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The Implementation of Short-term Countermeasures After a Nuclear Accident

(Stable Iodine, Sheltering and Evacuation)

Proceedings of an NEA Workshop
Stockholm, Sweden, 1-3 June 1994

NUCLEAR ENERGY AGENCY

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Proceedings of an NEA Workshop
organised by the OECD Nuclear Energy Agency
and hosted by the Swedish Radiation Protection Institute

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PUBLISHER'S NOTE
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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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— 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;
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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 European Member countries of OECD as well as Australia, Canada, Japan, Republic of Korea, Mexico and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of 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, 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.

FOREWORD

For many years, particularly since the accident at Chernobyl in 1986, the NEA Committee on Radiation Protection and Public Health (CRPPH) has been involved in promoting international co-operation in the areas of nuclear emergency planning and preparedness, and emergency management. Part of the CRPPH programme in this area is devoted to the organisation of international nuclear emergency exercises INEX 1, the first such exercise, was conducted in 1993. Based on the results of this table-top exercise, several follow-up actions were recommended. One of these was the organisation of a workshop to discuss the practical problems associated with the implementation of short-term countermeasures, specifically sheltering, distribution of stable iodine and evacuation. This workshop organised by the NEA and hosted by the Swedish Radiation Protection Institute (SSI), took place in Stockholm, Sweden, in June 1994. These proceedings contain the papers presented at the workshop and a summary of the conclusions and recommendations which emerged from discussions.

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

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INTRODUCTORY REMARKS

by

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Since the accidents at Three Mile Island in 1979, and more especially Chernobyl in 1986, many countries have intensified their efforts in emergency planning and preparedness for nuclear accidents. As a result of this interest by its member countries, the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD) has been actively involved in this area for some time.

As part of the work in this area, the NEA's Committee for Radiation Protection and Public Health (CRPPH) agreed in 1990 to launch a programme of work in the field of off-site emergency exercises. The Committee defined two broad objectives for the programme,

1. to contribute to the identification of those aspects of off-site emergency response which involve neighbouring countries and international organizations and which would benefit from improved international co-operation and co-ordination; and,

2. to contribute to increased understanding between participating countries regarding national approaches to the response to nuclear emergencies.

Part of this programme was devoted to the organisation of international nuclear emergency exercises. The first of these exercise, called INEX 1, was conducted in 1993 and comprised two stages. The first stage was a national Tabletop exercise, which was carried out during the months of March - May. A total of 16 countries, 14 NEA Member countries and 2 non-NEA Member countries, participated. The Tabletop 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, to analyze and discuss the results of the Tabletop exercise. Representatives of each participating country attended in order to share experience from the exercise and to discuss possible follow up work in the area of emergency response and exercises.

The participating countries concluded that INEX 1 had been a very useful and instructive undertaking. The Exercise was particularly beneficial in helping the participants to test the content and efficiency of their emergency plans, and to identify weak points and aspects requiring improvement. The Exercise also provided useful experience for the improvement of criteria and methods for the organisation and execution of emergency exercises at the national and international level.

Based in the preliminary review of the results of INEX 1, and on proposals made by participating countries, the CRPPH at its meeting in September 1993 established a follow-up programme of work for the following years. The CRPPH Expert Group on Emergency Matters was assigned the task of implementing this programme. One component of this work, a direct outgrowth of recommendations from INEX 1, was the organisation of a workshop on technical, organizational, economic and social aspects related to short term countermeasures, particularly stable iodine distribution to, and sheltering and/or evacuation of populations in emergency situations.

The Expert Group concluded that in relation to sheltering, evacuation, and stable iodine distribution many practical and operational problems exist. Although in theory these are relatively straightforward countermeasures, there exist in practice a number of problems related to the sheltering of various population groups (tourists and campers for example), the organizational aspects of large-scale population evacuations, the risks of stable iodine administration to various age groups versus the risk of radioactive iodine, the mechanisms which could be used to distribute iodine to large population groups, etc. Finally, many questions were raised as to the economic and social consequences of those countermeasures.

The main purpose of the Workshop was thus to address these practical issues, and to share experience on and review various technical, organizational, economic and social aspects associated with short term countermeasures, in particular sheltering and/or evacuation of, and stable iodine distribution to, populations in a nuclear emergency.

The specific objectives of the Workshop were:

1. To review criteria on short term countermeasures as established by international organizations;

2. To discuss the effectiveness and costs of, and risks associated with, the implementation of short term countermeasures in view of the experience gained from the Chernobyl accident as well as from other accidents and incidents;

3. To share information on national policies, practices, practical experience, and recent developments (e.g. research) in relation to stable iodine, sheltering, and evacuation;

4. To discuss factors influencing the choice of strategy for implementing the countermeasures; and

5. To develop conclusions and recommendations based on the workshop papers and discussions.

The Workshop was hosted by the Swedish Radiation Protection Institute, and was held in Stockholm, Sweden, 1 to 3 June 1994. Dr. J. O. Snihs acted as Chairman. The Programme for the Workshop, provided in its entirety as Annex 1, included five sessions as follows:

Session 1:	Criteria, Practice and Medical Aspects
Session 2:	Effectiveness and Risk of Countermeasures
Session 3:	Selection of Strategies
Session 4:	Implementation of Strategies and National Practices
Session 5:	Conclusions and Recommendations

The Programme Committee for the Workshop was Chaired by Mr. C. Viktorsson, Swedish Radiation Protection Institute (SSI), and included the as members Ms. R. Hänninen, Finnish Center for Radiation and Nuclear Safety (STUK), Finland; Ms. R. Hogan, Nuclear Regulatory Commission (NRC), United States; Dr. G. N. Kelly, Commission of the European Communities (CEC), D.G. XII, Brussels; Mr. I. Todd, Health and Safety Executive (HSE), United Kingdom; Mr. B. Weiss, International Atomic Energy Agency (IAEA), Vienna, Austria; and Dr. T. Lazo, NEA Secretariat.

Session 1

CRITERIA, PRACTICE AND MEDICAL ASPECTS

Co-chairman: Jan Olof Snihs, Sweden
Rapporteur: Peter Waight, Canada

WHO GUIDELINES ON THE USE OF STABLE IODINE AFTER NUCLEAR ACCIDENTS

by

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Abstract

The radioactive isotopes of iodine will form an early and important public health hazard following any accident to an operating nuclear power station. The sequelae of the Chernobyl accident strongly suggest that children are particularly at risk. Stable iodine, taken in appropriate amounts, can be used to block effectively the further uptake of iodine by the thyroid, thus reducing exposure to the isotopes of iodine. The WHO has produced guidelines for the implementation of such iodine prophylaxis in the event of nuclear accidents. These guidelines are briefly introduced and possible future developments discussed. In particular it is noted that if the isotopes with iodine are as effective at inducing thyroid cancer as external radiation, presently adopted levels for the initiation of iodine prophylaxis may need to be reduced, especially for children.

Introduction

It was the Chernobyl accident in 1986 that stimulated the WHO to frame its present guidelines on the prophylactic application of stable iodine in the event of a nuclear accident involving the release of the isotopes of iodine although experience from earlier accidents, in particular the Windscale accident in the UK in 1957, had much earlier stimulated the consideration of this problem. In any accident to an operating nuclear reactor which involves a release to the environment of fission products the isotopes of iodine will be a prominent, if transitory, cause of radiation exposure. Initially, exposure will be by inhalation of the radioactive cloud, to be followed, particularly if rainfall occurred at the time of the passage of the cloud, by ingestion as the radioactive iodine enters the food chain. The affinity of iodine for the thyroid gland and the extent to which it is concentrated by the small gland results in very high doses to the thyroid. A comparison, in table 1, of doses to populations close to the Chernobyl accident (IAEA 1991) reveals the extent of this problem and shows that thyroid doses were typically some 20 to 50 times those to the whole body, over the four years after the accident.

Table 1. **Comparison of doses to the whole body from external exposure and internal contributions from the isotopes of Cs and Sr with those to the thyroid from the isotopes of iodine (IAEA)**

	Whole body doses between 1986 and 1989			Thyroid doses	Ratio
Settlement	External mGy	Interna l mGy	mGy	In Children mGy	Thyroid/ Whole body
Bragin	26	24	50	1000	20
Korma	18	3	21	670	32
Veprin	32	7	39	1200	31
Narodichi	17	11	28	1300	46
Polessko	24	15	39	1900	49
Nozovebkov	16	5	21	640	30
Zlynka	26	10	36	1100	31

Even at much more remote distances from the accident, for example in the UK, the ratio of dose to the thyroid from iodine-131, to that from all other sources was still about 10 but at this distance ingestion was a much more important exposure route than inhalation (Baverstock 1986).

That the exposure to doses of the order experienced closer to Chernobyl leads to measurable health effects seems now to be indicated by the rise in

childhood thyroid cancer in the southern parts of Belarus (Kazakov et al 1992) and the northern Ukraine

An examination of these figures in the light of what is known about the sensitivity of the infant or child thyroid to radiation shows that the increases observed are consistent with the current knowledge of the effects of radiation on the thyroid (Baverstock 1994).

The infant thyroid is particularly at risk for two reasons, namely that for any given environmental exposure (radioactive iodine in the air or food chain), the dose to the infant thyroid is likely to be up to one order of magnitude greater than that to adults with the same exposure, because of the differences in mass of the infant thyroid (about 1.8g at six months) compared to that of the adult (about 20g). In addition the young thyroid is up to an order of magnitude more sensitive to the cancer inducing effects of radiation than the adult. (Shore 1992)

The thyroid is a complex organ responsible for the control of growth through the supply of hormones. Inorganic iodine, enters the body as a component of food and is rapidly transported to the blood stream from where the thyroid concentrates it. The extent of uptake may depend upon iodine status of the organ; in areas of iodine deficiency the gland is of greater size and uptake is more avid. Iodine is eliminated from the thyroid relatively slowly and for the case of all the radioactive isotopes of iodine except ^{129}I, which has a very long radioactive half life, the effective half-life of the isotope in the thyroid is dominated by radioactive decay with only marginal variations with age or previous iodine status.

With respect to iodine metabolism, the thyroid, under more-or-less steady conditions (100 ug/d) of iodine intake, adopts a steady state, responding to increased inorganic iodine by increasing the output of organic iodine. However, sudden and marked increases (more than 100 mg/day in the case of iodine prophylaxis) in iodine concentration in blood can cause an auto regulatory mechanism to be invoked which leads to the cessation of iodine conversion to organic states. This condition, known as Wolff-Chaikoff syndrome, temporarily suspends thyroid function and constitutes the main adverse effect of iodine prophylaxis.

However, the administration of relatively large quantities of stable iodine, either as iodide or iodate, orally can be used to rapidly, within a hour or so, block the uptake of further (radioactive) iodine by the thyroid for about 24 hours.

Iodine prophylaxis is thus effective, simple to administer but not entirely without a risk of adverse effects. It is against this background that the WHO has set its guidelines on the use of iodine prophylaxis.

Background to the WHO Guidelines

The WHO has adopted the concept of "near" and "far" field (WHO 1993, 1994) where actions to mitigate the effects of radiation exposure in the event of a nuclear accident are concerned. The near field extends to a few kilometres from the origin of the release and is a region in which external exposure from the radioactive cloud and inhalation of its contents may present significant health hazards to the general public. If the accident involves either, a prompt fission event, or a release from an operating nuclear reactor, the risk of exposure to isotopes of iodine is particularly important since the short lived isotopes, with half lives of a few hours to one or two days, will be present. In the near field there is therefore a need to be prepared to take very rapid action which may involve sheltering, evacuation and the distribution of iodine tablets.

In the far field the external and inhalation contributions to dose from the cloud are less important than the longer term problem of ingestion of radionuclides from the food chain. Consequently in the far field there is more time to consider appropriate actions.

A basic principle of the response to nuclear emergencies is that the risks incurred by mitigating actions should be less than the risks averted by taking them. The mitigation risks depend on a number of factors that may vary from circumstance to circumstance and so depend on local conditions. It is thus best to determine the mitigation policy for an accident in terms of the circumstances prevailing in each individual case. However, it is also advisable to have a plan of action to implement at the outset of an accident, even before the situation can be assessed in an individual case. Emergency Reference Levels (ERLs) are criteria for the implementation of mitigating measures in the very early stages of an accident. They are, at present, usually given as two doses, the lower one being a dose below which initial action is unlikely to be justified and the upper one the dose at which action should be taken to reduce exposure. ERLs are particularly useful in the case of mitigating iodine exposure since the earlier the first prophylactic dose is taken the greater the effectiveness of stable iodine.

Within the general population are groups with special varying sensitivities to radioiodine. They are as follows:

Foetuses and pregnant women: at about 90 days post conception the fetal thyroid starts to concentrate iodine and thus the risk of thyroid damage from radioiodine commences. There is a rapid increase in the dose per unit of activity up to about 100 to 120 days post conception and then a steady decline until birth. At the time of peak dose per unit intake the dose to the fetal thyroid probably exceeds, by a factor 2, that to the maternal thyroid but overall the pregnancy the absorbed dose to the maternal and fetal thyroids are about the same.

