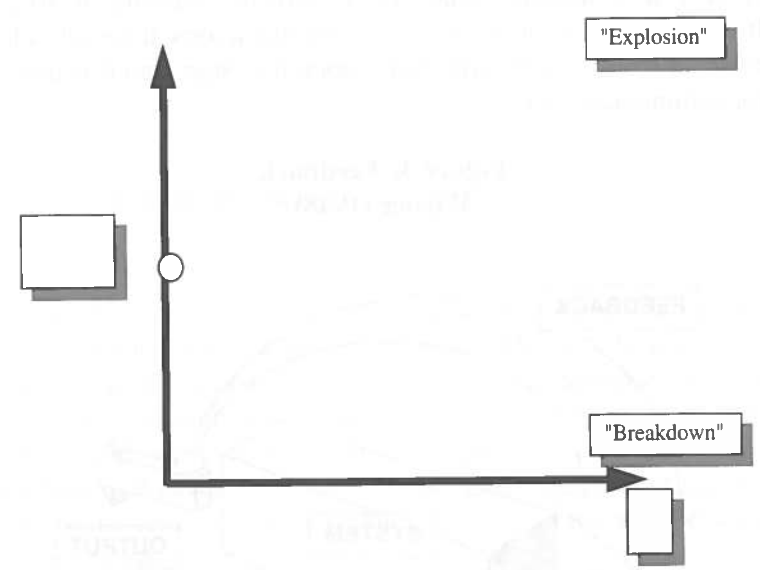
Figure 3. Feedback
Wiener (1948)



"Feedback" communication systems exhibit a high level of complexity. A notable aspect of this complexity is the fact that they are not entirely predictable [15]. It would be wholly mistaken for us to think that a "good communication technique" would be enough to persuade the farming population to adopt any measures we may recommend. For example, it is estimated that a good marketing campaign during an election will influence perhaps 2-3 per cent of the population. In theory, feedback can reduce this unpredictability. Feedback is not only a form of interaction between the constituent elements of a system, it is also serves to regulate that system [1].

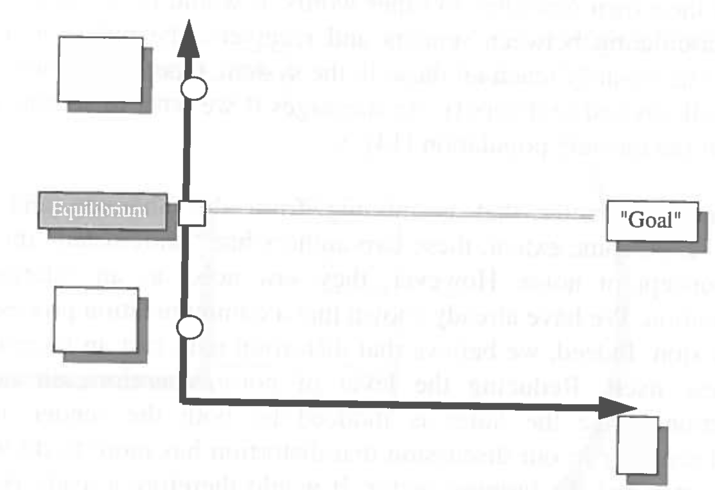
Feedback may be either positive or negative. Positive feedback (Figure 4) will maintain a system in its original course. The result will be a change in the status of the system over time, *i.e.* the system will become divergent. Divergence may ultimately destroy the system [14]. For example, let us suppose that, in order to inform the farming population of the counter-measures to be taken in a radiological emergency, we base our strategy on the results of an opinion poll carried out on a sample of that population. The results of the poll reveal that farmers wish to receive highly technical and highly specialised information. Over a period of time t1, therefore, we give them that information. Over a second period, t2, a further poll reveals that farmers would like to receive information of an even more technical and specialised nature. Over a third period, t3, we therefore supply them with such information. If this trend were to be maintained, there would come a time, tx, when the level of technical complexity and specialisation would be such that ultimately only a tiny minority of farmers would be capable of understanding the information that we were giving them. The vast majority would be unable to understand a word we were saying. The system of communication would thus break down. The same argument can be applied in the opposite sense should the results of the initial poll indicate that farmers would rather be given information of an extremely straightforward and general nature. In such a case, once the point tx had been reached, the information being given out would be so vague that each farmer could interpret it in a different manner. The communication system would explode.

Figure 4. Positive Feedback



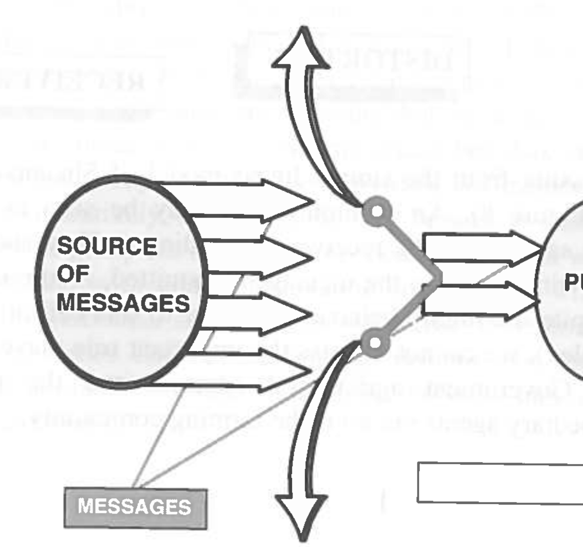
In contrast, if the feedback is negative (Figure 5), the system evolves in a direction opposed to original course. The result is that the system becomes homoeostatic over time, *i.e.* it becomes convergent. It is as though the ultimate aim of the system were to maintain its existence [14]. For example, let us suppose that we were to transmit a fairly technical message to the farming community. After an initial time period t1, an assessment of our message reveals that farmers would like to receive a simpler message. During the period t2, we provide them with a simpler message. During t3, a further assessment reveals that our information needs to be slightly more technical. Should this trend be maintained, then by period tx the goal of the communication system will have been achieved: we shall have transmitted our technical information in the correct semantic register for the farming population.

Figure 5. Negative Feedback



Another parameter that the theory elaborated by Shannon and Weaver fails to take into account is selection (Figure 6). First Lewin [6], and then others of his school such as White [16], drew attention to the role played by gatekeepers in communication processes. Gatekeepers are individuals or groups of individuals who filter messages; but in fact, both senders and receivers themselves act as gatekeepers [10]. When we disseminate nuclear information, we choose a number of specific themes from the totality of themes available. Therefore, while themes such as the safety of nuclear facilities, reactor operation, or the impact of ionising radiation on health may frequently feature in our messages to the public, they do not draw on the full range of information that could be given out on the nuclear energy sector. The information diffused has been filtered at source either because communicators have no real desire to change established practices, or because we have a particular perception of the reality of the nuclear sector, or even because the information has been tailored to meet the specific aims of those transmitting the information (depending upon whether they are pro - or anti - nuclear, spokesmen for industry, scientists, engineers, doctors, etc.).

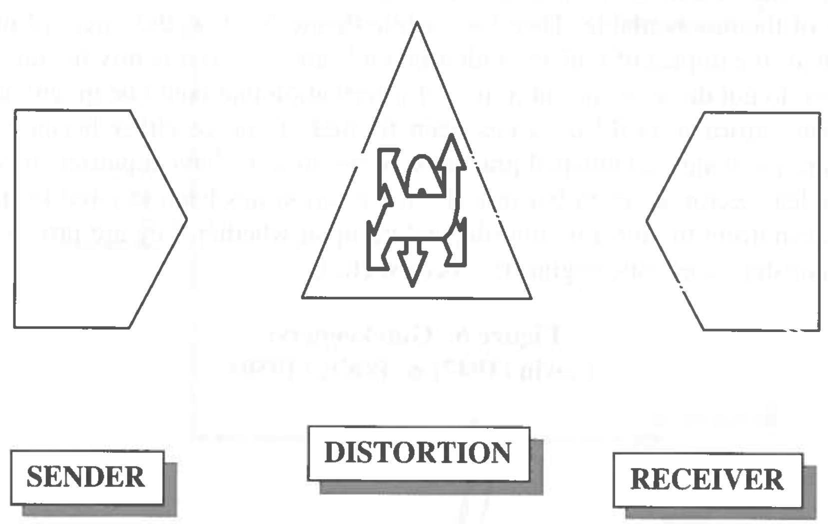
Figure 6. Gatekeepers: Lewin (1947) & White (1950)



Furthermore, the information thus filtered at source is subject to further refinement as the receivers of information choose those items which best match their own routines, their own vision of the nuclear sector and their own opinions. In other words, it would be incorrect to speak of a single flow of information circulating between senders and receivers; the public is awash in a flood of messages which do not necessarily reach all those in the system. One implication of this phenomenon is that we would be well advised to diversify our messages if we wish to communicate with as many members as possible of the farming population [14].

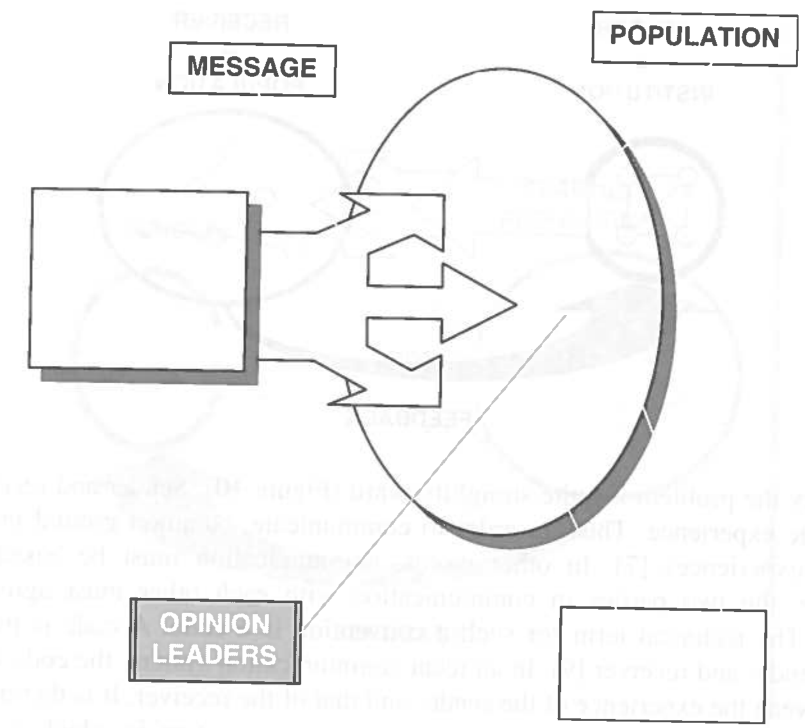
Another major parameter that is missing from the Shannon and Weaver model is distortion [3] (Figure 7). To some extent, these two authors had "anticipated" the effect of distortion by introducing the concept of noise. However, they saw noise as an external influence on the transmission of information. We have already shown that a communication process cannot be reduced to a model of transmission. Indeed, we believe that distortion is in fact an integral component of the communication process itself. Reducing the level of noise, therefore, in no way implies the elimination of distortion, since the latter is induced by both the sender and the receiver of information. We shall see later in our discussion that distortion has more to do with the cultural gap between the nuclear sector and the farming sector. It would therefore already be fair to say that we have far more to gain by attempting to narrow this gap than by limiting ourselves to improving our communication techniques.