Neonates: the immediate two to three weeks after birth are a time of enhanced iodine uptake and thus represent a period of abnormally high risk, doses from a given exposure (intake) being up to five time greater than in subsequent weeks. In addition, the infant thyroid is up to a factor 10 more sensitive than that of the adult.

Infants and children and adults under 40 years: the main factor in determining the dependence of dose on intake in children is the increasing mass of the thyroid gland with increasing age, there being about one order of magnitude between the dose per unit intake in infants and adults. Sensitivity of the thyroid to radiation decreases markedly with increasing age.

In all the above groups the principle adverse effect of iodine prophylaxis is the temporary deficiency in thyroid hormone production known as the Wolff-Chaikoff syndrome which effectively limits the safe prophylactic dose of stable iodine. Especially sensitive to this effect are neonates who should receive no more than a single dose of stable iodine. Pregnant women and lactating mothers should be limited to two doses. These groups should be removed from the exposure as soon as possible so as to limit exposure.

Adults over the age of 40 years: there is little evidence that in this age group the thyroid is sensitive to radiation induced cancer and the increasing incidence of thyroid disorders and predisposition to hyperthyroidism with age increases the risk of adverse side effects. The latency of thyroid cancer makes the administration of iodine prophylactically less effective.

Guidelines

The following serves as a very brief summary of the main points in the Guidelines (WHO 1989):

Near field: Iodine tablets (either as iodide or iodate) should be available for immediate distribution to all groups if the predicted doses to the thyroid are likely to exceed the national emergency reference level operative at the affected location.

Far field: Iodine, as above, should be available (either in tablet form or in solution as iodide or as iodate) for distribution to pregnant women, neonates, infants and children if the predicted doses are likely to exceed the emergency reference level in the country concerned but they should not be distributed on a wide scale to juveniles, adults or in more than the above prescribed doses, to pregnant women and neonates. Arrangements should be made to limit exposure to neonates and pregnant women by control of foodstuffs as a priority.

Dosage: For adults (including pregnant women) a daily dose of 100 mg (equivalent mass of iodide) will effectively inhibit iodine uptake without undue risk of adverse side effects, except as above The following table gives the dosages for all groups.

Table 2. **Recommended doses of stable iodine as potassium iodide or potassium iodate for various age groups in the population**

Age group	Equivalent mass of iodide (mg)	KI (mg)	KIO_3 (mg)
Birth - 1 month	12.5	15	20
1 month - 3 years	25	30-35	40-45
3 years - 12 years	50	65	85
Adolescents & Adults (including pregnant women)	100	130	170

Timing and duration of administration: The effectiveness of the blocking mechanism depends on the early administration in relation to the exposure so, in the near field, timing is of the essence. In the far field there will be more time so the issue of distribution is of less importance. Even if there is a delay after exposure, administration of iodine should not be discounted since, where ingestion is concerned, later administration may still be beneficial. With continuing exposure administration may be continued for several days, except as detailed above, but iodine prophylaxis should be considered in the context of other mitigation procedures, especially controls of food stuffs.

Storage and distribution

Near field (predictable): Close to nuclear installations iodine tablets should be stored or predistributed so that prompt utilization is facilitated. There needs to be a continuing surveillance of this situation by the competent authorities so that tablets are not lost or misused.

Near field (unpredictable): For mobile sources of potential public exposure to radioactive iodine arrangements should be made for the rapid distribution of tablets to potentially exposed populations.

Far field: Arrangements should be made for the distribution of iodine to special groups as defined above through the storage of iodine at emergency centres, produce stations and hospitals etc.

In all cases, because both iodide and iodate are relatively unstable, arrangements should be made for storage under optimum conditions and replacement of old stocks at regular intervals.

Informing the public: The public, especially in the predictable near field, should be aware of the arrangements for distribution, and the benefits and risks of the administration of stable iodine as a matter of course so that in the event of an emergency they are prepared for the actions required of them.

Implications of what we have learned since Chernobyl

Guidelines should not be "written on stone". The Regional Office for Europe keeps its advice on the response to nuclear emergencies under constant review and will periodically update its advice through the Handbook on Nuclear Emergencies (WHO 1994) presently in the process of publication. What follows are thoughts, to stimulate discussion, on developments that might be incorporated into future advice.

The sequelae to the Chernobyl accident in terms of childhood thyroid cancer, even apparent in populations at distances of several hundred km from the site of the accident, highlight the need for an efficient and reliable system for the administration of prophylactic iodine in the event of a nuclear emergency, in the far field or even in countries which do not have potential sources of radioiodine. In particular the high risk to young children is evident and thus the need to get iodine to them quickly. In Poland an early decision was taken to distribute iodine in the eastern part of the country. It is too soon to say how effective it was in preventing childhood thyroid cancer but the extent of adverse effects has been assessed and found to be small. (Naumanan and Wolff 1993).

A notable health effect of the Chernobyl accident is the incidence of stress related illness resulting from the widespread fear, in the affected populations, of the health implications of the accident. Such fear occurs regardless of whether exposure takes place or not and is more concerned with the perception among the population of the competence of the authorities, to deal with the situation, and the feeling that the situation is or is not under control by the authorities and whether they can act to protect themselves. Iodine prophylaxis is an effective risk control measure and public awareness of it and its application should help to mitigate the stress in the event of an accident..

As unplanned exposures, accidental releases do not fall within the framework of cost benefit analysis in which public dose limits are framed, *i.e.* the incurred risks of the exposure are not justified by societal benefits and mitigation of exposure must therefore be seen as being based purely on a balance between risk that can be averted by mitigation and risk associated with the mitigation measure. Thus, after the initial phase (lasting perhaps 12 hours) in which Emergency Reference Levels are operative, decision making should be based on the above criteria in the circumstances of the particular emergency. If mitigating measures of low risk can avert significant dose, and thus risk, they should be taken even though they may be below the lower bound of emergency reference level. In any case, in the event of an accident it is the risk to the individual that should dictate action and not population based risk.

The risk of severe reaction from the administration of 300 mg of stable iodine daily is up to $1x10^{-6}$ (Pochin 1990). Mild reactions (vomiting, diarrhoea, stain rashes, etc.) were reported in about 1% of the population given a single dose of potassium iodine solutions in Poland (Nauman and Wolff 1993). It is not, however, known to what extent these reactions were due to the way the

iodine was administrated and to what extent psychological factors played a role. The risk to a child of exposure to an absorbed dose to the thyroid of 1Gy is about 1% (ICRP 1991). It follows therefore that significant risk may be averted by the administration of stable iodine at doses somewhat less than the emergency reference levels of dose which is typically in the range from 50mGy. Taking into account the practicalities of distribution of iodine Paile of the Finnish Centre for Radiation and Nuclear Safety (personal communication) has proposed an intervention level in the region of 10 mSv to the thyroid for children.

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SHORT-TERM COUNTERMEASURES QUESTIONNAIRE

by

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Fourteen countries responded to the questionnaire. Countries marked more that one response to multiple choice questions if appropriate. Some countries did not respond to questions that did not apply.

What is the objective of your country's countermeasures?

Most countries stated that preventing sickness/deaths and limiting cancers were the objectives of their countries countermeasures. Five countries' objectives were to keep the dose to the public below an established level.

Which urgent countermeasures for the general public are employed in your country?

Sheltering, evacuation and stable iodine were listed by most countries as near field urgent countermeasures. Seven countries also initiate other countermeasures promptly such as access control and food restrictions. For far field urgent countermeasures, seven countries would shelter, but only four would evacuate and five would distribute stable iodine.

Which urgent countermeasures for specific populations are included as possible options in your country's emergency plan?

Ten countries plan specific countermeasures for special populations including hospital patients, prisoners, long-term care populations, school children, campers, etc.

Are different countermeasures intended for different groups within the populations, such as children pregnant women, etc.?

Most countries do not plan countermeasures for specific segments of the population, but a few countries plan to recommend special countermeasures to infants, children and pregnant women.

Are there established dosimetric criteria for emergency workers?

For life-saving activities, the range of dose limits is from 50-250 mSv(Gy)/event-year. For protecting property, the range is 15-100 mSv(Gy)/event-year. The dose limits for other activities were the most consistent with a range of 5-50 mSv(Gy)/event-year.

Are there different countermeasures planned (stable iodine, dosimetry, protective clothing, etc.) for farmers or other non- emergency workers who may need to be outside in an affected area?

Six of twelve countries plan countermeasures for non-emergency workers who may be outside. The responses did not identify which categories of non-emergency workers would receive separate countermeasure recommendations.

Are there different countermeasures planned (stable iodine, dosimetry, protective clothing, etc.) for emergency workers, such as police, army, monitoring teams who may need to be outside in an affected area?

All countries provided specific countermeasures for emergency workers, however, emergency workers were not specifically defined. From the responses it was not possible to discern whether police, army or other public workers would be considered emergency workers.

Were costs of implementing various countermeasures considered in developing the countermeasures plan that is used in your country?

Costs of implementation were included in half the countries when developing their plan. In other words, some countermeasures were not chosen or were designated as last choice if the costs to implement the countermeasure was high.

Were other factors considered in developing the countermeasures plan?

Most countries indicated that the time needed to implement a countermeasure, the time needed to complete the notification of the public and the availability of transportation for evacuation were factors when considering whether to include a countermeasure in their country's plan. Six countries considered the anxiety of the public toward a particular countermeasure and two countries considered the disruption a particular countermeasure might have on the public.

Was public preference considered in developing the countermeasures plan that is used in your country?

Only one country stated that the public's preference for a countermeasure influenced the choice of a country's preferred short term countermeasure.

What intervention levels are used to initiate countermeasures?

Despite efforts in recent years to harmonize intervention levels within the international community, there remains a wide range of levels. Nearly all countries expressed the level as a range. Lower levels of the ranges for sheltering were from 1 to 10 mSv while the upper limit was from 10 to 100 mSv. Some countries plan to shelter at 10 mSv or below while others plan to shelter at 10 mSv or above. Evacuation intervention levels are even more diverse. The ranges were from 10-50 mSv to 100-500 mSv to above 500 mSv. For stable iodine the intervention levels was generally starting at 30-50 mSv although some countries do not plan to distribute stable iodine until 250 mSv are projected. The upper limit for use of stable iodine ranges from 100-1000 mSv. These very different ranges for intervention levels could present a challenge to authorities of neighbouring countries in an emergency. This disparity highlights the need for coordination of countermeasures before public notification.

What type of organization is responsible for recommending the implementation of countermeasures?

What type of organization is responsible for deciding which countermeasures to implement at the time of an accident?

National level organizations in fourteen countries recommend that a countermeasure is warranted. Five countries mentioned regional organizations, four countries mentioned the nuclear power plant and two countries mentioned local organizations as having the responsibility to recommend that a countermeasure should be taken. Twelve countries stated that regional organizations were responsible for choosing the specific countermeasure during an emergency. Ten countries stated National organizations and four countries stated local organizations choose the countermeasure.

Has an attempt been made to harmonize emergency plans with neighbouring countries? If so, what parts of the emergency plan are/will be harmonized?

The most successful efforts at harmonization have been in the notification function mentioned by twelve countries. Drills and training are harmonized in nine countries. Less harmonization has occurred in intervention criteria, as was noted above, the emergency planning area and dose prediction methods with only four or five countries mentioning harmonization efforts in these functions. Three countries stated that no harmonization has taken place. This may be because there are no nuclear power plants in those countries or the borders are far from a nuclear power plant.

How is the general population told of the countermeasure decision?

A variety of communication methods are used in each country to notify the population. Mobile speakers were mentioned fourteen times, sirens with subsequent radio and television announcements-thirteen times, radio and television alone-ten times, fixed public address system-four times, door-to-door notification-three times, short-wave radio-twice and telephone notification-once.

Is there a geographic emergency planning area surrounding a nuclear power plant in which planning for implementing short term countermeasures should be in place?

Four countries have planning areas between 1-5 km, five countries have planning areas from 6-10 km, one country has planning areas of 11-15 km, two countries have planning areas from 16-20 km, one country has planning areas from 21-25 km. One country has no emergency planning area, but also has no nuclear power plant within its borders.

What factors are considered at the time of an emergency when selecting which countermeasures to implement?

Virtually all countries consider weather conditions, length of warning time, time of day, whether a release is in progress, time needed to complete implementation of the countermeasure and the size of the population designated to implement the countermeasure.

Are there plans for a phased implementation?

Nine countries plan to implement countermeasures first for close areas. Schools were mentioned by four countries and specific populations were mentioned by three countries for a phased implementation of countermeasures. Two countries do not plan any phased implementation of countermeasures.

Is sheltering ever intended to be used initially accompanied by another or followed by countermeasure?

Nine countries may accompany sheltering with evacuation and five countries will accompany sheltering with stable iodine. One country plans to recommend sheltering alone.

Has your country ever experienced sheltering, evacuation or issuance of stable iodine for an actual or potential radiological emergency?

The United States experienced shelter and evacuation for the Three Mile Island accident. Sheltering was recommended for persons within a 16 km radius. Evacuation was recommended for pregnant women and children (about 2500 persons) within 24 km.

The actual population that evacuated was about 144,000. The town of Kotka in Finland experienced sheltering of less than 1000 people during an exercise and stable iodine was distributed to the onsite staff of a gas-cooled reactor in the United Kingdom due to an onsite leak of coolant gas.

Are there early plans for warning of farmers, hospitals or others needing extra time for sheltering or evacuation?

Six countries provide early warning to people who need extra time to prepare for the implementation of sheltering or evacuation. Seven countries do not.

Are there any precautions planned for members of the public who may be allergic to stable iodine?

Of the nine countries that do issue precautions regarding stable iodine, seven provide a warning with the recommendation, three direct potentially allergic people to consult a physician and two do not recommend taking the stable iodine at all if an allergy is suspected. Four countries do not provide any warning.

If stable iodine is used as a countermeasure, where is the stable iodine stockpiled?

Stable iodine is stockpiled at a variety of locations. Nine countries store it with local officials, six at schools, five with National authorities, three at shelters, three at the nuclear power plant and two at pharmacies.

If stable iodine is used as a countermeasure, who pays for it?

The National authorities purchase the stable iodine in ten countries, the nuclear power plant in six countries, individual members of the public in four countries, local authorities in two countries and businesses in one country.

Is stable iodine a countermeasure that could be selected for accidents occurring in foreign countries?

Nine of fourteen countries plan to recommend stable iodine for an accident occurring in a foreign country. Stable iodine is not considered viable in some countries due to the distance to the nearest foreign nuclear power plant.

If stable iodine is used as a countermeasure, what form of stable iodine is used?

Virtually all countries use potassium iodide tablets to administer stable iodine. At least one country uses potassium iodate.

What iodine dose (mg) and ingestion frequency are recommended in territories with normal environmental iodine levels?

What iodine dose (mg) and ingestion frequency are recommended in territories with low environmental iodine levels?

The range of dosage for iodine is 12.5-65 mg for children less than one year, 50-150 mg for children and 100-300 for adults. Nearly all countries have the same doses for breastfeeding women, pregnant women and adults. Several responders stated that their country follows WHO guidelines. No countries indicated different iodine doses in territories with low environmental iodine levels.

Is there any plan for the usage of stable iodine in patients with thyroid diseases?

Six countries plan to administer stable iodine to persons with thyroid disease. Three do not plan to administer stable iodine and two plan to administer stable iodine to persons under 45 with thyroid disease.

What is the assumed shelf life of stable iodine?

Seven countries use five years as the shelf life of stable iodine. One country uses two years and one country uses eight years. Two countries have extended the shelf life to ten to twelve years.

Is there a quality control program for stable iodine?

For stockpiled stable iodine, nine countries have a quality control program while two do not. For predistributed stable iodine, only three countries have a quality control program while one country does not. Some countries do not have program for predistributed stable iodine.

The questionnaire provided insights into short term countermeasure planning and implementation. Countries can compare their situation to the responses of other countries and identify areas for further review and coordination. On the other hand, some questions elicited responses indicating a complex situation that raised more questions. A future questionnaire on the same issues would be beneficial in a few years. This would give countries an opportunity to conduct harmonization discussions and participate in more bilateral exercises.

THYROID CANCER RISK AMONG PATIENTS EXPOSED TO DIAGNOSTIC DOSES OF IODINE-131

by

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Abstract

The level of risk associated with ^{131}I is not well defined but appears lower than equivalent doses of x-rays. To provide quantitative data on the risk of thyroid cancer following ^{131}I exposure, 34,104 patients surviving ≥5 years after ^{131}I administration between 1950-69 for diagnostic purposes were studied. The mean thyroid dose was estimated to be 1.1 Gy (range 0-40.5). Overall, 67 thyroid cancers occurred in contrast to 49.7 expected based on rates from the general population (SIR=1.35; 95% CI 1.05-1.71). However, the excess rates was based entirely among patients referred because of a suspicion of a thyroid tumour whose risk was significantly higher than for those referred for other reasons.

Introduction

The correlation between high-dose rate ionizing radiation and thyroid cancer was first suggested more than 50 years ago (1,2) and thyroid cancer has since then been convincingly linked to ionizing radiation only after childhood exposure (3-7). In the most recent follow-up of A-bomb survivors, thyroid cancer risk was increased only among individuals under age 20 years at exposure (8). Age at exposure thus appears to be the most important determinant of future risk, and differences in reported risk estimates might merely reflect differences in age distribution.

No increased risk of thyroid cancer has been found among hyperthyroid patients treated with ^{131}I (9-11). Fallout from nuclear weapons tests has resulted in increased risk of thyroid cancer among Marshall Islanders, but most of the dose was delivered from gamma rays and short-lived radioiodines and not ^{131}I (12, 13). A recent registry evaluation reports high rates of thyroid cancer in children living in the Chernobyl area (14).

Against this background, we extended the follow-up of a large series of patients administered ^{131}I diagnostically (15). Individual radiation dose to the thyroid was computed for the first time. The aim was to provide quantitative data on the risk of thyroid cancer after exposure to relatively low dose and dose-rate exposures.

Methods

The cohort has been described elsewhere (15, 16). Patients were examined with ^{131}I during the period 1950-1969, less then 75 years of age at exposure, and had not received external radiotherapy. The cohort consisted of 34,104 patients (80% women and 20% men) with a mean age of 43 years (range 1-75 years) at first exposure, and a mean follow-up of 24 years (range 5-39 years). A total of 2,408 individuals were exposed before 20 years of age and 316 before the age of 10 years.

We estimated absorbed thyroid dose using the individual administered ^{131}I activity and 24 hour thyroid uptake of ^{131}I, as well as ICRP tables (17).

The follow-up period started at the time of first exposure or if exposed prior to 1958, at January 1, 1958, and lasted until thyroid cancer diagnosis, death, emigration, or December 31, 1990. The first 5 years at risk were excluded in order to reduce the number of thyroid cancers that were related to referral or to increased medical surveillance and not to the ^{131}I exposure. All thyroid cancers observed within the first five years of follow-up were excluded for the same reason.

The cohort was matched with the Swedish Cancer Register (SCR). The expected number of thyroid cancers were calculated using incidence data from the SCR and indirect standardization with adjustment for sex, attained age at exposure, and calendar period.

The standardized incidence ratios (SIR) were calculated as the ratio between observed and expected numbers of thyroid cancers. The 95% confidence

intervals (CI) were calculated assuming the observed number of cancers being Poisson distributed. Trends for SIR were calculated using the formulas suggested by Breslow and Day (18).

Results

The absorbed dose to the thyroid gland using ICRP tables was 1.3 Gy (range 0.0-25.7 Gy) among those referred under the suspicion of a thyroid cancer and 0.9 Gy (range 0.0-40.5 Gy) among those examined for other reasons.

Between 1958 and 1990, a total of 67 thyroid cancers were found more than 5 years after exposure. Forty-two were referred under the suspicion of a thyroid cancer, and 25 for other reasons. The mean time from exposure to ^{131}I and diagnosis of the thyroid cancer was 15 years.

The overall risk for thyroid cancer more than 5 years after exposure was 1.35 (95% CI 1.05-1.71; Table 1). A significantly higher risk was seen for those 10,785 patients referred under the suspicion of a thyroid cancer (SIR=2.86; 95% CI 2.06-3.86) compared to those referred for other reasons (SIR=0.75; 95% CI 0.48-1.10).

When patients were divided into different dose categories no trend of increasing risk with increasing dose was noticed regardless of reason for referral. The highest risks were seen during the period 5 to 9 years after exposure regardless of reason for referral (Table 1). For both referral categories a non-significantly higher risk was seen for the period 20 years of more after exposure compared to 10 to 19 years after exposure.

The risk of a thyroid cancer was highest among those exposed before the age of 20 years (SIR=1.69; 95% CI 0.35-4.93), although based on 3 thyroid cancers only (Table 2). Among the 1,764 exposed children not referred under the suspicion of a thyroid tumour, 2 thyroid cancers were found, giving a non-significantly elevated SIR of 1.38. The three individuals developing thyroid cancers were exposed between the age of 15-19 years.

Discussion

The thyroid gland of children appears to be one of the most susceptible organs to radiation carcinogenesis with relative risk estimates at 1 Gy ranging from 4 to over 30 (19). As 93% of our patients were over age 20 years when ^{131}I was administered, the absence of an overall effect might be attributable to the lower sensitivity of the adult thyroid gland.

A recent report from cancer registry data in Belarus purports high rates of thyroid cancer to be associated with radioactive fallout from the Chernobyl accident (14). This opinion was shared by an expert panel formed by the Commission of the European Communities, although they emphasized that the influence of screening should be carefully considered in assessing the results (20).

The strengths of this investigation include the unbiased and exceptionally complete ascertainment of thyroid cancers. and the doses to the thyroid were substantial and covered a wide range. Limitations include the relatively small number of individuals <20 years of age, and therefore a strong evaluation of age effects could not be made. The influence of the underlying condition on risk could operate in several ways. Patients with an underlying hyper/hypothyroid condition have been reported to be at slight increased risk of thyroid cancer, and clearly patients who are examined because of a suspicion of a thyroid tumour are at increased risk. These conditions, however, would lead to an overestimation of risk whereas none was found.

In conclusion, it is in some sense reassuring that the careful examination of about 34,000 patients who received substantial radiation doses to their thyroid glands from ^{131}I did not identify a significant increased risk of thyroid cancer. While it is impossible to exclude the possibility of a low risk associated with this exposure, nonetheless, it appears clear that exposures in adult life are associated with minimal risk. Contrasting studies of childhood exposures, ^{131}I appears considerably less effective in inducing thyroid cancer than acute exposure to x or gamma rays.

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Table 1. **Observed number of thyroid cancers, SIR, and 95% CI, in relation to reason for referral and years after exposure**
The first 5 years after exposure were excluded.

	Years after exposure									All		
	5-9			10-19			≥20					
Reason for referral	Obs.	SIR	95% CI	Obs.	SIR	95% CI	Obs.	SIR	95% CI	Obs.	SIR	95% CI
Suspicion of thyroid tumour	14	4.06	2.22-6.81	15	2.30	1.29-3.79	13	2.75	1.47-4.71	42	2.86	2.06-3.86
Other reasons	7	1.08	0.43-2.22	7	0.48	0.19-0.98	11	0.89	0.45-1.60	25	0.75	0.48-1.10
All	21	2.11	1.31-3.23	22	0.97	0.61-1.47	24	1.41	0.90-2.10	67	1.35	1.05-1.71

Table 2. **Observed number of thyroid cancers, SIR and 95% CI, in relation to age at exposure and sex**
The first 5 years after exposure were excluded.

	Men			Women			All		
Age / Years	Obs.	SIR	95% CI	Obs.	SIR	95% CI	Obs.	SIR	95% CI
All									
≤ 20	0	0.00	0.00-23.06	3	1.85	0.38-5.41	3	1.69	0.35-4.93
21 - 50	6	2.33	0.86-5.08	34	1.23	0.85-1.72	40	1.32	0.94-1.80
> 50	6	3.14	1.15-6.84	18	1.17	0.69-1.84	24	1.38	0.88-2.05

THYROID CANCER IN CHILDREN LIVING NEAR CHERNOBYL
Presentation of an Expert Panel Report

by

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Abstract

In January 1992, under the Radiation Protection Research Action, a Panel of experts was set up to evaluate the current situation concerning reported increased incidence of thyroid cancer in children living near Chernobyl at the time of the nuclear reactor accident on 26 April 1986.

The report written by this Panel documents their findings with respect to the occurrence of childhood thyroid cancer in Belarus and the Northern Ukraine. The Panel arrives to a consensus opinion and makes strong recommendations for urgent technical and humanitarian assistance and research cooperation. The Panel report and the response of the European Commission to these recommendations are discussed.

Background

The Chernobyl nuclear reactor accident on April 26 1986 released large amounts of radioactivity including radioactive isotopes of iodine into the atmosphere. In 1991 in Belarus increased rates of thyroid cancer in children under the age of fifteen living in the neighbourhood of Chernobyl at the time of the accident were reported.

In order to assess the authenticity of the reported increased rates of thyroid cancer in children the European Commission (EC) in cooperation with the European Office of WHO in Rome, held a meeting of thyroid experts, at Neuherberg on **15 January 1992**. The conclusion of this meeting was that there was a serious likelihood of these cancers being a consequence of the Chernobyl accident. It became clear that there was substance to the claims and that it was necessary to confirm the validity of the data by an independent international body of scientists. It was recommended that EC experts should reassess the pathology of the cases, review case notes, and receive the most appropriate material for histological examination.