Figure 7. Distortion
Galtung & Ruge (1965)



Another parameter missing from the simple linear model of Shannon and Weaver is the existence of opinion leaders (Figure 8). An opinion leader may be seen as a relay, a kind of intermediary agent between the sender and the receiver. According to Katz and Lazarsfeld [5], the role of this intermediary agent, with regard to the message transmitted, is to reinforce the impact of the message at local level. Despite the highly behaviourist slant to this definition (in that causality still remains linear, albeit complex), we cannot dismiss the important role played by opinion leaders in communication processes. Government agricultural advisers and the leaders of farmers' associations are the main intermediary agents vis-à-vis the farming community.

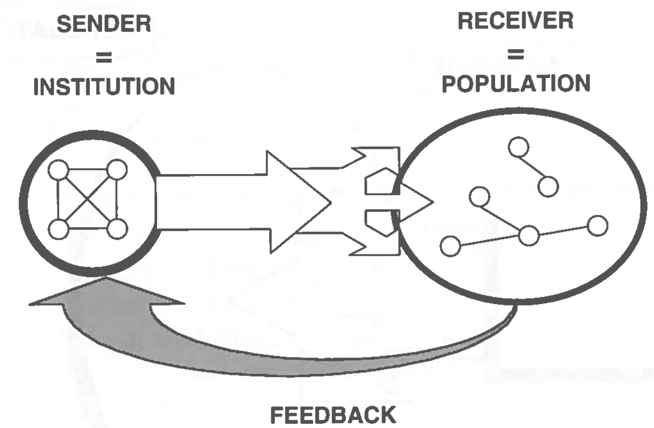
Figure 8. Opinion Leaders
Katz & Lazarsfeld (1954)



A critique of the Shannon and Weaver model, even one as cursory and incomplete as that given above, would be meaningless unless it were firstly to pin-point the basic shortcoming of the model, and secondly to propose a superior model. The basic shortcoming of the Shannon and Weaver model, in my opinion, is that it fails to take account of the context in which the communication takes place [13]. A superior model would clearly be one that took full account of context as well as the other elements to which we have drawn attention (Figure 9).

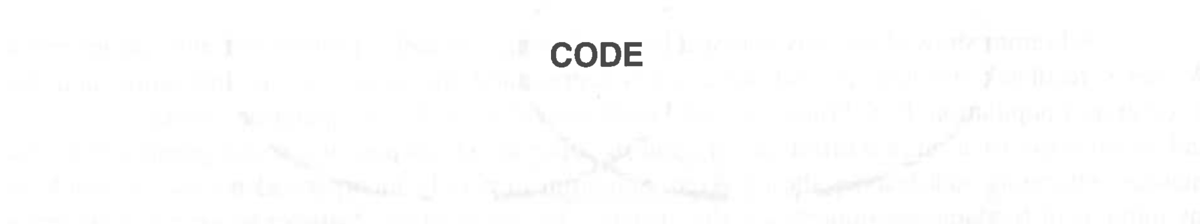
Schramm showed the way forward by developing a model [7] which not only incorporated Wiener's feedback mechanism, but which also represented the sender as an institution and the receiver as a population. In Schramm's model each individual within a population encodes, interprets and decodes information in a different way, but in doing so acts as part of a social group which also encodes, interprets and decodes the message. Schramm implicitly incorporated a concept which, to my mind, is of fundamental importance: the meaning that the receiver attributes to a given message is a function not only of the characteristics of the individual, but also, and perhaps more importantly, of the meaning that the social group of which the individual is a member attributes to that message. To express this idea more figuratively, a social group may be seen as a network of relationships in which individual members of the group are integral components, a network whose internal dynamics allow it to provide each individual with constant semantic support, but which at the same time receives feedback in the form of individual and collective semantic "inventions" [13]. The whole problem of communication thus becomes one of exchanging meanings or, in other words, the pooling of knowledge between individuals and other individuals, between individuals and groups, and between groups and other social groups [12].

Figure 9. Social Communication
Schramm (1954)



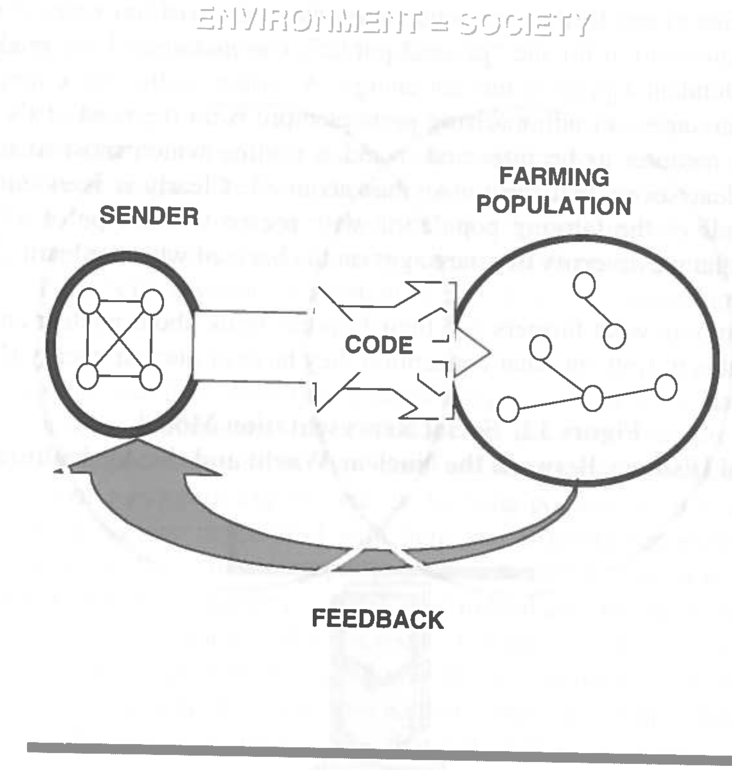
In theory the problem is quite straightforward (Figure 10). Sender and receiver do not have the same semantic experience. Thus, in order to communicate, common ground must be found for their respective experiences [7]. In other words, communication must be based on a semantic "convention", *i.e.* the two parties in communication with each other must agree on what their messages mean. The technical term for such a convention is a code. A code is the knowledge set shared by both sender and receiver [9]. In an ideal communication system, the code will be located at the interface between the experience of the sender and that of the receiver. It is therefore essential that we identify the code used within the type of communication system in which a group of experts transmits information regarding a nuclear emergency to the farming population [14].

Figure 10. Pooling of Knowledge



In order to tackle this intriguing problem, we must first make a synthesis of the various theoretical principles we have identified so far. Our communication with the farming community will clearly take place within a frame of reference (Figure 11). It is a fundamental law that a phenomenon cannot be understood unless the field of observation is large enough to encompass the context – the environment – in which that phenomenon takes place [15]. I cannot stress too strongly the overriding need for us to take proper account of the frame of reference; for, as Albert Jacquard points out, in our capacity as "experts" and "specialists", we often tend to attribute too much importance to certain factors, whereas the event we are studying is the result of a host of individual factors and conditions which are all applied at the same time which interact with one another [4].

Figure 11. Open Communication System:
Nuclear Data from Agricultural Society



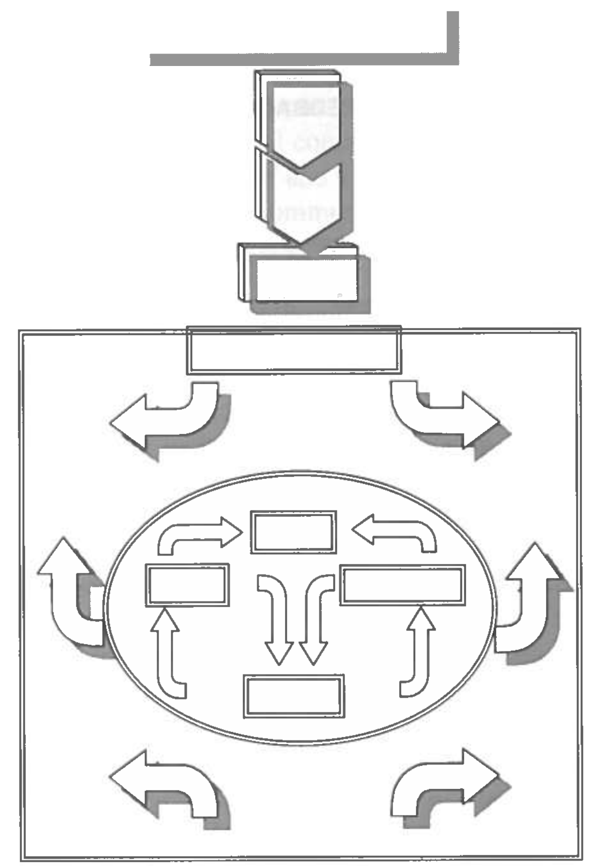
In the final analysis, this framework, or environment, is simply modern society – our increasingly technocratic post-industrial modern world [12]. The communication system we are examining here is an open system, *i.e.* one which is in permanent contact with its environment [1]. As we all know, any open system will have its own intrinsic properties. The most important of these, to my mind, is that of totality. An open system is greater than the sum of its constituent parts. This means that any disturbance to one of the elements in the system can upset many other elements, if not the entire system [15]. It also means that an open system will have its own internal logic, *i.e.* structure [13]. Lastly, it means that no open system can be subjected to summation in that interaction between two or more elements within the system will result in the emergence of new characteristics [15]. Consequently, an open system of the type in which nuclear information is communicated to the farming community will be highly complex [14]. It is characterised by a wide variety of elements, a wide variety of interactions between those elements, non-linear interactions and endo-determinism. We would be grossly mistaken to believe that we can supply "inputs" to such a system based solely on our own determinants.

Another important property of open systems is that of equifinality. An open system can achieve a condition of temporary autonomy which is unrelated to the initial conditions and which is determined solely by the parameters of the system [20]. This type of system is governed by a feedback loop and subject to cybernetic causality [1]. This means that such a system is determined by its own relational parameters. It is therefore on the latter that we must focus our efforts, and not on isolated parameters such as the perception of radiological risks at the level of the "layman".

Lastly, one property we must not neglect is that of limitation. Any exchange of messages within a communication sequence reduces the potential number of further exchanges [15]. The messages exchanged become an integral part of the context of the communication process, thus delimiting the boundaries to any further communication. Over the past ten years or so over which we have been providing information for the "general public", our messages have gradually confined to certain specific and redundant aspects of nuclear energy. A certain routine has emerged with regard to the "content" of our messages, a routine arising perhaps more from the need of the sender to inform than from that of the receiver to be informed – and a routine which most assuredly reflects the perception of the nuclear sector that the sender has acquired. Clearly it is essential that we listen properly to the demands of the farming population with regard to the type of information farmers wish to be given, and that we diversify our messages on the basis of what we learn [14].

While determining what farmers and their families think about nuclear energy is important, what is more important is to find out what conception they have of nuclear energy (Figure 12).

Figure 12. Social Representation Model
The Cultural Distance Between the Nuclear World and the Agricultural World



The conception that the farming population has of the nuclear sector is based on the reference criteria common to their community – that much is patently obvious. What should be noted, however, is that their criteria differ from ours. This difference in terms of reference criteria constitutes what I refer to as the cultural gap. The immediate world surrounding the individual member of the farming population consists of a network of readily identifiable links between elements such as the farm, the family, land, livestock, etc. This network is "naturally" integrated into

the wider network constituted by rural society. Relations with the latter, however, are of a different nature. The immediate world is that of the commonplace of daily life – everyday living. Relations within such a world are reiterated endlessly. Cause and effect are linked together in a closed loop of meaning: the land is there to be cultivated, the role of the farmer is to cultivate the land. It is the activity of farming which gives meaning to such relations [1].

Relations within rural society appear to be based on the principle of classification by type; otherness, *i.e.* the other components of the rural world, is perceived in terms of a typology [11]. The rural world contains, for example, the "city-dweller" who has come to live in the country, the "sugar mill", the "dairy", the "agricultural adviser", the "vet", the "people in the village", etc. Each of these entities is a type in that the behaviour of that entity is expected to relate directly to the daily pattern of life in the rural world: the "city-dweller" is a potential customer, the "agricultural adviser" is expected to give advice, etc.

What these empirical data show is that parties engaged in an act of communication establish their own definition of their relationship [15]. This does not pose too many problems, provided that a certain distance is maintained between the two parties. Unfortunately, once the parties engaged in communication consist of a group of experts and the farming population, it is as though this distance no longer existed. What we are confronted with here are differing representations of the nuclear sector [11]. When I refer to the "cultural gap", it is to such differences in representation that I am referring. We all know that homo sapiens sapiens – or indeed any group of humans – is capable of "representing", *i.e.* constructing, reality. Modern social anthropology teaches us that reality is always constructed within a social group [19]. We also know that in complex societies there are very many social constructions of reality [12]. It is therefore neither "abnormal" nor "irrational" for the farming population to represent the nuclear sector in a way that differs from our own.

In the conceptual system of the farming world, the nuclear sector is represented as a wholly external entity imposed from outside and with no intelligible link with either day-to-day reality or rural society. In other words, the nuclear sector represents a break with the perceived world. The sudden materialisation of a nuclear facility in this world – or even simply reference to the nuclear sector – creates a semantic barrier. It is as though the farmer were simply incapable of typifying the extraordinary – in the proper sense of the word – object, the nuclear power plant, which has appeared at the bottom of his field and which he has even been able to visit on several occasions. The reactions of the farming community tend to follow the same lines [11]: "we visited the plant", "we know people who work at the plant", "one of my relatives works there"; and yet all "that" remains impenetrable: "it's another world". Those who work in nuclear plants are "off their heads". Those who operate such plants "simply out to make a profit." Scientists are "technocrats" and policy-makers are "out of touch with reality", etc.

In such a conceptual system, radiological risks are not so much "perceived" as interpreted; radiological risks are seen explicitly in terms of the inability of the common man either to understand or to apply nuclear technology [11]. Farmers are not afraid of nuclear technology because ionising radiation is dangerous, mysterious, invisible, etc. They fear nuclear technology because it is a powerful symbol of the modern world. Nuclear technology is simply the focus for farmer's rejection of a society based on technology [11]. In view of this, a radiological emergency simply does not have the same potential reality for us as it does for them. For farmers, it is an abstract concept entirely removed from the reality of every-day life. I have had farmers say to me "the first thing I would want to know if there were a nuclear accident is what to do with my livestock; the second thing I would want to know is whether the people who wanted to make us into a nuclear society really knew what they were doing." In other words, animals are more important than human beings, and at human level the main problem is that of our society. This difference in interpretation even extends as far as the meaning given to individual words [11]. A good example is the definition of the term "environment". For farmers, the environment sometimes extends no further than the boundary to their farm – where their land ends, so does the environment. Sometimes the word is used to mean taxes, expenses and other financial burdens which farmers must contend with.

In practice, farmers, like any other homo sapiens sapiens, organise their daily lives by continuously revising their semantic values. Ideas are constantly being rearranged into new patterns of association. Garfinkel and the ethnomethodologists refer to this process as the redefinition of vocabulary [18]. Such redefinition is clearly governed by "social representation". Again according to the ethnomethodologists, social representation is a form of ethnoknowledge, that is to say a reduction of reality to common forms used by the individuals within a given social group [18]. Consequently, any relationship between two different types of ethnoknowledge – such as that of nuclear experts and that of the farming population – constitutes a dialogue between the two different common forms to which reality has been reduced. Such a relationship presupposes a negotiation between sender and receiver over the infinite number of discourses (logos) possible. It is therefore the quality of this negotiation which will ultimately determine whether different social groups communicate either fully or partially. And in order to "negotiate", we must listen to what the receiver is saying, understand his conceptual system and, as far as possible, take account of his expectations, complaints and queries with regard to the message we are communicating.

The fact that farmers and their families do not ask the same questions as we do with regard to the reality of nuclear technology should not be seen as a barrier to communication. In my opinion, issues regarding the response of human societies to nuclear technology can be dealt with just as "scientifically" as questions regarding the safety or operation of nuclear facilities. It is for this reason that I would advocate carrying out the basic research needed to provide a platform for a genuine social anthropology of nuclear energy. Besides the obvious gains in terms of our knowledge of the impact of nuclear technology on society, such research would also help us to improve the quality of our communication with the population. This has already been shown by the results of the assessment of the leaflet which we drew up to inform the farming population in Belgium of the risks associated with the use of nuclear power [14]. We divided this leaflet into two sections. The first dealt with the problems posed to society by the use of nuclear power, the second with measures to counter such risks in the agricultural sector in the event of a radiological emergency. The first section responded to the concerns of 80 per cent of the target audience, compared with merely 40 per cent with regard to the second section. It is because of this first section, however, that the second was read and not thrown away; and it is because there was a negotiation with the farming population that the leaflet was published in the first place.

In conclusion, if we wish to communicate with the farming population in the event of a nuclear emergency, I think that we must:

- draw up message scenarios that have been properly tailored to this population before such a situation arises; which means that we must
- improve our understanding of communication systems involving groups of experts and the farming population;

- carry out studies on the representation of nuclear technology among the farming population;
- diversify the content of our messages in order to satisfy the expectations of both the sender and the receiver;
- assess the impact of our messages on the farming population.

REFERENCES

1. De Rosnay, J., Le macroscope. *Vers une vision globale*, Paris, Seuil, 1975.
2. Gaffiot, F., *Dictionnaire abrégé Latin-Français*, Paris, Hachette, 1936.
3. Galtung, J. & Ruge, M.H., *The structure of foreign news*, Journal of Peace Research 2, 1965.
4. Jacquard, A., *Inventer l'homme*, Brussels, Ed. Complexe, 1991.
5. Katz, E. & Lazarsfeld, P.F., *Personal influence*, Glencoe, 1954.
6. Lewin, K., *Channels of group life*, Human Relations 1, 1947.
7. Schramm, W., The process and effects of mass communication, Urbana, 1954.
8. Shannon, C. & Weaver, W., *The mathematical theory of communication*, Urbana, 1949.
9. Thoveron, G., *Sociologie des moyens de communication*, Université Libre de Bruxelles, 1988.
10. Van Nuffelen, D. & Balieu, M., Informer : un temps de réflexion, Information du corps médical et rayonnements ionisants, Paris, NEA, 1993.
11. Van Nuffelen, D., *L'agriculteur et le nucléaire*. Etude de sociologie compréhensive, Brussels, CSH, 1993.
12. Van Nuffelen, D., *La communication en question : le point de vue du sociologue*, Interaction sciences humaines et radioprotection, Brussels, ABR 18-3, 1993.
13. Van Nuffelen, D., *Anthropologie et information nucléaire*, Les politiques d'information des organismses de réglementation nucléaire, Paris, NEA, 1994.
14. Van Nuffelen, D., L'avant-projet de brochure "Risque nucléaire et agriculture" : un concept nouveau de l'information nucléaire, Radioécologie et agriculture, Bruxelles, ABR (forthcoming).
15. Watzlawick, P; Helmick Beavin, J; Jackson, D.D., *Pragmatics of human communication*, New York, 1967.
16. White, D.M., The gatekeepers: a case study in the selection of news, Journalism Quarterly 27, 1950.
17. Wiener, N., *Cybernetics*, Paris, 1948.
18. Garfinkel, H., *Studies in ethnomethodology*, New Jersey, Practice Hall, 1967.
19. Berer, P. & Luckmann, T., *La construction sociale de la réalité*, Paris, Méridiens Klincksieck, 1986.
20. Von Bertalanffy, L., *General system theory*. A critical review, General Systems Yearbook 7, 1962.

EXCHANGE OF INFORMATION ON AGRICULTURAL ISSUES IN A RADIOLOGICAL EMERGENCY SITUATION

by

Aino Rantavaara
Finland

Introduction

In a nuclear emergency situation, most sectors of industry and economic life are in some way involved in exchange of information with nuclear and radiation protection experts. The more developed the structure of a national policy in radiation situations is, the more efficiently can different protective actions be carried out, assuming that all groups involved in intervention are trained in advance. Agricultural industry as a whole can in a relevant way be integrated in emergency preparedness plans.

The content of information needed and distributed varies in different phases of a radiological emergency. The phases are often given as follows: the period of threat, an acute, intermediate and late phase of an emergency. Acute phase is lasting until the radioactive releases have stopped and the fallout received. The length of the intermediate phase may vary between weeks and months. The late phase in this context lasts until the active measures to reduce radiation exposure have been cancelled. A continuos process of information exchange starts immediately when the threat of a nuclear accident or radiological emergency appears. It continues until even the follow-up analyses after the late phase have been completed. The goal of versatile cooperation and communication is to carry out optimized measures for preventing or reducing health risks of radiation, considering also social and economic values.

The main tasks of nuclear/radiation protection experts are analysis and prognosis of the radiation situation, preparation of proposals for countermeasures and giving information to the authorities, to the public and the economic life. To quantify the effects of radioactive fallout on agriculture and food market, reliable data on contamination, based either on predictive models or surveillance measurements or both are needed. The more consequence-related the information is the more other than nuclear experts are needed to prepare it. If radioactive contamination of foodstuffs is obvious in a large scale, agricultural industry and other sectors of food supply should be integrated in planning and execution of dose reducing actions.