A Panel of thyroid experts was formed of the following individuals: Prof. Sir Dillwyn Williams (Cambridge University, UK), Prof. A. Pinchera (Pisa University, Italy); Prof. B. Egloff (Kantonsspital Winterthur, Switzerland); Prof. C. Reiners (Essen University, Germany); Dr. P. Fragu (INSERM, France); in addition Dr. K. Baverstock (WHO Europe, Rome Division, Italy) was also invited to participate.

In *June 1992*, several of the experts who attended the Neuherberg meeting met together with Dr. A.W. Furmanchuk from Minsk and Commission officials in Dublin. After viewing a series of slides made by Professor B. Egloff from microscopic examination of thyroid tissue samples from Belarus, the experts were convinced of the validity of the pathological diagnosis. The aim of this Dublin meeting was to discuss a joint EC/WHO mission by an international panel of thyroid experts to Belarus to examine, in collaboration with Belarussian physicians, the childhood thyroid cancer excess. In *October 1992* the EC Panel Members and EC Officials of the Radiation Protection Research Action visited Minsk together with a representative of WHO Europe. Japanese and American thyroid experts were invited to participate as observers representing their respective countries. Switzerland and The Netherlands also sent participants to accompany the Panel as observers. The aim of this mission was to examine the data and the available patients, to make a thorough assessment of the newer cases, and to prepare a detailed report for the Commission. In Minsk the Panel defined future needs and actions which would aid these children, drafted recommendations for the report and arrived at a consensus opinion.

The Panel Report

The report entitled "Thyroid cancer in children living near Chernobyl" (EUR 15248 EN) was published in October 1993. It is a comprehensive report including a Consensus Opinion and Recommendations. The Consensus Opinion

of the Panel Members and Observers documents the agreement reached that there is a true increase in childhood thyroid cancer in areas around Chernobyl, that intensive screening programmes are unlikely to account for much of the increase in cancer incidence, and that exposure to radioactive isotopes of iodine from the Chernobyl accident is the most likely cause of this increase. The report therefore proposed that urgent action be undertaken to deal with both the humanitarian and scientific aspects of the problem. The recommendation for Technical Assistance proposes a complete package of facilities and training to provide optimal treatment for the childhood thyroid cancer patients.

The report explains the situation concerning the children suffering from thyroid cancer. Childhood thyroid cancer is a rare disease but if optimally treated does not have to be fatal. The number of childhood thyroid cancers reported in Belarus and also in the Ukraine is already of the same order of magnitude as the total number of all types of cancers which have been ascribed over the past 40 years to the Atomic Bomb Explosions in Japan.

The opinion of the Panel is that the situation is serious and the children are not receiving optimum treatment despite all the efforts of the Medical Authorities in Belarus and the Ukraine because of the lack of adequate surgical and therapeutic facilities. Humanitarian aid would have an immediate impact on the health of these young victims. The magnitude of this health problem should not be underestimated and may persist for decades.

Thyroid Cancer in Children: the Evidence

The phenomenon of childhood thyroid cancer following the Chernobyl nuclear accident can be examined in terms of the observed increase in incidence rates, the geographic distribution of increased rates, the effect of screening on observed incidence rates and the clinical and histopathological nature of the observed tumours. The most important factors to be considered are radiation exposure after the Chernobyl accident and intensified screening as a result of the accident, or a combination of those. However, only 30% of the thyroid cancers were found by screening and not the remaining 70%. Concerning the geographic distribution incidence rates were highest in the Gomel region, closest to Chernobyl.

The reported incidence of thyroid cancer in children living in Belarus and the Ukraine was steady in the few years immediately after the Chernobyl accident. Since 1990 the reported incidence has increased in both republics with higher rates in the areas closer to Chernobyl.

The number of cases of childhood thyroid cancer recorded in the three CIS countries during the years 1986 to 1993 inclusive, was Belarus 252, Ukraine 127, and Briansk (Russian Federation) 7. The total number is 386 cases.

In the republic of Belarus, which has a well developed cancer registry, there was an increase in the rates of confirmed cases of thyroid cancer among children aged 0-14 years as follows:

1978-1988	:	between 0 and 0.14/100,000/yr.
1989	:	0.25/100,000/yr (confirmed cases)
1990	:	1.15/100,000/yr. (confirmed cases)
1991	:	2.25/100,000/yr.

The increase was about twenty-fold from before the accident to 1991 for the whole of Belarus.

The pathology diagnosis has been confirmed by international experts in over 90% of the cases studied from Belarus (1986 to 1991). The majority (96%) of cases in Belarus were papillary in type with about 16% well differentiated, 40% moderately differentiated, 18% poorly differentiated and 18% follicular variant. Of the 86 histologically verified cases occurring between 1986 and 1991, more than half of the cases were between 0 and 4 years old at the time of the accident and many of the rest were 5 to 9 years old. At diagnosis more than half of the cases were between 5 and 9 years old and many of the rest were between 10 and 14 years old. This data indicates that the first cancers are starting to appear after about 4 years, in accordance with what has been found previously for childhood thyroid cancer. Nearly half of the cases from Belarus showed involvement of thyroid cancer. No statistically significant changes in thyroid function or in antibody levels have been consistently reported in all three CIS countries. The reported increase in thyroid cancer does not appear to be associated with a consistent increase in any other type of thyroid disease including nodules across the three CIS countries.

Concerning the dosimetric aspects, the May-June 1986 thyroid doses for 120 000 subjects have been reconstructed, of which 30 000 children, from Gomel and Minsk cities. This work was realised by the Institute of Biophysics, Moscow. The analysis of the data showed that the largest thyroid exposure doses have been received by children under 7 years of age who lived in the 30 km zone at the moment of the accident. Mean dose for this age group in Khoiniki district was 5Gy, for adults 1.5Gy, and in Bragin 2Gy for children of 0-7 years.

Response of the European Commission to the Panel Recommendations

Following the publication of the thyroid report in October 1993, *in response to the recommendations of the panel for research activity*, the Radiation Protection Research Action initiated two thyroid research projects 2 months later. The projects are dependent upon cooperation between EC and CIS centres. The context of this cooperation for the research projects is the Agreement for International Collaboration on the Consequences of the Chernobyl Accident between the European Commission and the representatives of the Republics of Belarus, Ukraine and the Russian Federation signed on June 23 1992. In the first period (1991-1992) of the Agreement a series of Experimental Collaboration Projects on environmental issues and Joint Study Projects on emergency management have been initiated. In order to carry out the research, European projects groups have been composed which are working very closely together with scientists from the three republics, under the supervision of a competent Coordination Board. In 1992-1993 six additional projects on the Health consequences of the Chernobyl accident were launched. The total number of projects is 16.

The main objectives of this CEC/CIS collaboration are to increase the possibilities for training of CIS scientists; to provide financial support to CIS institutes for allocating staff to the joint projects; to introduce new technologies and to train CIS specialists to improve the local infrastructure and to create a regional network of data management/information centres in Belarus, Russia and Ukraine and to underpin their activity with dedicated collaborative research projects.

The overall objectives for the projects on the health consequences of the Chernobyl accident are to evaluate the medium (1-10 years) and long term (10-50 years) consequences of the accident, evaluate the health consequences of the accident for the public and the "liquidators", and to establish international guidelines for treatment of victims.

The two thyroid projects will contribute to a better understanding of thyroid cancer induction in children and to the development of improved treatment protocols. Local assistance, exchange of scientists, training and equipment for research is included in these projects.

Description of the Projects

Development of Optimal Treatment and Preventive Measures for Childhood Thyroid Cancer

The scope of research is:

- To develop appropriate protocols for diagnosis, treatment and follow-up of radiation-induced childhood thyroid cancer in the CIS. Most International centres have common general guidelines for the management of differentiated thyroid carcinoma, but protocols may differ in relation to local conditions. In Belarus, however, variable diagnostic and therapeutic approaches have been followed in relation to the limited facilities available in most local centres. Protocols specifically aimed to solve the problems related to local situations will be developed in collaboration with CIS scientists by the experts participating in this programme.

- To train CIS medical specialists and technicians in the management of childhood thyroid cancer and other radiation-induced thyroid diseases. The institutions involved in this project will provide training of personnel, assistance and implementation of technical procedures (thyroid sonography, scintigraphy and fine needle aspiration cytology).

- To develop new technologies for the assessment and management of thyroid cancer and related disorders.

- To standardize laboratory diagnostic and monitoring procedures. Methods and evaluation criteria should be standardized in order to ensure comparability and reproducibility of the data among and within different centres.

- To evaluate the features and the outcome of the post-Chernobyl radiation-induced thyroid carcinoma as compared with the differentiated thyroid carcinoma observed in children living in unexposed areas in Western Europe.

- To evaluate the effectiveness of iodine supplementation and thyroid suppressive therapy as a secondary measure in the prevention of radiation-induced thyroid cancer. Since the correction of iodine deficiency by iodine prophylaxis decreases the risk of radiation-induced thyroid cancer by decreasing thyroidal uptake of radioiodine, admittedly, iodine prophylaxis by distribution of iodised salt would be most effective if instituted before a nuclear accident.

The objectives of the above project are based on the facts that:

Differentiated thyroid carcinoma is in general susceptible to effective treatment and may be cured, provided that early diagnostic and therapeutic measures are undertaken; b) Benign thyroid nodules need to be differentiated from malignant lesions, require appropriate treatment and careful follow-up, given their potential susceptibility to malignant transformation. The effectiveness of the above diagnostic, therapeutic and follow-up procedures imply the availability of adequate facilities, equipment and know-how. Because of the rarity of childhood thyroid cancer and the limited experience acquired with this disease in most hospital centres, the specific expertise of major European referral institutions are being made available to Belarus and other CIS countries in order to cope with the multiple and difficult aspects of the post-Chernobyl outbreak of childhood thyroid cancer.

Molecular, Cellular, Biological Characterisation of Childhood Thyroid Cancer

The scope of research is:

- Pathological, Cytological and Molecular Biological characterisation of childhood thyroid cancers in the CIS;
- Confirmation and statistical analysis of the pathology of current and new cases;
- Classification and prognosis of tumours;
- Cytological and molecular analysis of thyroid tumour cells including specific radiation induced changes, oncogene expression, tumour suppressor genes, mutation and correlation with dose assessment;
- Comparison with normal tissue and benign tumours;
- Preservation of samples of tissue for future examination.

The overall aim of the project is to investigate both the pathological and molecular biological features of the tumours concerned to identify changes which may be specifically related to radiation and to investigate the fundamental changes which relate radiation exposure to the development of thyroid neoplasia.

In response to the recommendations of the panel on humanitarian aid, in March 1994, the European Office for Humanitarian Aid (ECHO/2) of the European Commission has submitted a purely humanitarian project to supply specialist equipment and medicines for the diagnosis, treatment and follow-up of the children suffering from thyroid cancer for Belarus and the Ukraine. These will be delivered to the two republics as soon as possible.

The facilities include:

- Nuclear medical facilities for radioactive iodine for diagnosis and treatment of metastases (e.g. scanners or gamma cameras for radioiodine scans);
- Modern equipment for diagnostic use i.e. microtomes, microscopes, consumables and material (glass slides, etc); (These needs will necessarily be accompanied by training of anaesthetists, surgeons and other specialists, and assistance in the quality control of the equipment);
- Continuing provision of replacement therapy drugs after surgery since the children adequately treated will be hypothyroid. Centres will be provided with drugs of sufficient quality necessary for medical treatment or trained to be able to produce these drugs independently, in their own countries;
- High quality reagent kits for laboratory analysis, for the follow-up of the children.

Implementation

The first step was the bilateral formulation of projects by centres of the CIS countries and the CEC. The projects are realized as partnerships between Eastern and Western hospitals and research institutions. With the financial support of Radiation Protection Research, the medical staff (physicians, nurses, technicians) will be invited to visit hospitals in the EC specializing in the diagnosis, treatment and follow-up of thyroid cancer. In the same way, research personnel will visit relevant research institutions in Member States of the European Union.

The programme will enable senior physicians and scientists of CIS countries to become familiar with the special methods used for diagnosis, therapy and follow-up of thyroid cancer as well as with methods used in radiation dosimetry and biology. This will usually be achieved by relatively short visits to EC centres (2-4 weeks). After delivery of equipment and material financed by

ECHO/2, medical and research partners of the European Union will support CIS partners concerning implementation of technical procedures, quality control and continuing education.

The future

As time passes the cohort of children in the 10-14 year age group at the time of the accident will gradually decrease as these children move into the group above 15 years of age and are classified as young adults. Cancers arising in this group after they had turned 15 would no longer be classified as childhood cancers. Unfortunately no information is at present available to us on the occurrence of thyroid cancer in young adults in Belarus.