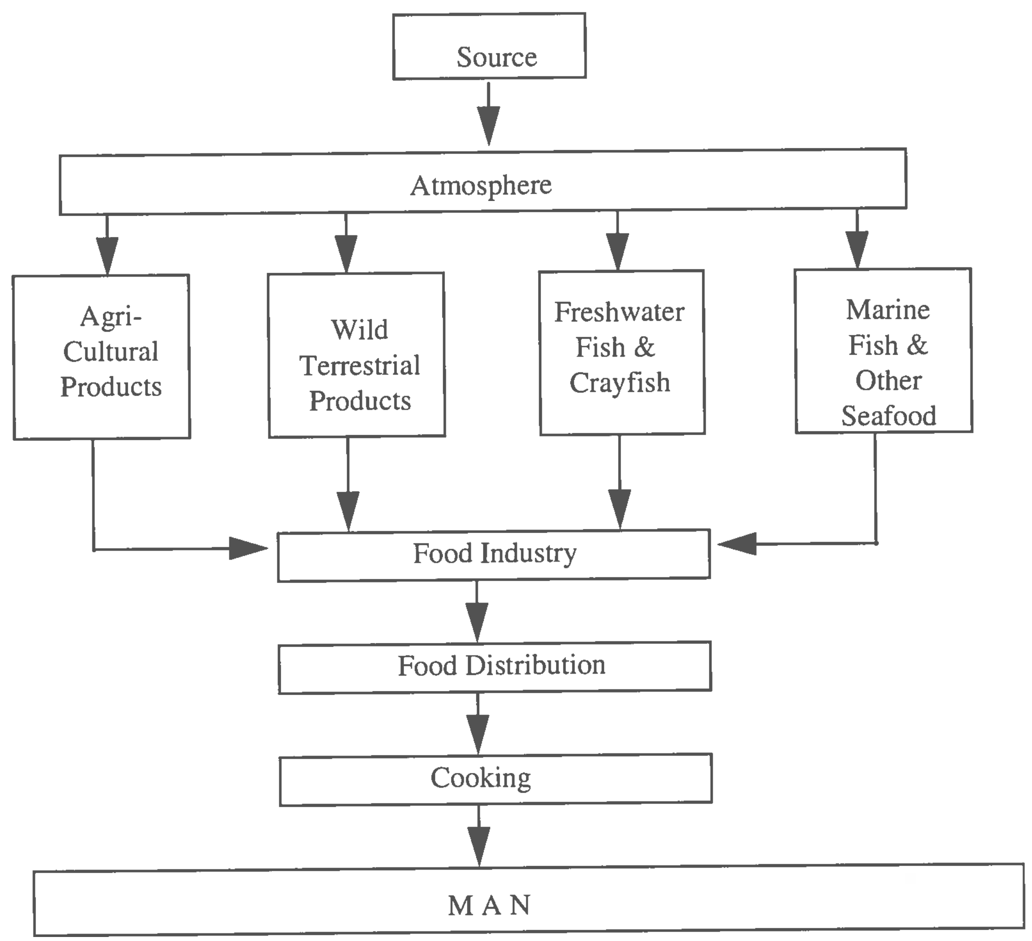
Agricultural industry and phases of radiation situation

Agricultural branch and the food branch as a whole need as early as possible consultation with radiation experts and information addressed especially to them. In addition to the general view of the radiation situation the questions to be answered are: What does this mean? How long does this last? Do the risks increase with time? What can be done? These are actually questions of all sectors of society and especially questions of an individual [3].

During the threat of a nuclear accident mostly the instructions for immediate action given in emergency plans are applied. Protection of the public during the cloud passage is the first issue. Avoiding contamination of domestic animals, milk and beef by keeping the cattle indoors are some of the first measures in agriculture. In an acute phase of an accident, *i.e.* until the releases have stopped, the analysis of situation is very intensive. Consequences to food production are of primary importance together with sheltering of people.

The intermediate phase, lasting weeks or months, includes implementation of both short-term and long-term countermeasures. Their content, scale and duration is optimized. The importance of different pathways (Figure 1) of fallout radionuclides to food vary with season and weather conditions during deposition, and with radionuclide composition and activity level of fallout. After deposition in the middle of growth period the contamination of field crops and pastures is the greatest. Harvest times and hunting seasons may delay the contamination of some foodstuffs from a consumers point of view. The increase of, for instance, radiocaesium content in fish is gradual and varies with fish type and water system. Peak contents are reached in 1-2 years. Vegetables, milk and beef are the first foodstuffs to be considered after deposition in the growth period. Their contamination level is decades lower during indoor feeding with stored feeds than in summer.

Figure 1. Transfer of radionuclides from atmospheric fallout to man through ingestion



Carrying out surveillance of critical foodstuffs, based on a frequently updated analysis of situation, gives basis for intervention. In an early phase of an accident, urgent protective measures are also applied without prior surveillance, for example based on information of releases. In the late phase both analysis in advance and follow-up of the practical intervention improve essentially the results.

In the late phase the consequences of an accident are seen, efficiency of applied countermeasures is estimated, and received radiation doses assessed. The late phase is finished when all sectors of society return to normal life and active countermeasures have been cancelled.

Information to the public and its subgroups

During threat or the acute phase of an accident the need of general information is enormous. The risks to people's health and economic losses of different sectors of industry should be predicted as early as possible. An individual receives information from several sources at the same time [5] (Figure 2). Radio, TV and newspapers give both information of the situation in general and backgrounds to what has happened and what it means. The nature of different communication media is well understood. When TV is used for processing an acute issue, receivers of information easily identify themselves as participants in the programme. Panels, where people can call directly are suggested and used to assure for example the proper understanding of instructions in radiation situation. Reducing stress is also an important aspect of information. Processing of problems and their possible solutions should be facilitated, especially if people's normal life, their work and earnings are seriously disturbed due to the emergency [5].

Figure 2. Sources of information to the public in a nuclear emergency situation

To be credible the information must be true. Coordination is important in order to avoid inconsistency. Rather often even close colleagues from the same expert team use different formulations, and thus cause unnecessary confusion. The receiver of information should be considered first and last. Information must be reliable, consistent, understandable and timely [5]. Psychological and sociological expertise in preparation of messages would improve understanding and acceptance of information by the public.

In an emergency situation, members of the family, colleagues and friends are trusted and their influence is important. The attitudes adopted earlier will very probably influence people's behaviour. Instructions of the authorities may not be relied on if previous history has left negative attitudes in people's minds [3, 4].

Reports on other countries intervention policies different from the national policy cause concern among the public. Contacts between experts and discussions about reasons behind differences are important to avoid confusion. Harmonization of intervention criteria and explicit information about them is important to the credibility of the authorities.

Among deliverers of information are also some controversialists. Their privilege is to question the motives and competence of experts and authorities responsible for the management of radiation situation. Opponents are allowed to use their freedom of speech in open societies. The most pluralistic views also find audience but will not violate a soundly based work for protection of the people.

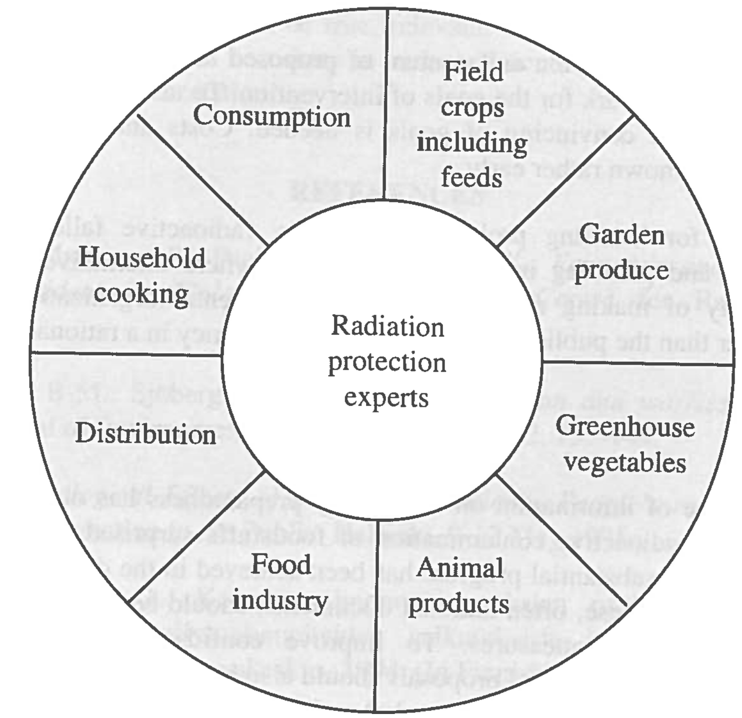
Exchange of information with food branch

Consultations between radiation experts and food industry are needed at all stages of the situation. Possible contamination of foodstuffs can be avoided or essentially reduced by properly timed countermeasures. They can be treatments of soil, protection or change of feeds, use of agents preventing the uptake of radionuclides by animals from the feeds, and treatment of foodstuffs by industry and/or by the households. Banning some types of food is necessary if no other measures are possible and activity levels are unacceptable. Considering the whole food branch related to agriculture (Figure 3) means exchange of information with farmers, commercial gardens, dairy and meat industry and food market. Consumers expect to have ready access to relevant information on the safety of food.

Best channels for giving instructions and advice to people responsible for different sectors of food branch should be found. Issues related to farming might well be communicated through networks of agricultural consultants, known to local farmers. When households are expected to change or modify their cooking and consumption practices, womens organizations promoting for example knowledge and capabilities of their members in household economy would be a possible group to be trained for giving advice. The practical questions are answered in everyday language by people who are familiar with these questions. TV is ideal for demonstration of practical instructions.

In northern Europe farmers are an independent, competent group of experts in their own business. In the process of intervention they should be given a part of a real expert. Information on aims and backgrounds of suggested countermeasures should be distributed through relevant channels to them. Probably the agricultural consultants should be better than representatives of authorities to motivate and instruct the farming society, having also resources for interpersonal communication. The compensation of economic losses is an issue to be clarified as early as possible.

Figure 3. Different branches of food supply receiving information from nuclear experts



Perception of risk

Problems of food contamination inevitably influence consumer attitudes. Even the most advanced plans for an efficient intervention for the safety of food may fail if the consumers don't trust on authorities and consequently not on the safety of food either.

After the Chernobyl nuclear accident, people refused some types of food on emotional grounds, although the radioactive contamination was well below a relevant intervention level. For many people the whole concept of contamination was alarming. In northern Europe the strict attitudes changed gradually when more was learned about different levels of contamination. Open, comprehensive information on radiocaesium contents in foods, the exposure to radiation, and future trends were frequently explained in information bulletins. However, a high number of phone calls was answered daily by radiation experts for example in Finland during several months after the spring 1986. The main issue was food. The numbers of calls increased in summer for many years. People's interest in food excluded the question of external radiation, which in fact was not negligible compared to the contamination of food.

The authorities should understand the thinking of the public and the feedback to earlier messages when information and instructions are prepared. At the end of the 1980s a major part of non-nuclear people in Sweden rated the risks from nuclear reactors very much greater than better known risks of everyday life [2]. Swedes also shared the concern about safety of food with many other nations. The concern was most pronounced among women and parents of small children in the most contaminated areas of the country. Same type of concern was found among Finns in a retrospective study from 1990 [1].

Farmers were a professional group most worried about the radiation situation after the Chernobyl accident in Sweden [2]. Their business for themselves was severely touched both by the actual contamination of environment and by the public concern about food.

Information, communication and content of proposed actions should also motivate people other than nuclear experts to work for the goals of intervention. To achieve this, not just information, but also understanding and convincing of goals is needed. Costs and compensation of them in different cases should be known rather early.

Preparedness for handling problems caused by radioactive fallout can essentially be improved by training and planning in advance. Exercises where alternative actions are analysed improve the capability of making right decisions. Governmental organizations and industry are probably trained better than the public to face a radiation emergency in a rational way.

Training

The acceptance of information on emergency preparedness has obviously increased since 1986, when wide-scale radioactive contamination of foodstuffs surprised many nuclear experts in Europe. In about ten years substantial progress has been achieved in the development of intervention policies. The main ideas in these, often national documents, should be clarified to those involved in the implementation of countermeasures. To improve confidence and cohesion in practical cooperation, the basic principles behind proposals should also be explained to the large audience. The young generation should be carefully considered. Another important group are elderly people whose education did not include anything about radiation. Popularized, yet accurate information should be available to all persons who are concerned about or interested in the radiation situation.

Training in advance would improve the results of carrying out practical methods of intervention in production, industrial processing, distribution, household cooking and consumption of foodstuffs. Knowing the means to handle the problems in practice will certainly also reduce the stress of people. Experts from nuclear and radiation protection institutions can analyse different food contamination problems together with representatives of farming society, industry etc. The readiness to face radiation situations and identify issues to be worked for will thus increase.

The intervention related to foodstuffs may be necessary or not. In both cases the aims of radiation protection would be better reached if representatives of different groups concerned have contacts with radiation experts for clarification of instructions.

Advisors who speak each groups own language are needed and they should be trained to understand both the mechanisms of contamination and the methods of intervention. They know how to communicate with different people. Also the people working for food market should be advised to answer the questions of their customers.

Conclusions

To achieve optimal results for protection of people in a radiation situation, information to the public and the exchange of information between different expert groups are key questions. To find and realize the best methods of intervention, efficient communication between expert groups is

necessary. All professional groups involved in the chain which take from soil to food table should be considered. In the best situation they are participants in the process of intervention.

Information to the public must be true, relevant, consistent and understandable. Although frequent releases of information are necessary in early and acute phases of an accident the quantity cannot replace the quality of information.

REFERENCES

1. Blomqvist L., Mustonen R., Paakkola O., Salminen K., *Economic and social aspects of the Chernobyl accident in Finland.* Helsinki: Finnish Centre for Radiation and Nuclear Safety, 1991.

2. Drottz-Sjöberg B-M., Sjöberg L., (1990) *Risk perception and worries after the Chernobyl accident*, Journal of Environmental Psychology, 10, No. 2, 135-149.

3. Eränen L, *Psychological Effects of Public Information – People's reactions in crises.* IAEA Workshop on Information to the Public, Helsinki, 9-12 May 1995.

4. Haukkala A, Eränen L. Katsaus ydinonnettomuuksien psykologisiin seurauksiin sekä empiirinen tutkimus säteilytoimenpiteiden vaikutuksista käyttäytymiseen kuvitteellisessa tilanteessa, Helsinki, Säteilyturvakeskus, 1994. (In Finnish).

5. Wiio O. A., *What we know about communication in a Crisis?* IAEA Workshop on Information to the Public, Helsinki, 9-12 May 1995.

SESSION V

NATIONAL PRESENTATIONS

Chairperson: George E. Bickerton, United States

CANADIAN NATIONAL PRESENTATION

by

Dianne E. Hedley
Canada

Slide 1

Federal Nuclear Emergency Response Plan Scope: covers the federal response to nuclear emergencies requiring federal action

In cases, in Canada, where there is a nuclear emergency that requires federal action there is a plan in place designed to ensure compatibility with Provincial plans and provides an interface between federal and provincial governments. The definition of a nuclear emergency is an emergency which involves the release of radionuclides, but does not include the hostile use of nuclear weapons against North America. This plan is the Federal Nuclear Emergency Response Plan.

Examples of a nuclear emergency requiring activation of the Plan include:

- an accident in the nuclear energy cycle in Canada with off-site implications;
- an accident in the nuclear energy cycle in another country which may effect Canada;
- nuclear powered devices impacting on Canada.

Slide 2

Effects of Radioactive Emissions on Agriculture direct exposure of agricultural crops from radioactive materials internal exposure of animals from inhalation of radioactive materials internal exposure from ingestion of food and water containing radioactive materials

Radioactive emission to the environment can effect agriculture in a number of ways:

- direct exposure to radiation from radioactive materials;
- internal exposure from inhalation of radioactive materials;
- internal exposure from ingestion of food and water containing radioactive materials.

Slide 3

Preparation and Co-ordination Lead Agency: Health Canada Federal Nuclear Emergency Response Plan Support Agency: Agriculture and Agri-Food Canada Food and Agriculture Emergency Response System

Health Canada is the designated lead federal agency to respond to nuclear emergencies, and as a result Health Canada is responsible for the preparation and the co-ordination of the federal response. If the plan is activated and the emergency has agriculture implications the lead support agency would be Agriculture and Agri-Food Canada, through the Food and Agriculture Emergency Response System (FAERS).

Slide 4

FOOD AND AGRICULTURE EMERGENCY RESPONSE SYSTEM

The activation of FAERS is done pursuant to the Emergencies Act

Slide 5

Assumptions
• emergency identified • use existing management processes • co-ordinate Centre activities

The response procedure assumes that:

- a real or potential emergency affecting the Agri-Food Sector has been identified;
- the various branches of the Department and provincial organisations will use existing management processes to respond to those emergencies falling above normal day-to-day programmes and operations;
- the FAERS Operations Co-ordination Centre will be activated.

Slide 6

Purpose
• mobilise federal, provincial and private sector resources combined effort to mitigate the effects of an emergency on the Agri-food Sector • ensure continuity and safety of Canada's food supply

The purpose of FAERS is:

- to mobilise the Agri-Food resources of the federal, provincial and private sector resources in a combined effort to mitigate the effects of an abnormal emergency affecting the Canadian Agri-food Sector;
- to ensure the adequacy, continuity and safety of Canada's food supply.

Slide 7

Scope
• for abnormal emergency situations, such as Nuclear Emergency no covered by Existing Operational Programmes

The scope of FAERS is to react to an emergency defined as an abnormal situation requiring prompt action, beyond normal operating procedures., in order to prevent injury or damage to people, plants, livestock or land. In general Canada's emergency response policy is based on the premise that initial responsibility rested with those directly affected, then moves through successive orders of government from municipal to provincial and lastly to the federal level. The federal government only becomes involved when requested or when the emergency.

Slide 8

How does it work
• 1 Central and 12 Regional Components – Federal, Provincial and Private Sector Resources
• flexible response starting at the Local (municipal) level and escalating to Provincial and Federal Levels delineates stakeholder responsibilities, predefined arrangements linking Federal, Provincial and Private Sector Resources all Agri-Food System resources mobilised under the Minister of Agriculture and Agri-Food Canada links resources through predefined arrangements builds on existing Agriculture and Agri-Food Canada programme such as: – Foreign Animal Diseases – Exotic Plant Pests – Agri-Food Safety – Crop Insurance – Soil and Water Conservation • Safety Net or Financial Assistance Programme

Organisationally, FAERS is made up of one Central and 12 Regional/provincial components, which are similar in organisation and structure and are capable of operating on either a centralised or decentralised basis depending on the severity of the emergency:

- links these resources together through a series of predefined arrangements;
- builds on existing programmes and structures within the Department such as the mandated programmes in Animal Health, Plant Protection and Agri-Food Safety.

Slide 9

Benefits
• provides co-ordinated emergency response by all stakeholders • efficient and effective use of resources for emergency response • meets the legislative requirements for emergency management in the Agri-Food Sector

There are three major benefits to the Food and Agriculture Emergency Response System:

- it provides a co-ordinated emergency response by all stakeholders;
- it makes more efficient and effective use of resources for emergency response;
- it meets legislative requirements for emergency management in the Agri-Food Sector.

Slide 10

Responsibilities

- provide control and regulation of agriculture production, agriculture and food processing, storage, allocation and distribution of food
- control and regulate
- help secure water to be used in agricultural production and food processing
- control or eradication of plant pests and foreign animal diseases
- protect, treat and handle animals or their by-products that have been exposed to or affected by hazardous agents
- use and handle plants, animals, land and Agri-food products that have been exposed to or affected by hazardous agents
- assure safety, wholesomeness and to minimise the loss from hazards of animals, animal products and agricultural commodities and their products, including food
- co-ordinate and manage response through liaison
- communicate information to all interested stakeholders
- assess and mitigate damage priorities

The responsibilities and functions of each component of FAERS, when activated are:

- providing for the control and regulation of agriculture production, agriculture and food processing, storage, allocation and distribution of food and agricultural products and to provide for domestic distribution of seed, feed, fertiliser, pesticides and farm equipment to agriculture producers;
- providing for the control and regulation of food and agriculture products to meet national and international responsibilities;
- help to provide the food processing and distribution sector with production and facility resources;
- controlling or eradicating plant pests, animal diseases or other hazardous agents affecting plant and animals or their parts;
- protecting, treating and handling animals or their by-products that have been exposed to or affected by hazardous agents;
- using, handling plants and animals, agricultural commodities and lands that have been exposed to or affected by hazardous agents;
- assuring the safety and wholesomeness and t minimise the loss from hazards of animals, animal products and agricultural commodities and products, including fish;
- communicating timely and accurate information to the Agri-Food Sector, to other departments, governments and the concerned public;
- co-ordinating with other Departments in the development and implementation of plans for such things as the designation of essential human resources, mass feeding of the population, allocation of energy to the Agri-Food sector, the transportation of food and agricultural products and the allocation of resources for the production of farm equipment and food processing and distribution equipment and facilities;
- assessing and determining loss and damage to resources or facilities of the Agri-Food Sector.

Slide 11

Mandated Emergency Plans

- if required – plans adapted to respond to nuclear emergencies affecting livestock, crops or Agri-food management in the Agri-Food Sector

These plans are:

Slide 12

Foreign Animal Disease Eradication Support Plan

- eradication of foreign animal disease outbreaks – authority under the Health of Animals Act and Regulations

a) Foreign Animal Disease Eradication Support Plan:
This plan deals with the eradication of foreign animal disease outbreaks as legislated by the Animal Health Act and Regulations. The organisation consists of a National Management Team located in Ottawa and Regional Outbreak Teams located in the area of the emergency. Most provinces have either a support plan or have signed a Memorandum of Understanding to support the federal plan, when implemented.

Slide 13

Plant Pest Emergency Response Programme

- control or eradication of non-indigenous plant pests of quarantine significance –authority under the Plant Protection Act and Regulations

b) Plant Pest Emergency Response Programme
This plan deals with ways to handle emergency situations that may arise in the area of agricultural or forestry crops, to prevent the spread of introduced non-indigenous plant pests of quarantine significance to Canada.
This programme outlines how day to day procedures under the authority of the Plant Protection Act and Regulations can be enhanced to deal with an emergency plant pest outbreak.

Slide 14

Agri-Food Safety Emergency Response Plan

- deals with emergency situations affecting Agri-food products – authority Canada Agricultural Products Standards Act

c) Agri-Food Safety Emergency Response Plan
This programme identifies the linkages between Agriculture and Agri-Food Canada, Health Canada, provincial counterparts and industry representatives and defines the internal branch response structures that would be implemented in the case of an emergency, such as a nuclear accident affecting Agri-Food Products.

Slide 15

Conclusions

- overall response – Health Canada Federal Nuclear Emergency Response Plan
- support role – Agriculture and Agri-Food Canada Food and Agriculture Emergency Response System

In conclusion, in the case of a nuclear emergency in Canada, Health Canada when requested would assume the lead role by activating the Nuclear Emergency Response Plan.

Slide 16

AN ALL-HAZARDS CO-ORDINATED APPROACH BASED ON EXISTING STRUCTURES AND RESOURCES

If the emergency affects the Agri-Food sector, Agriculture and Agri-Food Canada would activate the Food and Agriculture Emergency Response System which is an all hazards emergency management system designed to link the federal, provincial and private sectors to provide a co-ordinated approach to abnormal emergency situations.

The system is built on existing organisations, programmes and resources which may be augmented by additional emergency management plans and arrangements when emergency response requirements exceed current operational and programme capabilities.