Similarly, the low number of cases noted in the 0-4 year group at diagnosis is not surprising as this cohort contains a decreasing proportion of children who were actually exposed to radioactive iodine from the Chernobyl accident as the year at diagnosis increases. The number of cases is further decreased by the latency period between exposure and the appearance of the tumour which seems to be at least three years. One will expect a drop in the cancer incidence in children who were conceived after April 1986 and whose thyroids were unaffected by the radioactive iodine compared with those children who were born before the accident. A study of the cancer incidence in children as a function of date of birth through the period of the accident could provide the best information linking the radioactive iodine from the Chernobyl accident to the increased incidence of childhood thyroid cancer.

The future extent of the incidence of thyroid cancer is not predictable. Because there is likely to be a long-term continued considerable increase in thyroid carcinoma incidence, it is most important that steps be taken now, to provide help for the current 386 children with thyroid cancer and for the future patients. It is the aim and the hope of the European Commission to be able to continue this collaborative work with the CIS on a longer-term basis.

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Session 2

EFFECTIVENESS AND RISK OF COUNTERMEASURES

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EFFECTIVENESS AND RISKS ASSOCIATED WITH SHELTERING AND EVACUATION

by

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Abstract

The United States Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) have assessed the risks and benefits associated with evacuation and sheltering following a severe reactor accident. In the case of a severe accident and the associated uncertainties with the source term and containment behaviour, these assessments suggest that prompt evacuation of areas close to the plant offers the highest protection of the public against acute doses. Sheltering may be used as an alternative in special circumstances where evacuation may not be feasible. The source term associated with reactor accidents and containment failure mechanism affect the effectiveness of different protective measures. A comparison of different protective measures is made and results discussed.

Introduction

The United States Nuclear Regulatory Commission (NRC) has adopted the concept of defense-in-depth at commercial nuclear power plants. This concept is based on designing plants that have accident prevention features (Emergency Safety Features), accident mitigation features (siting, containment, containment sprays), and emergency planning features such as determining the emergency class, activating the emergency operation facility, the technical support centre, and the operational support centre, notifying offsite officials, and recommending protective measures to limit offsite adverse consequences on public health and safety. Emergency planning has, in many respects, reached maturity since the accident at Three Mile Island (TMI). The plant operator uses in-plant instrument readings and emergency plans and procedures to determine whether an emergency condition exists. The operator priorities are to prevent accidents, mitigate their consequences, and provide support to offsite agencies to implement appropriate protective measures for the public. The plant operator promptly notifies offsite authorities if an emergency condition exists and, if warranted, issues recommendations to the State for public health and safety. The offsite authorities will evaluate the licensee's recommendations and notify the public of the existing emergency and protective measures to be implemented. These authorities use their emergency plans and procedures which direct them to determine the extent of the threat to the public and the most appropriate countermeasures. These plans and procedures are based on federal guidance issued by the US Environmental Protection Agency (EPA), on risks associated with radiological emergencies and the recommended countermeasures (1). The plant operators make offsite recommendations based on the EPA and NRC guidance (2). Recently the NRC clarified its guidance on protective measures for severe reactor accidents. The recent guidance recognized the effectiveness of prompt evacuation close to the plant and downwind. This clarification in NRC guidance was based on the effectiveness and risks associated with sheltering and evacuation. The following discussion will provide some insight on the assessments and evaluations that led to this clarification.

Cost of Evacuation and Sheltering

Evacuation risks were reviewed by EPA and determined to be no different from routine automobile travel (3). In the United States, the risk of death from travel is about 9E-8 per person-mile; or 9E-6 for a 100 mile round trip. This corresponds to a risk of about 0.03 rem, based on the assumption of a fatal cancer risk of 3E-4 per person-rem. The EPA determined that the cost of evacuation is $185 (1982 dollars) per person for a 4-day evacuation involving a 100 mile round trip, with an average of 3 persons per household (4). The EPA study applied the acceptable range of costs for avoiding a statistical death from pollutants of $400,000 to $7,000,000 as an acceptable range of costs for avoiding a radiation caused deaths. When this range is applied to a risk of 3E-4[1] cancer deaths per person-rem, the result is a range of $120 to $2000 per person-rem avoided.

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1 EPA currently uses 5E-4 cancer deaths per person-rem.

Most nuclear sites in the US use a key hole approach when applying protective measures; that is, people are advised to evacuate if they live within a small circle of a 2-mile radius from the plant and a 90 degree sector downwind up to distances where EPA protective action guides (PAGs)[2] are not exceeded. The EPA study found that the cost per unit dose avoided is greatest for wide angle evacuation and for the most stable atmospheric conditions. Other general conclusions drawn by the EPA study are listed below (3):

1. Advanced planning is essential to identify potential problems that may occur in an evacuation;

2. The risk of injury or death to evacuees does not change as a function of the number of persons evacuated;

3. The risk of injury or death to evacuees can be approximated by the National Highway Safety Council statistics for motor vehicle accidents;

4. Most of the evacuees use their own personal transportation during an evacuation;

5. Most of the evacuees assume the responsibility of acquiring food and shelter for themselves;

6. Evacuation costs are highly area dependent and should be computed based on local demographic, economic, and geographic conditions;

7. No panic or hysteria has been observed in evacuations.

Sheltering is considered to be a low cost activity and easy to implement. The value of sheltering, however, depends on the kind of shelter available and the kind of radioactive release (5). In the United States, most residents within 2 to 3 miles around commercial nuclear plants live in wood-frame houses, which will not provide shielding for radioactive releases comparable to evacuation. Evacuation routes are generally known and adequate transportation planned for transportation-dependent residents.

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2 Protective action guides (PAGs) are projected doses at which prompt protective action should be initiated. The EPA has developed the PAGs for the early phase of a nuclear accident to be 1-5 rem total effective dose equivalent (TEDE), and 5-25 rem committed dose equivalent to the thyroid.

While sheltering may be preferable to evacuation in some situations for some special groups, EPA recommends that, under normal conditions, evacuation of the general public should be initiated at a projected dose of 1 rem. This approach is partly due to the uncertainties associated with severe accident phenomena and atmospheric dispersion (6). Because it is a low cost-low impact action, EPA did not set a specific minimum level for the initiation of sheltering. In fact, most sheltering is considered more to be a means to ensure communication with the general public than it is for radiation shielding.

A simplistic approach to compare the effectiveness of evacuation with sheltering was published in the CRC Handbook of Management of Radiation Protection Programmes in 1986. The dose to an individual travelling downwind with a puff was calculated and compared with the dose to a stationary individual. It should be noted that this represents an extreme scenario and is presented here only as an illustration. Table 1 shows the results of this calculation (7):

Table 1. **Travelling to stationary dose ratios for shielding factors 1 and 0.5**

Traveller's speed

Starting distance (miles)	5 mph (PF* of 1/0.5)	10 mph (PF* of 1/0.5)	20 mph (PF* of 1/0.5)	30 mph (PF* of 1/0.5)
1	0.4/0.8	0.2/0.4	0.1/0.2	0.07/0.14
2	0.8/1.6	0.4/0.8	0.2/0.4	0.17/0.34
3	1.2/2.4	0.6/1.2	0.3/0.6	0.20/0.4
4	1.6/3.2	0.8/1.6	0.4/0.8	0.27/.054
5	2.0/4.0	1.0/2.0	0.5/1.0	0.33/0.66

* Shielding protection factor represents the ratio of indoor dose to outdoor dose.

It is assumed that the puff duration is 0.5 hrs. Longer duration releases will decrease the calculated dose to traveller, thus resulting in lower travelling to stationary dose ratios. Exposure to ground contamination by the stationary individual is ignored. Accounting for this exposure would reduce the ratios

further. It is also assumed that the traveller's speed is equal to the wind speed. Doses to the traveller would be less if the traveller's speed were different than the wind speed, or if the puff did not follow the road.

The table shows that the evacuation doses are generally much less than the stationary doses for persons starting at close range; this means that leaving areas closer to the plant provides greater benefit than leaving areas further away. It also shows that the benefits of evacuation increase with evacuation speed.

This simplistic analysis shows that the effectiveness of evacuation during a release depends on the evacuation speed. For example, at a starting distance of 5 miles, the dose to an individual travelling at 10 mph would be the same as the dose to a stationary individual who remains unshielded. It is clear that for events where there is enough warning time, evacuation can prevent exposures. It should also be noted that doses to an individual travelling across a puff would be even less than travelling downwind with the puff. If the release is of longer duration, the ratio of the travelling dose to the stationary dose would be even smaller. A more site specific analysis was performed for 5 US nuclear power plants and documented in NUREG-1150 which provides more insight on the effectiveness of different protective measures.

Source Term

The effectiveness of a protective measure such as evacuation or sheltering depends largely on the timing, quantity, and radionuclide mix of a release, referred to as the source term. Source terms for five US plants were analyzed and documented in NUREG-1150. In this document, a number of general conclusions were drawn for severe accident source terms which are listed here (3):

1. The uncertainty in radionuclide source terms is large and represents a significant contribution to the uncertainty in the absolute value of risk. The relative significance of source term uncertainties depends on the plant damage state;

2. Source terms for bypass sequences, such as accidents initiated by steam generator tube rupture (SGTR), can be quite large and comparable to the largest Reactor Safety Study source terms;

3. Early containment failure by itself is not a reliable indicator of the severity of severe accident source terms. Substantial retention of radionuclides is predicted to occur in many of the early containment failure scenarios in the BWR pressure suppression designs, particularly for in-vessel period of release during which radionuclides are transported to the suppression pool. Containment spray system and ice-condenser decontamination can also substantially mitigate accident source terms;

4. Flooding of reactor cavities or pedestals can eliminate the core-concrete release of radionuclides, if a coolable debris bed is formed, or can significantly attenuate the release from the molten core-concrete interaction by scrubbing in the overlaying pool of water.

Reference (6)[3] shows the predicted frequency of radioactive releases among five U.S. plants: 3 PWRs, Surry, Zion, Sequoyah, and 2 BWRs Peach Bottom and Grand Gulf. Virtually all source term groups developed for this study have two release phases: an early phase and a later phase. The most outstanding feature of these curves is their relative flatness over a wide range of release fractions. For the iodine, cesium, and strontium groups, the curves decrease only slightly over the range of release fractions from 1E-5 to 1E-1 and then fall rapidly from 0.1 top 1. For the lanthanum group, the rapid decrease in the curve occurs at a release fraction od 1E-2 to 1E-1.

The NRC has defined fission product barriers whose status can be used to determine the severity of an accident and potential offsite consequences. These fission product barriers are the fuel cladding, the reactor coolant system (RCS) pressure boundary, and the containment. In a severe accident, the fuel cladding and the RCS pressure boundary are assumed to be significantly degraded or breached. The containment status, under these conditions, will determine the magnitude of offsite consequences. If the containment remains intact, like the TMI accident, or if it fails late, the offsite consequences can be non-existent or minimal. Table 2 shows the containment failure mechanisms and their predictability (8,9).

3 Figure 10.1 in this reference contains the predicted frequency of releases among five plants.

Table 2. **Containment failure mechanisms**

When	Failure	Is it predictable?
Start of accident	existing leak isolation failure bypass	no no no
Before vessel melt through	over pressurization hydrogen combustion late bypass late SGTR venting	no no no no yes
At or Soon After vessel melt-through	steam spike/explosion hydrogen combustion direct containment heating core melt contact with containment venting	no no no no yes
Later > 2 hours After vessel melt through	overpressurization hydrogen combustion basemat melt through	no no no

As Table 2 shows, given a core melt accident, containment performance remains unpredictable except for containment venting.

Evacuation Versus Sheltering

Human response to a major unfolding disaster depends on the availability of timely information to the key decision makers and the ability of those decision makers to use the information to make sound judgements about the best and most effective public protective measures. In a rapidly changing situation, like a severe reactor accident, time is of the essence. Decisions which impact large populations need to be made with minimum room for error. Experience has showed that in the early hours of an accident, critical information is scarce, and sometime later, the amount of information available to decision makers increases so rapidly in rate and volume that management and assessment becomes a challenge at a very critical time. Not all information is of equal value, nor is all information accurate. Sorting through the raw data to extract meaningful information during a crisis is particularly challenging.

During severe accidents, decision making should be simple and straight forward. There are many reasons for keeping the decision making process simple. Decisions that affect large populations usually involve many jurisdictions and agencies. These jurisdictions and agencies should be able to agree on the very basic issues and not be bogged down in controversy and detail. Since time is of the essence, the number of parameters affecting the decision should be reduced to a critical minimum.

Furthermore, whatever the decision, it has to be conveyed to the public in a manner that is understandable and reasonable. The official position should be presented to the public so that the average individual considers the recommendations to be implementable, adequate, and timely. Different jurisdictions should ensure consistency with each other when issuing their assessment of the risk and the recommended countermeasures. The decision makers should remain focused and be clear in their assessment. To achieve these objectives, the decision making process should remain simple.

In the United States, for severe reactor accidents, the principal protective action is evacuation, with sheltering serving as a suitable alternative under some conditions. This is based on the studies and estimations of the risks, uncertainties, and effectiveness of evacuation versus sheltering.

Studies such as NUREG-1150 have shown that the effectiveness of evacuation is "very site specific and source term specific. It is largely determined by two site parameters, namely, evacuation delay time and effective evacuation speed, and two source term parameters; namely, warning time before release and energy associated with the release (which during some meteorological conditions, could cause the radioactive plume to rise while being transported downwind.)" (6, p. 11-10)

In NUREG-1150, the effectiveness of various protective measures were evaluated for the Zion plant. The conditional probabilities of acute red bone marrow doses exceeding 200 rems and 50 rems were calculated for different protective measures. These protective measures were:

1. Normal activity: no protective actions were taken during the release but the people were relocated within 6 hours of plume arrival;

2. Home sheltering: Sheltering in a single family house. After an initial delay of 45 minutes from the reactor operator's warning, people get indoors and remain indoors and are relocated to uncontaminated areas within 6 hours of plume arrival. The penetration fractions for groundshine and cloudshine were representative of masonry houses without basements as well as wood frame houses with basements. Indoor protection for inhalation of radionuclides was assumed;

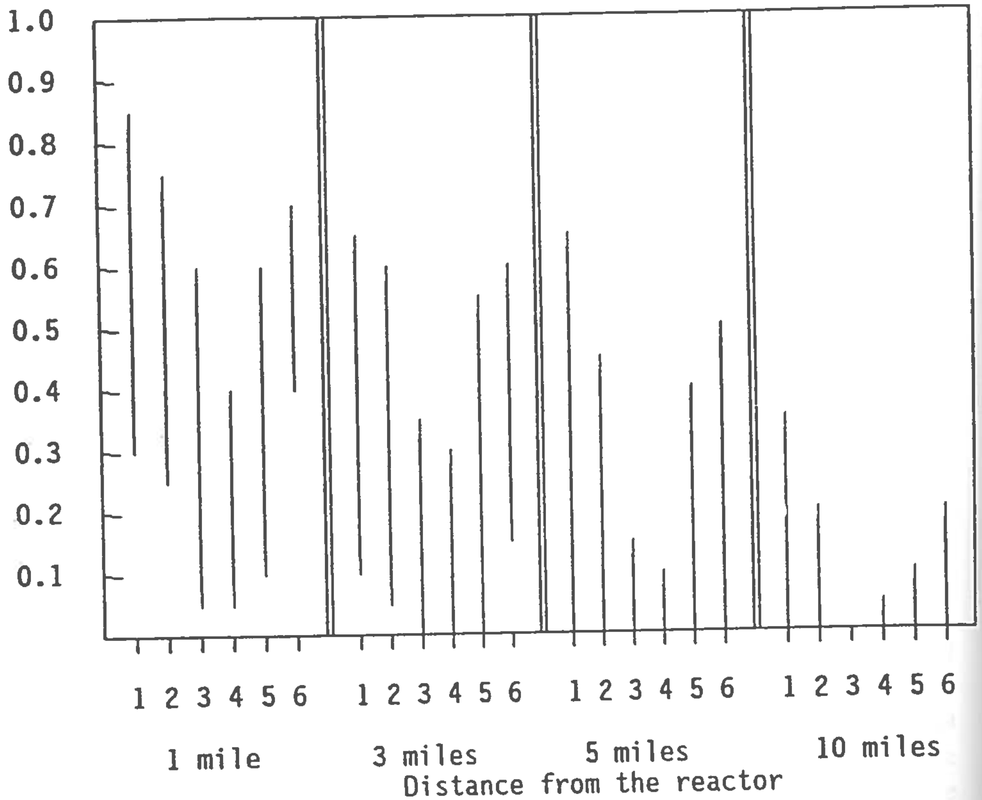
3. Large building shelter: sheltering in a large building, for example, an office building, hospital, apartment building, or school. Indoor protection for inhalation of radionuclides was assumed. People were relocated from the shelter mode within 6 hours of plume arrival;

4. Evacuation: doses were calculated for people starting to travel at the time of release, 1 hour before start of release, and 1 hour after start of release. An evacuation speed of 2.5 mph was assumed.

Figures 1 through 4 show the conditional probabilities of exceeding a 50-rem and a 200 rem red bone marrow dose for the various possible response modes assuming an early and late containment failure at Zion with source term magnitudes varying from low to high. It can be concluded that if a large release occurs, there is a large probability that doses may exceed 200 rems within 1 to 2 miles from the plant. Sheltering does not significantly lower this probability. Prompt evacuation would provide the best protection. At distances 3 miles and beyond, sheltering in large buildings provides comparable protection to prompt evacuation. Basement sheltering does not reduce the probability of exposure significantly.

In the event of a severe accident, prompt evacuation of areas nearby the plant offers the highest degree of public protection against acute health effects. In the case of late containment failure, there is time to complete evacuation of the population close in and avoid exposure entirely. For early containment failures, prompt evacuation provides protection better than, or as good as, sheltering in large buildings. Because of the unpredictability of containment performance, however, prompt evacuation of areas close in offers the highest assurance of public protection from acute doses.

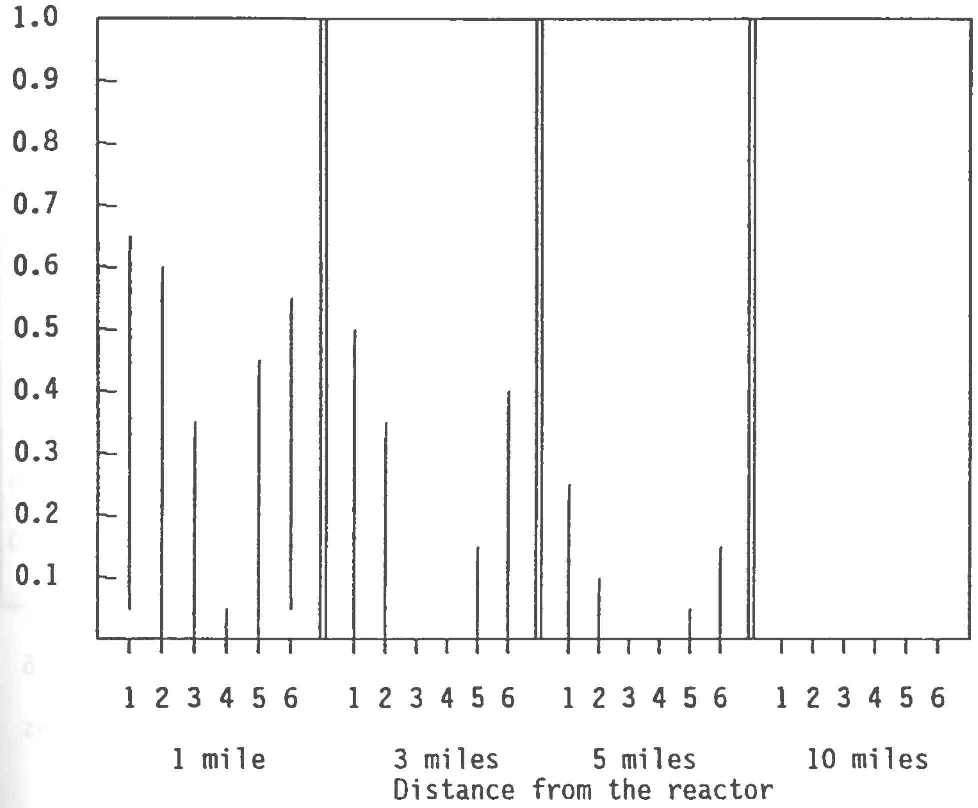
Figure 1. Probability of Exceeding 50-Rem Acute Red Bone Marrow Dose
Early Containment Failure



Note: The effects of different protective measures are depicted in the figure. The numbers denote different protective measures and are listed below:

1. normal activity
2. basement shelter
3. shelter in large building
4. start evacuation 1 hour before release
5. start evacuation at release
6. start evacuation 1 hour after release

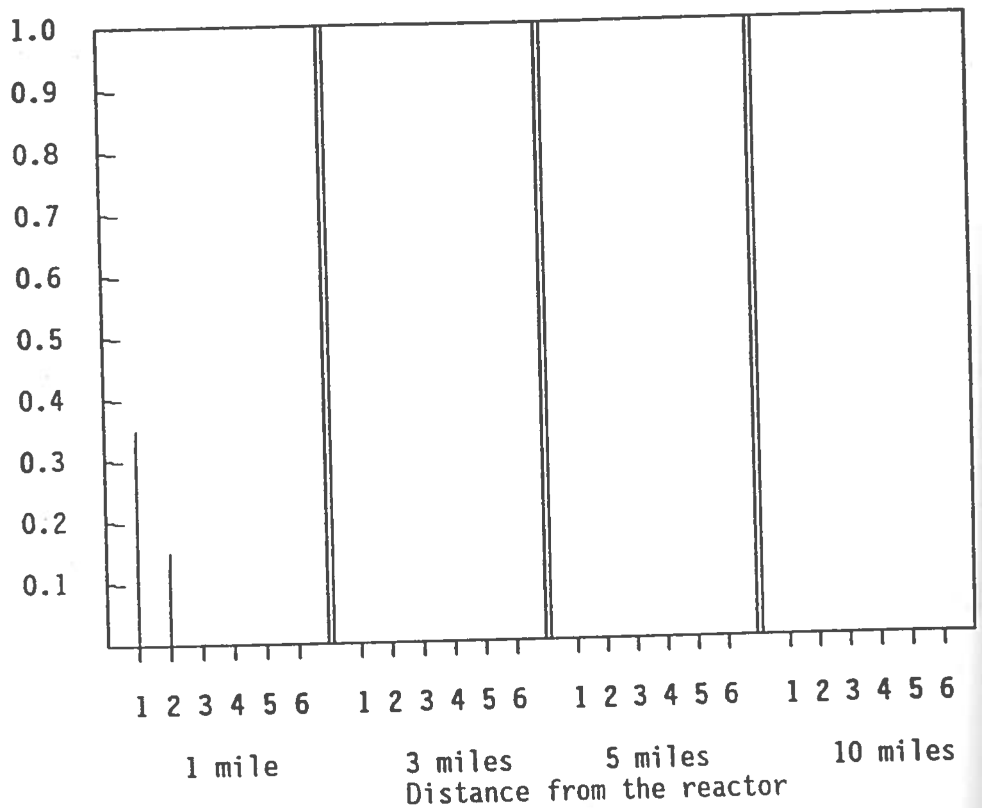
Figure 2. Probability of Exceeding 200-Rem Acute Red Bone Marrow Dose
Early Containment Failure



Note: The effects of different protective measures are depicted in the figure. The numbers denote different protective measures and are listed below:

1. normal activity
2. basement shelter
3. shelter in large building
4. start evacuation 1 hour before release
5. start evacuation at release
6. start evacuation 1 hour after release

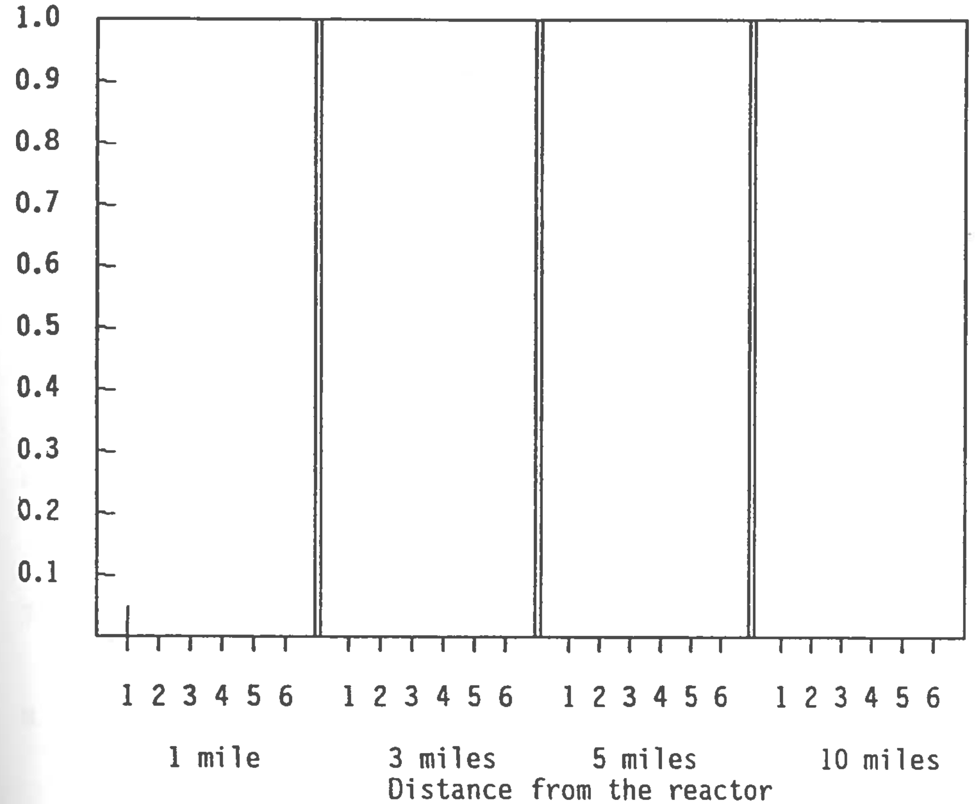
Figure 3. **Probability of Exceeding 50-Rem Acute Red Bone Marrow Dose Late Containment Failure**



Note: The effects of different protective measures are depicted in the figure. The numbers denote different protective measures and are listed below:

1. normal activity
2. basement shelter
3. shelter in large building
4. start evacuation 1 hour before release
5. start evacuation at release
6. start evacuation 1 hour after release

Figure 4. **Probability of Exceeding 200-Rem Acute Red Bone Marrow Dose Late Containment Failure**



Note: The effects of different protective measures are depicted in the figure. The numbers denote different protective measures and are listed below:

1. normal activity
2. basement shelter
3. shelter in large building
4. start evacuation 1 hour before release
5. start evacuation at release
6. start evacuation 1 hour after release

Conclusion

The EPA and the NRC have independently assessed the risks and benefits associated with evacuation and sheltering following severe reactor accidents. As part of the defense-in-depth concept, the two agencies have issued guidance on protective measures following radiological accidents. The guidance emphasizes the effectiveness of prompt evacuation in the vicinity of the plant. In the case of severe accidents and the associated uncertainties with the source term and containment behaviour, prompt evacuation offers the highest protection of the public against acute doses. Sheltering will be recommended in the areas farther away from the plant. Sheltering may be used as an alternative in special circumstances where evacuation is not feasible. The basis for this guidance is documented in the EPA Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.