PRECAUTIONS IN GERMANY FOR ACCIDENTS AND/OR INCIDENTS INVOLVING POTENTIAL DAMAGE TO PERSONS AND THE ENVIRONMENT FROM THE RELEASE OF RADIOACTIVITY

by

Dieter Kaspar
Germany

Prior to the Chernobyl accident, Germany had disaster control plans for the area immediately surrounding nuclear power stations, but no measures were planned for incidents below the threshold of what would be classed as a disaster. This led to a situation whereby, for example, in the case of recommendations not to drink fresh milk, threshold values of between 10 Bq/l and 560 Bq/l iodine 131 were used, which led to great uncertainty amongst the population at large. In addition to this, each individual federal state within Germany was able to issue its own recommendations.

In order to avoid such uncertainty in the future an "Act on the Precautionary Protection of the Population against Radiation Exposure" (Strahlenschutzvorsorgagesetz) has been passed. This contains precise regulations concerning the rights and duties of the federal states and central government. The Federal Government alone has the right to issue recommendations to the population at large as to their conduct. Only in the case of a restricted area of one region being affected by radioactivity can the individual federal states also issue recommendations and initiate measures.

The situation is different in the case of an accident in a nuclear power station with catastrophic effects on the immediate neighbourhood. Here the federal states are exclusively responsible for their area. But in order to achieve consistency of measures the federal states have reached agreement with the Federal Government on "Framework Recommendations for Disaster Control in the Neighbourhood of Nuclear Plants".

In both cases – precautionary measures and disaster control – what applies in Germany are the "Radiological Principles for Decisions on Measures for the Protection of the Population in the Case of Accidental Discharge of Radio Nuclides". A further basis is provided by the EC regulations on maximum values for contamination of foodstuffs and animal food.

The measures themselves and the threshold values for intervention contained in the radiological principles are largely based on ICRP 40. A range of values is laid down for each measure on the basis of upper and lower thresholds for action which are determined in such a way that in the case of radiation doses below the lower threshold the measures do not have to be taken. If the calculated or expected dose is above the upper threshold then the measure must be initiated in all cases.

Between the two thresholds there is some room for discretionary decisions to be made by those responsible depending on what is known about the type of accident and the sequence of events involved and other marginal conditions such as, for example, meteorological or road conditions.

Figure 1 shows a schematic representation of this manner of proceeding. Tables 1 to 3 show some examples of dose levels requiring the initiation of disaster protection measures.

For incidents below the threshold set, the same procedure basically applies. However, as in this case there is more time available, actual measured values can be used to a much greater extent when assessing the radiological situation and the doses to be expected can be determined from these. The measures to be taken are contained in a comprehensive catalogue of measures which was drawn up and published in the years following Chernobyl. This is at present undergoing revision.

This catalogue, for example, contains measures for the avoidance of contamination in the agricultural sector, or measures to prevent or at least reduce the transfer of nuclides in foodstuffs or animal foods. The catalogue is structured in such a way that, following a general introduction explaining how to use the catalogue, orientation diagrams have been included which lead from the information available, for example on the amount of radioactivity released, the local doses received or the soil contamination caused via nuclides representing groups or individual nuclides, to detailed tables and graphic illustrations of the measures to be taken. The catalogue only describes the feasibility of carrying out the measures and their effectiveness. No cost-benefit analysis is included. As this comprehensive catalogue – even after it has been revised – will still be difficult to use, it is planned in the long term to make it available in computerised form so as to allow easier access to the information it contains.

The use of computer programs as aids in coping with nuclear accidents is already widespread. In the case of disasters, the scope offered by on-line nuclear reactor remote monitoring systems should be used. Together with meteorological dab and measured emissions values, the concentrations of radioactive materials and therefore the dose received by the surrounding environment can be calculated. These systems are already being utilised by the federal states in Germany.

The Federal Government has set up an integrated measuring and information system for cases which fall short of the disaster threshold which uses, amongst other things, computer programmes to calculate contamination in Foodstuffs and animal foods in relation to many different parameters such as, for example, meteorological conditions, the time of year, the growth phase etc.

These calculations are complemented and enhanced by measurements taken and thus provide a reliable basis for the recommendation of measures This system is also used for conveying recommendations for the implementation of measures and instructions to the public on conduct.

However even the best computer, measurement and monitoring programmes are of little use if there is not experienced and well-trained personnel available in the control centres capable of properly using the results calculated. A computer can be an aid to decision-making, but it is people who have to actually make the decisions. The authorities responsible in Germany have made available sufficient quantities of hardware and software in order to make it possible to react swiftly and appropriately to accidents involving radioactive materials. Constant rehearsals ensure that in a real case the right decisions will really be made by well-trained personnel.

Figure 1. Schematic representation of the dosage scheme to be used in planning each individual measure

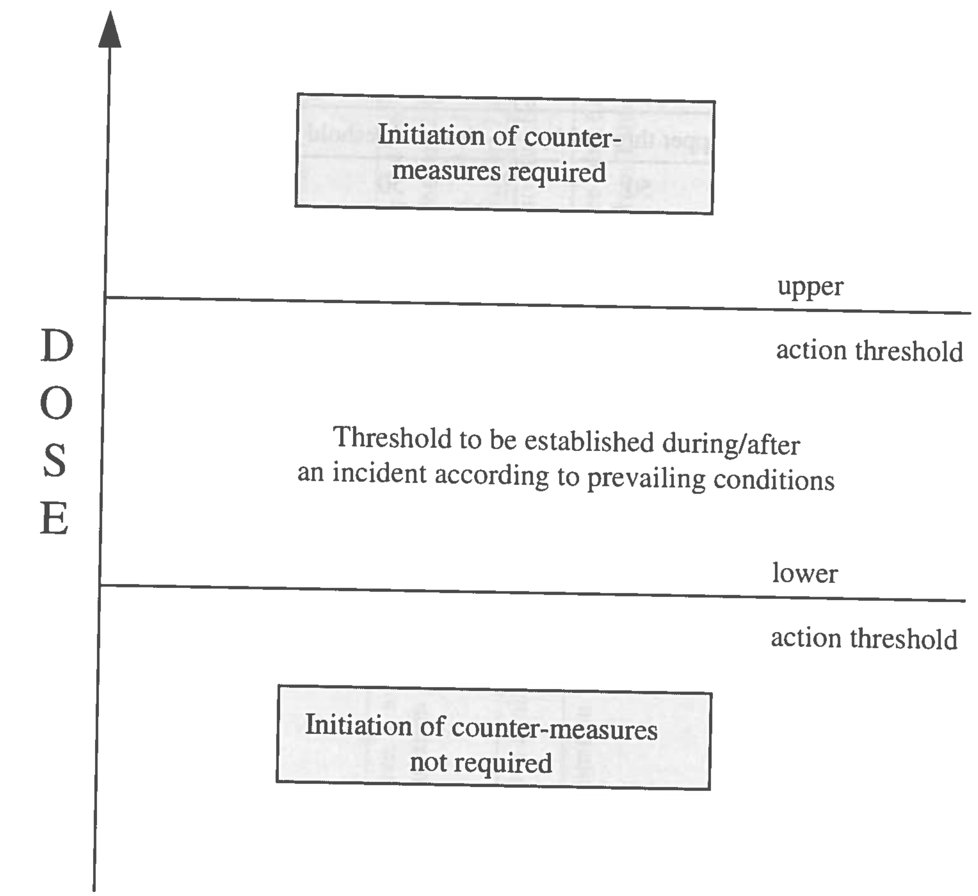


Table 1. Dose values for "stay indoors" "take iodine tablets" and "evacuation" as set by the "Framework Recommendations"*

Action	Dose in mSv					
	Whole body (external exposure and inhalation)		Thyroid (inhalation)		Lungs or any particularly exposed organs* (external exposure and inhalation)	
	lower threshold	upper threshold	lower threshold	upper threshold	lower threshold	upper threshold
Stay indoors	5	50	50	250	50	250
Take iodine tablets	–	–	200	1000	–	–
Evacuation	100	500	300	1500	300	1500

* excluding the skin

Table 2. Dose values for ceasing direct intake of foodstuffs

50 or 70 year dose in mSv based on activity in the first year			
effective dose		particularly exposed organs	
lower threshold	upper threshold	lower threshold	upper threshold
5	50	50	500

Table 3. Dose values for relocation of the population

Whole body dose in first year in mSv from ground level radiation	
lower threshold	upper threshold
50	250

Table 6.2.1 – 1 Measures which substantially or completely prevent contamination
Preventive measures prior to arrival of radiation (for notes see Section 11.1.1 (Park), 11.1.2 (SBG) in Annex)

Method	Feasibility limitations	Efficiency	Basis for decision EU maximum values for foodstuffs are reached with:	
Immediate harvesting of all mature crops (vegetables, fruit, grain, etc.) (before arrival of radiation)	Constraints: time required to harvest, limited harvesting machine capacity, labour and storage space	Avoidance of contamination	Expected air concentration over time	
			Dry storage	See table 6.2.1-1A (from Table 6.2.1 – 1)
			Additional data:	
Closure of greenhouses and early vegetable beds	Danger of overheating in intense sunlight	Extensive avoidance of contamination	Proportion dry/wet storage critical periods:	Ss. 7.4 – 6,7,8 (chapter 7.4) Ss. 7.4 – 3,4,5 (chapter 7.4)
Cover for vegetable, herbal and fruit crops	Only feasible for high value special crops over small	Extensive avoidance of	Expected ground contamination in kBqm,	
(during growing period)	areas; sheeting permeable to water must be rapidly available, high labour requirement	contamination	*Further additional data:*	See table 6.2.1. – 1B (from Table 6.2.1. – 1)
Cover for open fodder and foodstuff storage facilities	Sheeting or tarpaulins widely available, articularly for silos and transport vehicles	Extensive avoidance of surface contamination	critical periods:	Ss. 7.4 – 9,10,11 (chapter 7.4)

Tables 6.2.1 – 1A Threshold values according to PARK, airborne radiation
Threshold values for atmospheric radiation levels over time for dry storage
for atmospheric radiation levels for wet storage

Nuclide: I131

	Storage		Relevant
	wet	dry	Period
	Bq/m³	Bqh/m³	
Grain	75	2600	1.5 to harvest
Milk	7.3	340	1.4 to 1.11
Fruit	61	1830	15.4 to 15.10
Vegetables	87	3430	14.4 to 13.10
Green Vegetables	4	165	whole year

Nuclide: Cs 137

	Storage		Relevant
	wet	dry	Period
	Bq/m³	Bqh/m³	
Grain	5.7	720	1.5 to harvest
Milk	12	2600	1.4 to 1.11
Fruit	19	1390	15.4 to 15.10
Vegetables	17	2600	14.4 to 13.10
Green Vegetables	2.3	350	whole year

Nuclide: Sr 90

	Storage		Relevant
	wet	dry	Period
	Bq/m³	Bqh/m³	
Grain	13	2400	1.5 to harvest
Milk	1.7	540	1.4 to 1.11
Fruit	39	4260	15.4 to 15.10
Vegetables	33	8000	14.4 to 13.10
Green Vegetables	0.6	210	whole year

Note: The figures for atmospheric radiation levels over time for dry storage can be estimated from the estimated transit time and the atmospheric radiation levels.