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EFFECTIVENESS AND RISKS OF STABLE IODINE PROPHYLAXIS

by

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Abstract

The factors upon which the efficacy of stable iodine prophylaxis depends are reviewed, with particular reference to the dose of stable iodine, the timing of the dose, the influence of dietary iodine and the impact of other protective actions. The risks of stable iodine ingestion are estimated, and the their application to the principle of Justification is outlined.

Introduction

Stable iodine administration in the event of a nuclear power reactor accident appears to be assuming the status of a "desirable" protective measure. It seems to be so generally accepted that it is almost unquestioned. There appear to be a number of reasons for this: one is that it is the only substance available which has been clearly shown to afford protection, albeit only to the thyroid, during a nuclear accident. Another is that its administration carries with it trivial public health consequences. These two characteristics elevate stable iodine to a unique position in the preventive measures armamentarium and uncritical acceptance of its justification could lead to blanket application in situations where it might not be appropriate. In addition, these attributes make it very attractive for decision makers, who may feel obliged to adopt the policy if only to demonstrate that something is being done to protect the public. I do not wish to imply that I condemn stable iodine prophylaxis, but merely to alert you to the danger of uncritically adopting a measure which may not be as universally effective as we might hope. This is one of the questions that I hope we will be discussing over the next few days.

I have been given the task of summarizing my views on the effectiveness and risks of stable iodine administration as a preliminary step in our discussions.

Effectiveness

The criterion upon which to judge the effectiveness of stable iodine ingestion during a nuclear power reactor accident, is the level of dose to the thyroid averted, leading to a reduced risk from this exposure pathway. Stable iodine ingestion prior to exposure reduces the uptake of radioiodine by the thyroid in a number of ways, such as saturating the iodide transport mechanism, increasing the storage of stable iodine, impeding the re-circulation of radioiodine and by eliciting the Wolff-Chaikow effect. The oral administration of 100mg of stable iodine is effective in reducing the uptake of radioiodine to between 0.5 and 5%, provided it is given just before exposure. It becomes less effective as the time interval before or after exposure is extended. Thus a single dose of 100 mg of stable iodine given 24 hours before the radioiodine will reduce the uptake by about 60% and given 40 hours before, by 20-25%. If stable iodine is given 3 hours after radioiodine, it will reduce the uptake by up to 50%. Some reduction can be expected up to 6 hours after exposure to radioiodine, but by 10 hours, the administration of stable iodine will only have a minimal effect on uptake. The blockade induced by a single dose of 100 mg of stable iodine will be significantly reduced after about 48 hours, but it is interesting to note that ingestion prior to exposure confers a greater period of protection than ingestion of stable iodine after exposure. Where an accident continues to involve the release of radioiodine for an extended period, several daily doses of stable iodine may be necessary. After 11 days administration of 100 mg of iodine, the thyroid takes about six weeks to recover most of its iodine trapping function. Thus the timeliness of ingestion of stable iodine is a critical factor in its efficacy, being maximal just prior to exposure and falling within hours after exposure. The other major factor which influences the efficacy of stable iodine is the average uptake of radioiodine in the population that you are trying to protect. This varies quite widely, depending mainly on the level of dietary iodine. For example, in USA and Canada, where iodine is added as a supplement to the diet, average 24-hour uptakes are in the 20% range. However, in some countries with mild iodine dietary deficiency, such as south eastern

Germany, the uptake may be two or three times greater, which will enhance the protective effect of stable iodine ingestion and increase the dose averted. This will need to be considered in the optimization process, and may well work against the introduction of a harmonised approach even in the same general region.

Stable iodine administration should not be considered in isolation. It needs to be integrated with other short-term intervention measures such as sheltering and evacuation. Sheltering in cold climates, where buildings are constructed with minimal air exchange, can be an effective way to reduce thyroid dose; but in warmer climates where some reliance is placed on air exchange for cooling, sheltering will have virtually no effect on thyroid dose from inhalation. Evacuation prior to the passage of the plume may avoid the need for stable iodine prophylaxis, but if evacuation is deemed necessary during the passage of the plume, the evacuees could be more exposed to radioiodine, providing a compelling reason for stable iodine ingestion.

I have only dealt with the metabolic aspects of effectiveness. It is clear that the overall effectiveness of the countermeasure is dependent also on the logistics of the plan for timely distribution.

Effectiveness

1. Dose — 100 mg of iodine for an adult, less for children and infants.
2. Timing — Maximal just before exposure, useless 10 hours after exposure. Effective to some degree up to about 40 hours before exposure.
3. Uptake — The higher the average uptake, the greater the dose averted will be.
4. The influence of other protective actions.

Risk

The risks associated with stable iodine ingestion have been reviewed extensively in NCRP 55 and Iodine Prophylaxis following Nuclear Accidents published by WHO.

The adverse reactions to stable iodine can be divided into two categories: effects on the thyroid itself and other effects.

a) Effects on the Thyroid

Thyrotoxicosis: The induction of thyrotoxicosis has been observed in the treatment of iodine deficiency goitre, but in most areas where there is an adequate iodine intake, this should not be a problem, especially as the ingestion of stable iodine would be for a short period. This side effect has been noted where very much larger doses of stable iodine are ingested over a long period. There is the real possibility that these doses will provoke a recurrence of thyrotoxicosis in those patients who have been successfully treated for the disease in the past.

Hypothyroidism: Prolonged hypothyroidism is extremely rare after iodine ingestion. Transient hypothyroidism can be induced by the Wolff-Chaikoff effect, but this is usually self limiting and recovers within a matter of days. The foetus and neonate are more sensitive to the Wolff-Chaikoff effect than the adult. It is possible that persons who have been treated for hyperthyroidism or who have existing thyroid disease such as Hashimoto's disease can have hypothyroidism precipitated by iodine ingestion, although this ingestion needs to continue for several weeks. This is unlikely in the circumstances of a nuclear power reactor accident.

b) Other Effects

Swelling of Salivary Glands: A swelling of the salivary glands, which normally concentrate iodine, is only seen after gram doses of orally ingested iodine or intravenous iodine containing contrast media. It appears within two days and disappears within days of stopping iodine ingestion.

Cutaneous eruption (Cutaneous Iodism): This rare complication of a pustular skin rash occurs only in those who ingest iodine in large doses over long periods of time.

Other: Fever, generalised skin rash and arthralgia have been reported but are extremely uncommon. Allergic systemic reactions may require treatment in a few people if a large number are given prophylactic iodine.

It should be emphasized that many of the conditions listed above are only seen after large oral doses over a long period, or after intravenous iodine containing contrast media. They are most unlikely to be seen after a few daily

doses of 100 mg for the adult. In addition, these side effects disappear within days of stopping iodine ingestion.

Risk Estimates

Iodine, often in the form of Potassium Iodide, has been used extensively in medicine to treat respiratory disease especially asthma. NCRP 55 has estimated the frequency of side effects from data obtained from manufacturers of Potassium Iodide. One manufacturer produced about 43.2×10^6 therapeutic doses of 300 mg of KI solution per year and had not received any reports of adverse effects over a period of five years. Another manufacturer produced a further 4.9×10^6 doses of 300 mg of Potassium Iodide. Together, these two of the six manufacturers produced about 48×10^6 doses of 300 mg of KI, a significant underestimate of the actual production. During a seven year period, 168 adverse reactions were reported. Assuming that all 168 reactions in 7 years were to iodine, then it can be expected that there would be 24 reactions per year, and the reaction rate can be estimated at $24/48 \times 10^{-6}$ or 5×10^{-7}. In view of the obvious under-reporting of the doses and the dose reduction involved in stable iodine ingestion during a nuclear accident, it can be predicted that the risk to the general population would be of the order of 10^{-7}.

Pochin, in the WHO publication "Iodine Prophylaxis following Nuclear Accidents", quotes a report on the use of iodine containing contrast media in radiology of the urinary tract. This report notes a total of 26 deaths in 662,000 procedures involving the intravenous injection of 2.5 to 16.8 grams of iodine. Of these, eight deaths were thought to be due to the underlying disease or its complications, which gives a death rate of 2.7×10^{-5}. Other reports on smaller series appear to be consistent with this figure. These data can be regarded as the risk from iodine delivered intravenously in high doses, and are the upper bound on the risk of oral ingestion of iodine in milligram doses.

In the same WHO Publication, Nauman reviews the experience gained in Poland from the widespread use of Potassium Iodide following the Chernobyl accident. While this data is still being evaluated, Nauman reports that transient elevations in TSH, but not T3 or T4 were noted in about 10% of neonates who were treated. About 8 million adults took 70 mg of iodine once or repeated times, and it was noted that those who were euthyroid but who had had previous thyrotoxicosis, were prone to develop a recurrence of their hyperthyroidism. Of the 8 million adults treated, only three had severe allergic reactions (bronchospasm) which required treatment with intravenous steroids. The number of mild or moderate side effects (unspecified) was assessed at

5,000 in the adults. In the 10.5 million children who received Potassium Iodide, there were no reported adverse effects. From this, it can be calculated that the risk across the whole population for severe adverse effects is of the order of 1.6 x 10^{-7}, very similar to the previous NCRP estimate. In summary, it can be concluded that the risk of severe detriment to the general public from the oral ingestion of Potassium Iodide in the doses recommended for a nuclear accident is vanishingly small, of the order of 10^{-7}. Having reached this conclusion, perhaps we should discuss its impact on our deliberations and how we can use it.

This low risk to the general public from stable iodine ingestion strongly suggests that it can be implemented at low dose saving because the lack of inherent risk heavily weights the Justification analysis in its favour. However, we should try to arrive at a more quantitative comparison by comparing this predicted low risk with the risks involved in exposure to radioiodine.

WHO suggests that the total detriment risk from ^{131}I exposure is, over a lifetime, 8.4 x 10^{-3} Gy^{-1} at age less than 20 years, and 1.9 x 10^{-3} Gy^{-1} at age greater than 20 years. The 1991 Canadian census shows that the fraction of the population which is over 20 years of age is 0.723, giving an overall detrimental risk weighted for that population of 3.7 x 10^{-3} Gy^{-1} [(1.9 x 10^{-3} x 0.723) + (8.4 x 10^{-3} x 0.277)]. This would mean that for an average individual dose saving of 500 mGy, 18 persons with severe detriment would be avoided in a population of 10,000 exposed. For an average individual dose saving of 50 mGy, about 2 persons in 10,000 exposed would be saved severe detriment. Compared with the risk from stable iodine ingestion (10^{-7}), the same 10,000 people would run the risk of one in one thousand of a severe detriment occurring. It is therefore clear that stable iodine ingestion will be Justified, even at small dose savings. However, the next phase - Optimization - is not that easy and will need more sophisticated treatment.

THE ECONOMIC COSTS AND BENEFITS OF POTASSIUM IODIDE PROPHYLAXIS FOR A REFERENCE LWR FACILITY IN THE UNITED STATES

by

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Abstract

Policy decisions relating to radiation protection are commonly based on an evaluation in which the benefits of exposure reduction are compared to the economic costs of the protective measure. A generic difficulty countered in cost-benefit analyses, however, is the quantification of major elements that define the costs and the benefits in commensurate units. In this study, the costs of making KI available for public use and the avoidance of thyroidal health effects (i.e., the benefit) in the event of a nuclear emergency are defined in the commensurate units of dollars.