RADIOLOGICAL PROTECTION OF THE AGRICULTURAL SECTOR, GENERAL APPROACH AND COUNTERMEASURES

by

Hans-Jörg Lehmann
Switzerland

Introduction

First of all, I should like to thank you for giving me this opportunity to present our approach to the protection of the agricultural sector against the consequences of a nuclear disaster. Although nobody can predict when such an event might occur, one thing that is known for certain is that agriculture will inevitably be affected by a nuclear or chemical accident or attack. While the authorities had long been aware of this fact, they did not realise its full significance until the accident at Chernobyl. It was then that they decided to take action and to develop countermeasures for use in the agricultural sector; these measures were subsequently put in place by the Federal Nuclear and Chemical Protection Committee in collaboration with the Federal Agriculture Department. In this presentation I shall endeavour to explain the approach we have adopted and to describe the countermeasures we have developed.

1. Our approach

Protecting agriculture against radioactive fallout requires action at several levels: on the one hand, steps must be taken to ensure that in the event of an accident the farming population takes the correct action, and on the other that the necessary resources are given to the bodies responsible for dealing with accidents, namely the fire brigade, the police and civil defence units. Political decision-makers must shoulder the responsibility which falls to them as leaders, and in this respect it is imperative that they keep the farming population properly informed of the situation.

Our aim is to provide farmers with appropriate information so that they can take the proper action in the event of a nuclear or chemical emergency. Our approach is therefore to:

1) provide the rural population, livestock, food, feedstuffs and agricultural workers with the highest degree of protection possible against nuclear and chemical fallout;

2) give farmers specific instructions so that they are able to take essential countermeasures without outside help;

3) equip agricultural buildings in advance with simple and lasting protective devices so as to reduce emergency countermeasures to a minimum.

2. Implementation

In Switzerland, agricultural training establishments and local civil defence organisations are responsible for the work needed to achieve these objectives. The former are primarily charged with raising farmers' awareness and providing them with basic education on the issue, whilst the role of the latter is to assist farmers' families with the implementation of countermeasures on farms.

The objective of the training programmes which have been developed in this area is to ensure that:

a) farmers are made aware of the threat that chemical and nuclear emergencies pose to agriculture and of the countermeasures which can be taken;

b) in the event of danger, farmers are able to protect their farms unassisted.

The "Instructions regarding nuclear and chemical countermeasures" comprise both the basic elements to be included in training programmes and a set of procedures to be followed in emergency situations. These procedures indicate the appropriate action to take according to circumstances. In addition, a special assessment grid is used to record the emergency resources available on farms and to determine the extent to which these resources should and could be improved for protection against higher levels of radioactivity.

At federal level, educational aids have been produced for agricultural teachers and advisers to assist them with what is, in fact, a difficult task. People's knowledge of radioactivity and possible countermeasures is generally very sketchy and most people think that a nuclear emergency could only arise in the event of war.

3. Instructions regarding nuclear and chemical countermeasures

In conclusion, allow me to present in detail the instructions regarding nuclear and chemical countermeasures referred to above.

These instructions are intended for farm managers. Our guiding principle is that the protection of people always takes priority over any other measure. On this basis, we have laid down procedures which managers must follow in specific circumstances. These procedures explain, for example, what farmers should do when the authorities order the population to:

- stay indoors;
- ake refuge in the cellar or nuclear shelter;
- stay in the nuclear shelter.

The instructions tell farm managers what to do to limit damage. Emergency measures should be taken immediately after the event. Then, when the irradition has been measured, the authorities will give further instructions via the media. Emergency procedures for such action have already been put in place.

4. Final remarks

Protecting the agricultural sector against the impact of nuclear and chemical emergencies is a complex task. For the moment, we are not in a position to estimate with accuracy the chances of success of our approach. We are convinced, however, that measures to raise farmers' awareness and improve their knowledge will enable the farming population to react to emergency situations in an appropriate manner.

SUMMARY OF SESSION V

by

George Bickerton
United States

The accident at Chernobyl appears to have been the catalyst that prompted many countries to take a critical look at their radiological emergency response plans in an effort to determine what areas needed to be improved or strengthened. A common theme among countries was the need to effectively train and educate the general population as well as emergency responders.

It was agreed that protecting the health and safety of the population potentially at risk, is of paramount importance. Once this has been addressed, protecting the food supply becomes a major goal.

Most countries that have two or more levels of government, (*e.g.*, national, provincial or state and local) are faced with the challenge of developing a plan or plans which clearly acknowledge(s) the roles and responsibilities of the various levels of government and the interactions that must occur between and among them if the emergency response is to be effective. Regular recurring exercises or rehearsals of the plans will enhance the probabilities that the appropriate decisions will be made by competent and well trained personnel.

The use of on-line computer programmes has proven to be an effective way of calculating contamination in food and animal feed after allowing for such variables as time of year, growth phase, and meteorological conditions. It is acknowledged that well trained personnel are essential if computerised programmes to project, monitor and assess contamination are to be effectively utilised.

The issue of threshold values for intervention has also been considered along with the need for harmonisation of the derived intervention levels among countries. Harmonisation can result in favourable economic consequences among countries involved in trade in addition to assuring consistent protection of the public at all levels of government.

Issues currently being studied include the relationship between ground contamination and milk concentrations and grass concentrations. Also, methods for disposing of milk contaminated with large concentrations of caesium. It is acknowledged that dairy herds and other domestic animals need to be cared for when people have been evacuated. Alternate means of effectively responding to this need are being considered by some of the countries.

Finally, the importance of public trust was introduced. Public perception may determine the effectiveness of the emergency response effort. If the public is comfortable with the actions that are taken and believes that the programme is being directed by competent officials who are truly interested in the personal well being of the individual citizens, then the effort has a much greater chance to succeed.

SESSION VI

CONCLUSIONS AND RECOMMENDATIONS

Chairperson: M. Carrette, France

CONCLUSIONS AND RECOMMENDATIONS

1. Introduction

The papers presented during the workshop were seen by the participants as being interesting and stimulating, and incited active discussions of the topics presented as well as of other associated, relevant topics. Based on these discussions, a restricted group of participants met after the close of Session IV to develop a series of proposed conclusions and recommendations which could then be presented to the full workshop, edited, modified, eliminated, and/or added to as appropriate, and then agreed to by the full workshop. The final session of the workshop was devoted to the discussion of these proposed conclusions and recommendations. The results of this final session are presented here, and represent the views of the workshop participants in this area.

2. Conclusions and recommendations

During the discussions in the first session, it became clear that there were differences between countries in the approach used to determine standards for the control of food contaminated with radionuclides as a result of a nuclear accident. In some cases, an action level at which food would be controlled is derived from a level of dose, taking account of food consumption rates and other assumptions about the fraction of the food that might be contaminated. In some cases, action levels are derived from optimisation studies. In others, action levels have been developed taking account of political and social factors and the need for consistency with other national or international recommendations. Whilst it was recognised by the workshop participants that control of food within a country was a national matter, it was felt that better understanding of these differences could help to avoid trade disruptions in the case of a future accident.

It was also noted that there was wide variation in import/export certification requirements among countries. While it was reported that the World Trade Organization had recently adopted the CODEX standards, these are not universally accepted, and here again, differences in certification requirements could lead to trade disruptions. As such, the following recommendation was made:

Recommendation

A better understanding is needed of the differences which still exist between various national and/or regional intervention levels for food, and maximum permitted levels for food, such as CODEX, for international trade, and the European Commission regulation for trade with the European Union.

Another area which was greatly discussed was that of the practical problems associated with the implementation of agricultural countermeasures; the central theme of the workshop. Numerous examples of specific problems were described. Workshop participants unanimously agreed that while these problems are national in nature and can be fairly country-specific, there are very few examples of workable solutions. As such, the international community is interested in any specific experience with such countermeasure implementation.

One such specific problem which was discussed was the question of what to do with agro-food products containing unacceptable levels of radionuclides, for example, milk contaminated with Cs. The potentially large volumes of such wastes, and the biological nature of such things as animal carcasses, pose difficult logistical problems. In that the radionuclide concentration at which waste must be treated as radioactive will have a large effect of the volumes of waste requiring radiologically controlled disposal, this question was also discussed.

Based on these types of issues, the workshop participants felt that the following recommendation would be appropriate:

Recommendation

After nine years of post-Chernobyl study of agricultural countermeasures, practical problems with their implementation still exist. Work should continue to address these issues. As an example, there is a need for further discussion of alternative methods for the treatment of agro-food products containing unacceptable levels of radioactivity.

Various aspects of public acceptance were also discussed during the workshop. Particularly, several of the papers in Session II focused on the social, political, and communicational aspects of emergency management. The workshop participants agreed that these were among the most difficult issues to treat, and that the trust of the public in their government and emergency management officials and experts was the key to acceptance, by the public, of decisions made for their protection. It was noted, however, that this trust is not always forthcoming. Such things as a general lack of knowledge by the public of the complex issues of emergency management, poor and/or uncoordinated communication with the public by government officials, media interest in sensationalizing stories, and anti-nuclear interest group attempts to exaggerate danger can erode public trust.

At the same time, it is clear that self-interest is a driving social force. This may lead to concern, by the various groups in the agro-food industry, over the potential loss of income which may be associated with a nuclear emergency. Farmers will be concerned about the care and feeding of their livestock, the care of their crops, and the status of their equipment, and may thus ignore recommendations to evacuate. Food distributors will be concerned about the image of their products in the eyes of the consumer, and may thus turn to suppliers from areas unaffected by the accident. The public, interested in their own health, may refuse to buy products containing any radionuclides, even if assured by the government that low radionuclide levels are safe. These factors will also play large roles in the acceptance of recommended countermeasures by these various groups.

Based on the discussions in these areas, the workshop participants agreed that the following conclusions would be appropriate:

Conclusions

- **Public acceptance of agro-food products which contain radionuclides at levels below internationally accepted values (Codex) is not predictable.**

- **The agricultural industry (farmers, processors, distributors, etc.) may not follow the advice of radiation protection experts following an accident.**
- **The agricultural industry may tend to follow the desires of the consumer and the forces of the market.**

The workshop participants noted that these issues are largely based on the effectiveness of communications, both before, during, and after nuclear emergencies. It was also noted that improving basic education in radiation, radiation effects and risks, and nuclear power in general is one of the most effective ways of facilitating effective communications such that all parties in the dialogue have a similar understanding of the facts. In this regard, education of the young, starting as early as possible, was seen as very important. With these ideas in mind, the workshop participants agreed upon the following conclusions:

Conclusions

- **Communications and public relations will play an important role in situations involving agro-food product restrictions, and will help the public to better understand and accept any implemented countermeasures.**
- **Public information and education, particularly for the young, play an important role in communication.**

In this same context, communications with the public was discussed. Here it was stressed that emergency management and government decision-makers must establish two-way communications with the public, and must listen to the public's concerns. Understanding the nature of this communication can be a very complex issue, and to establish and maintain communications requires not only understanding the mechanisms of communication, but requires a detailed understanding, and perhaps reevaluation, of the message which is being passed. Based on this and on the above-listed conclusions, the workshop participants felt that the following recommendation was important:

Recommendation

The social and cultural aspects of communications play an extremely important role in providing information to agricultural populations, before, during and after nuclear emergencies. Further study is needed in this area.

Another area which was addressed in the workshop was the nature of nuclear power reactor accidents. Specifically, it was noted that many accident scenarios result in the release of radionuclides without the need for sheltering, evacuation, or the use of stable iodine. Nonetheless, such scenarios may well result in the need to impose food restrictions. While still unlikely, such scenarios are in fact more likely than those resulting in major releases with evacuations, and are thus also worthy of the attention of those involved with emergency planning, preparedness and management. It was also noted that, for those scenarios which do involve major releases and evacuations, the area likely to be affected by the need for food restrictions will be many times larger than that requiring evacuations, again indicating that the inclusion of agro-food type countermeasures in planning and preparedness is very important.

Because of these types of considerations, it was noted that those agricultural countermeasures which could prevent the contamination of agro-food products, or lessen the extent of their contamination, would be more cost effective if applied early than late, and should thus be addressed at an early stage by emergency management personnel.

From these thoughts, the following conclusions and recommendation were agreed upon by the workshop participants:

Conclusions

- **Departures from normal operation at nuclear power plants, which would not generally be classified as major accidents, may necessitate the imposition of agro-food product restrictions even though other short-term countermeasures (sheltering, evacuation and/or the use of stable iodine) are not required.**

- **In any accident, the areas covered by agro-food product restrictions will be much greater than those covered by other countermeasures (sheltering, evacuation and/or the use of stable iodine).**

Recommendation

Emergency exercises should take full account of agricultural aspects, and therefore, exercise programmes should cover the late phases of accident as well as a wide range of accident scenarios.

Recommendation

Preventive agricultural countermeasures should be considered for implementation as early as possible to avoid the necessity for costly late actions.

Another area which was addressed during the workshop was that of lingering latent problems which might lead to exposures; specifically, contaminated forests. It was noted that a large fraction of the lands contaminated after the Chernobyl accident were in fact forests, and that the management of these forests had been somewhat ignored. Semi-natural ecosystems, in general, tend to retain deposited radionuclides for long periods. As such, forest fires could result in the recontamination of adjacent, previously decontaminated areas and this should be avoided by appropriate forest management. In that the chopping down of contaminated trees leads to doses to forest workers and to wood processing personnel (transportation, paper making, etc.), such "occupational" exposures should be considered when optimising countermeasures.

In the case of fisheries, consideration should be given to the potential long-term uptake of radionuclides by fish as a result of release of radionuclides from contaminated sediments.

With these thoughts in mind, the workshop participants felt that a recommendation was necessary in this area:

Recommendation

In devising agricultural countermeasures, due consideration should be given to the management of contaminated semi-natural environments, especially forests and freshwater ecosystems, and their effects on agriculture.

Finally, based on the presentations of national programmes in the area of agricultural countermeasures, it was noted that the inclusion of non-governmental agricultural groups in planning, preparation, and management activities was not only essential, but desired by such groups. These groups include the farmer, professional agricultural associations, agricultural unions, and agro-food product processors and distributors. Considering this, and the previous conclusions and recommendations regarding communications, the workshop participants felt that the following conclusions were appropriate:

Conclusions

- **Some of the stake-holders in the agro-food system should be more involved in the nuclear emergency preparedness and management process.**

- **The inclusion of all stake-holders from the agro-food system (farmers, processors, distributors, government agricultural officials, veterinarians, etc.) in the preparation of emergency programmes, and in subsequent training programmes and in emergency exercises, is very important.**

LIST OF PARTICIPANTS

Republic of BELARUS

Prof. Alexandre LUTZKO
Director
Sakharov Institute of Radioecology
23 Dolgobrodshaya
220 009 Minsk
Tel: +375 (172) 306 888
Fax: +375 (172) 306 897

BELGIUM

Mr. Dominique VAN NUFFELEN
Chercheur en Anthropologie Nucléaire
Service de Protection contre
les Radiations Ionisantes (SPRI)
Cité Administrative de l'Etat
Quartier Vésale
B-1010 Bruxelles
Tel: +32 (2) 210 49 55
Fax: +32 (2) 210 49 67

Dr. Christian VANDECASTEELE
Head, Radioecology Laboratory
CEN/SCK
Boeretang, 200
B-2400 Mol
Tel: +32 (14) 33 52 81
Fax: +32 (14) 32 03 72

Mr. Olivier BURTON
Faculté des Sciences Agronomiques
de Gembloux
Groupe de Radioecologie
8, Avenue de la Faculté
B-5030 Gembloux
Tel: +32 (81) 62 24 95
Fax: +32 (81) 61 45 44

CANADA

Ms. Dianne E. HEDLEY
Plant Protection Division
Agriculture and Agri-Food Canada
59 Camelot Dr.
Nepean Ontario
K1A OY9
Tel: +1 (613) 952 8000
Fax: +1 (613) 943 2482
x400 c=ca; a=govmt.canada
p=gc+agr; o=w;g=Dianne;s=Hedley

Republic of ESTONIA

Mrs. Elle TANNER
Head of Department
Estonia National Veterinary Laboratory
3V. – Paala Str.
EE-0014 Tallinn
Tel: +37 (2) 109 90
Fax: +37 (2) 638 00 10

FINLAND

Ms. Aino RANTAVAARA
Head of Foodchain Laboratory
Finnish Centre for Radiation
and Nuclear Safety
P.O. Box 14
F-00881 Helsinki
Tel: +358 (0) 7598 8436
Fax: +358 (0) 7598 8498
e-mail: aino.rantavaara@stuk.fi

FRANCE

M. Lovis CAYEUX
Féderation nationale des syndicats d'exploitants agricoles (FNSEA)
11, rue de la Baume
F-75008 Paris
Tel: +33 (1) 4563 1177
Fax: +33 (1) 4563 9125

M. Henri MAUBERT
IPSN/DPEI/SERE/LMTR
CE/Cadarache
Bâtiment 153
F-13108 Saint-Paul-lez-Durance Cedex
Tel: +33 (16) 4225 3543
Fax: +33 (16) 4225 6373

M. Jean BRENOT
IPSN/DPHD/SEGR
60-64, avenue de la Division Leclerc
Bât. 01
F-92265 Fontenay-aux-Roses Cedex
Tel: +33 (1) 4654 8159
Fax: +33 (1) 4654 8829

M. PICAT
CEN Cadarache
IPSN/DPEI/SERE
BP 1
F-13108 Saint-Paul-Lez-Durance CEDEX
Tel: +33 (1) 4225 3341
Fax: +33 (1) 4225 4948

M. GERBALDI

M. BARRIÈRE

Mlle BERTHIER
IPSN/Ecole Nationale d'Agriculture

M. Pupin
IPSN/Ecole Nationale d'Agriculture

GERMANY

Mr. Dicter KASPAR
Umweltministerium
Baden-Württemberg
Postfach 103439
D-70029 Stuttgart
Tel: +49 (711) 126 2531
Fax: +49 (711) 126 2885
e-mail: um52kas@umscl1.lfu-bw.de

Ms. Sabine BITTNER
Federal Ministry for the Environment
Nature Conservation & Nuclear Safety
Referat RS II (3CN)
Hüsareustr. 30
D-53 117 Bonn
Tel: +49 (228) 305 2920
Fax: +49 (228) 305 2828

Republic of LATVIA

Dr. Uldis PORIS
Senior Adviser
Civil Defence Centre
6 Kalpaka Boulevard
LV-Rïga 1050
Tel: +371 222 8683
Fax: +371 8 820 336

LITHUANIA

Mr. Vincas VIGRAITIS
Chief Agronomist
Ministry of Agriculture of Lithuania
Gedimino Ave. 19
2025 Vilnius
Tel: +3702 61 95 15
Fax: +3702 22 44 40

SWEDEN

Mr. Jan PREUTHUN
Swedish Board of Agriculture
S-551 82 Jönköping
Tel: +46 (36) 155 951
Fax: +46 (36) 166 250

Dr. Inger ANDERSSON
Research Officer
Swedish University of Agricultural Sciences
Department of Agricultural Biosystems & Technology
POB 59
S-23053 Alnarp
Tel: +46 (0) 40 41 50 00
or 41 52 18
Fax: +46 (0) 40 41 09 20
e-mail: inger.andersson@jbt.slu.se

Mrs. Agneta BRASCH
Head of Division
Swedish Board of Agriculture
S-55182 Jönkoping
Tel: +46 (36) 15 58 15
Fax: +46 (36) 30 81 82

SWITZERLAND

Dr. Andrea SCHENKER
National Emergency Operations Centre (NAZ)
Postfach
Ackermannstrasse 26
CH-8044 Zürich
Tel: +41 (1) 256 9435
Fax: +41 (1) 256 9497

Dr. Dominique RAUBER
National Emergency Operations Centre (NAZ)
Ackermannstrasse 26
CH-8044 Zürich
Tel: +41 (1) 256 9487
Fax: +41 (1) 256 9497
e-mail: ra@naz.ch

Ms. Marina VISANI
National Emergency Operations Centre (NAZ)
Ackermannstrasse 26
CH-8044 Zürich
Tel: +41 (1) 256 9289
Fax: +41 (1) 256 9497

UKRAINE

Mr. Boris PRISTER
Director
Ukrainian Institute of Agricultural Radiology
7, Mashinostroitelci St.
Chabany, 255205
Kiev region
Tel: +7 (044) 266 45 02
Fax: +7 (044) 266 71 75

UNITED KINGDOM

Ms. Frances FRY
Assistant Director
National Radiological Protection Board
NRPB
Chilton, Didcot
Oxfordshire OX11 ORQ
Tel: +44 (1235) 822 618
Fax: +44 (1235) 822 630
e-mail: 643-5950@MC1MAIL.COM

Dr. G.P.L. NAYLOR
Nuclear Site Inspector
Food Safety (Radiation) Unit
Ministry of Agriculture Fisheries & Food
MAFF
Nobel House
17 Smith Square
London SW1P 3JR
Tel: +44 (171) 238 5965
Fax: +44 (171) 238 6591

UNITED STATES

Mr. George BICKERTON
Director, Emergency Planning Office
Food Safety and Inspection Service, PEPS
U.S. Department of Agriculture
218 West End Court
Washington, D.C. 2050-3700
Tel: +1 (202) 254 2500
Fax: +1 (202) 254 2485

FAO/IAEA

Mr. John Irwyn RICHARDS
Head,
Agriculture & Biotechnology Laboratory
International Atomic Energy Agency and
Food and Agriculture Organization
of the United Nations
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna
Tel: +43 (2254) 7225 1267
Fax: +43 (2254) 7895 1222
e-mail: richards@rial1.iaea.or.at

CEC

Mr. A. JANSSENS
CEC DG XI. C.1
Plateau du Kirchberg
Bât. Wagner C-353
L-2920 Luxembourg
Tel: +352 4301 363 95
Fax: +352 4301 362 80

IPSN/CEA

Mr. Denys ROUSSEAU
Assistant, Institut de Protection
et Sûreté Nucléaire
CEN/FAR – B.P. No 6
60-64, Ave de la Division Leclerc
F-92265 Fontenay-aux-Roses Cedex
Tel: +33 (1) 4654 7758
Fax: +33 (1) 4654 4553

OECD/NEA

Dr. Ted LAZO
Radiation Protection and
Waste Management Division
OECD Nuclear Energy Agency
Le Seine St-Germain
12, boulevard des Îles
F-92130 Issy-les-Moulineaux
Tel: +33 (1) 45 24 10 45
Fax: +33 (1) 45 24 11 10
e-mail: lazo@nea.fr