Introduction

Today, there are approximately 110 licensed power reactors in the United States that provide nearly 20 percent of the country's electricity. Most of these facilities are sufficiently close to major population centres that in the event of a major accident, human exposure to airborne radiation would be inevitable. Exposure to radioactive isotopes of iodine, in particular iodine-131, and the resulting irradiation of the thyroid gland presents possibly the most serious radiological risk from the accidental release of fission products into the atmosphere.

In the United States, the early and dominant hazard would arise from population exposure to a passing plume containing radioiodines and other radioactive fission products. There is unanimous scientific consensus that the administration of stable iodine can prevent thyroidal uptake of radioiodine with a near 100 percent efficiency. In spite of the effective remedial action of stable iodine, there are, however, some limitations on its use in protecting the public.

Policy decisions relating to radiation protection standards have to balance the benefits of exposure reduction to the economic impacts of protective measures. As a rule, whenever radiation exposures can be controlled by a protective measure, its endorsement by policy makers is linked to a favourable cost-benefit ratio. A major difficulty that is frequently encountered, however, is that the cost-benefit analysis requires value judgements for which there are few points of reference, and on which administrative and political authorities must, nevertheless, take a stand.

A common problem encountered in defining a cost-benefit ratio is the quantification of major elements that constitute the costs and the benefits. When the elements are expressed in their usual units, a highly subjective approach is required at the final stage of decision-making. Conversely, when all major elements that define the cost and the benefit of KI prophylaxis are expressed in the commensurate units of dollars, the decision can be supported by a defensible cost-benefit analysis.

The quantification of *cost* for the protective measure can be made by the conventional method of assigning monetary values to materials, labour, and other resources needed. The assignment of monetary values to avoidable radiation health effects, however, is not well established. For this reason, experts in several disciplines were consulted to provide guidance in assigning monetary equivalency values for thyroidal health effects that could potentially be avoided by the timely administration of KI.

Information presented in this chapter has been extracted from a comprehensive study performed by S. Cohen and Associates, Inc., McLean, Virginia and Scientech, Inc., Rockville, Maryland for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC-04-90-070 (see Behling 1992).

Due to the limited scope of this paper, only the most relevant topics are summarized for the derivation of cost-benefit ratios. Topics discussed include estimates for (1) the cost of providing KI to the public, (2) the potential magnitude and distribution of thyroid doses and associated thyroid health effects, and (3) the assigned monetary equivalence of avoidable thyroid health effects. Correspondingly, these topics are discussed in Section 1, 2, and 3, with Section 4 providing the cost-benefit ratios.

The reader is cautioned that the derived cost-benefit ratio values should not be viewed as rigid numbers. In addition to numerous uncertainties (most prominently the frequency of the severe accident release categories), the derived cost-benefit ratios include subjective factors and socioeconomic factors, which may not have the same values for facilities outside the United States.

The Cost of Providing KI

Critical to the assessment of cost is the method by which KI is made available to the general public. The two principal options include stockpiling and predistribution, and any policy decision must address not only the economic aspects but also logistical factors imposed by either option. Logistical considerations are governed by (1) the potentially short time interval between the initiating events of a serious reactor accident and atmospheric releases of radioiodines and (2) the need to administer KI prior to plume exposure for optimum thyroid protection. The timeliness of KI availability is most critical to persons living in close proximity to a nuclear facility where potential plume exposures are maximal and plume travel times are small.

In spite of the perceived advantage of timeliness for the predistribution option, there are limitations as well as disadvantages, which include the following:

- *Accessibility* - KI predistributed to households (and assumedly stored at the residence) may not be readily available during times when residents are at work, school, etc.

- *Availability* - At any point in time, there are transients as well as new residents to whom KI may not have been provided.

- *Loss or misplacement* - Based on a 5-year shelf-life/replacement period, there is a significant probability that tablets will be lost or misplaced during this lengthy time interval.

- *Improper storage* - Improper storage may adversely affect its shelf-life and potency at time of administration.

- *Misuse and accidental administration* - Like any pharmaceutical kept by a household, there is a potential for misuse and/or accidental administration with prolonged possession by the general public.

- *Improper disposal* - For expired tablets, there is a loss of control for proper disposal.

Per Capita Cost of Stockpiling: Most of the disadvantages associated with predistribution are either eliminated or minimized for the stockpiling option. A programme can be developed under the direction of a State's emergency management staff, which provides for the necessary controls and oversight of stockpiles. Thus, the benefits include proper storage, controlled access to stockpiles, assurance of adequate replacement and proper disposal of expired capsules.

With a properly trained emergency staff and an informed public, potential problems associated with a timely distribution of KI can be minimized. Timely distribution requires an adequate number of strategically located stockpiles within the community. Suitable locations include police stations, fire houses, schools, community centres, hospitals and major health care centres from which an efficient localized door-to-door distribution could be initiated or where residents themselves could procure the needed KI.

Beyond logistical and practical issues, cost considerations are likely to be the major factor in a policy decision that selects stockpiling, predistribution, or a combination of these two options.

A unique aspect of the stockpile option is that it is essentially transparent to the public and the cost of distribution to residents only becomes a reality in the unlikely event of a major nuclear emergency. Thus, for the stockpile option, the principal cost is the initial purchase of KI and its periodic replacement from the two FDA approved sources: Carter Wallace and ANBEX.

- *Carter-Wallace* - At the current purchase price of $75.00/carton containing 100 vials with 14 tablets of 130 mg KI per vial, the cost per tablet is about 5 cents. With a suggested 5-year shelf-life (*i.e.*, replacement period) and a 10-day supply (i.e., 10 tablets/individual), the annual cost of KI prophylaxis per individual is about 10 cents for the stockpiling option.

- *ANBEX* - The initial cost for 14 scored tablets of 130 mg KI in a moisture resistant blister pack is 60 cents per pack with a guaranteed 4-year shelf-life. Thereafter, annual payments of 15 cents per package would be required if, and only if, the stockpiled product can pass required FDA tests for stability and effectiveness. The annual stockpiling cost of KI procured from ANBEX would also be about 10 cents per individual.

For some nuclear facilities, additional costs might include the amendment of existing emergency plans to include protocols for distribution, public notification and training of the emergency staff. These one-time costs, however, are likely to be modest and may only marginally add to the baseline purchase/replacement cost of KI at 10 cents per year per individual.

Per Capita Cost of Predistribution: For predistribution, the cost of dispensing KI tablets to residents is an integral part of the programme cost. Additionally, for a predistribution programme to be effective, there has to be a very comprehensive public relations programme that not only informs the public of the objectives of iodide prophylaxis and provides supportive information regarding safe storage, proper usage, dosage, contraindications, etc., but also establishes public confidence. In summary, the cost for predistribution of KI includes the purchase/replacement of KI, the predistribution of tablets, and a comprehensive public information programme.

An assessment of cost for the predistribution option was derived from the Tennessee pilot programme in which State officials predistributed KI to residents within a 5-mile radius of the TVA's Sequoyah Nuclear Power Plant. Following the Three Mile Island Accident and the failure to provide KI to the public in a timely manner, an attempt was made to simulate distribution of KI to area residents as part of a nuclear emergency drill at the Sequoyah Plant operated by the Tennessee Valley Authority. On two separate occasions, the simulated distribution of KI to downwind residents was considered "too slow" with respect to plume arrival time in order to protect residents effectively (Fowinckle 1983).

As a result, Tennessee public health officials decided to predistribute KI to residents within a 5-mile radius of the power station. A significant consideration was the anticipated degree of public acceptance and anxiety induced by the predistribution of KI tablets. State health officials proceeded on the premise that open communications and proper explanations can achieve public acceptance. The method for predistribution included the following:

1. A letter from the Tennessee Commissioner of Public Health advised residents that a member of the local health department would come to their home to deliver a vial of KI tablets and to explain their proper use.

2. A trained field staff made house-to-house deliveries, provided technical information, and responded to questions.

3. News coverage of the project was extensive and involved local and national television and newspapers.

4. Each household was provided a package containing a child-proof capped vial of 14 tablets each containing 130 mg of KI.

5. The labelling on the vial and a package insert from the manufacturer provided carefully worded information and instructions that the drug was to be used only for thyroid-blocking in a radiation emergency.

It is estimated that the cost of predistribution of KI to the 3704 households around the Sequoyah Nuclear Power Plant was accomplished at the cost of about $125,000 (Fowinckle 1992, personal communication). On the assumption of a 5-year KI replacement schedule and that the average "household" represents four individuals, the cost per individual for the predistribution option is estimated at $1.70 per year. (It is important to note that this cost estimate is conservative since it does not consider the loss of KI within the 5-year interval or relocation of households into or out of the prescribed area.)

Population Distribution: The ratio of cost to benefit for KI prophylaxis is not a constant value but varies among population segments as a function of distance from the reactor. For individuals living close to a reactor facility where potential exposures are highest, the benefit (*i.e.*, avoidance of thyroid effects) is also highest per unit expense associated with the stockpiling/predistribution of KI tablets. For this reason, an attempt was made to determine representative population densities around reactor facilities as a function of distance.

To date, comprehensive information regarding population densities around nuclear facilities does not exist in the open literature. A suitable alternative was to construct a "Reference Population" density distribution from Final Safety Analysis Reports (FSARs) filed by utilities as part of the NRC licensing process. At the time of filing, FSARs typically contain the most current population data,

as well as projected data at 10-year intervals, taking into account national and regional population trends.

FSAR population data were obtained from the NRC's Public Document Room from all currently licensed light water reactor (LWR) facilities. For some licensees, however, population data were either insufficiently detailed or formatted so that the data could not be collated with that of other utilities. In total, usable population data were obtained for 55 LWR facilities representing 26 BWRs and 60 PWRs. Population data for 16 sectors were added to yield total population values for each successive annular area starting at the exclusion zone of a facility and out to a 50-mile radius.

Population densities beyond the 50-mile radius are not defined in FSARs and had to be derived by alternate means. All States in which at least one licensed commercial nuclear facility exists or whose borders are within 50 miles of a reactor facility were identified. The average population density was defined for each State by dividing the 1990 State population by the State's area defined in square miles. States with multiple reactors were weighted proportionately. An overall population density of about 200 individuals per square mile was thus obtained. This value was used to represent population density beyond a 50-mile radius.

Table 1. **Population Distribution for Reference LWR (representative of U.S. facilities)**

Distance Interval (miles)	Mean Population		
	Density (person/mile^2)	Total (persons)	
		Radial Segment	Cumulative
< 1	63	185	185
1 - 5	138	10,406	10,591
5 - 10	234	55,142	65,733
10 - 25	284	468,472	534,205
25 - 50	309	1,820,396	2,354,601
50 - 100	200	4,713,000	7,067,601
100 - 150	200	7,855,000	14,922,601
150 - 200	200	10,994,000	25,919,601
200 - 350	200	51,843,000	77,762,601
350 - 500	200	80,121,000	157,883,601

Annual Programmatic Costs: Annual cost estimates for providing KI to population segments of the reference LWR are readily derived by the multiplying annual per capita costs by the number of individuals residing within corresponding distance intervals. Table 2 cites annual costs with and without predistribution to the less than 5-mile population.

Table 2. **Annual Programmatic Costs of KI Prophylaxis**

Distance (miles)	Number of Individuals	Distribution Options			
		Stockpile		Combination*	
		segment cost (x $1000)	cumulative cost (x $1000)	segment cost (x $1000)	cumulative cost (x $1000)
< 5	10,591	1.1	1.1	18.2	18.2
5 - 10	55,142	5.5	6.6	5.5	23.7
10 - 25	468,472	46.8	53.4	46.8	70.5
25 - 50	1,820,396	182	235.4	182	252
50 - 100	4,713,000	471	706.4	471	723
100 - 150	7,855,000	786	1492	786	1509
150 - 200	10,997,000	1100	2592	1100	2609
200 - 350	51,843,000	5184	7776	5184	7793
350 - 500	80,121,000	8012	15,788	8012	15,805

* includes predistribution for the < 5-mile resident population.

Computer-Modeled Thyroid Exposures and Risks

The economic benefit of KI prophylaxis is the avoidance of potential thyroidal health effects that can be assumed to occur among exposed individuals following plume exposure associated with a severe nuclear accident. Thyroid health effects that are avoidable by the timely administration of KI include thyroid cancers (fatal and non-fatal), thyroid nodules, and hypothyroidism.

The expected occurrence of thyroidal health effects is determined primarily from thyroid doses received by individuals among the exposed population. In turn, thyroid doses are determined by numerous factors that include *i)* quantities of radioiodine species released into the atmosphere, *ii)* release duration, *iii)* plume dispersion, and *iv)* the location of individuals relative to the passing plume. Additionally, the thyroidal health risks are significantly modified by the age and sex of the exposed individual as well as the dietary intake of stable iodine.

An Overview of MACCS: For the calculation of population exposure doses, the MELCOR Accident Consequence Code System (MACCS) computer code was used (Chanin 1990; Rollstin 1990). Developed by Sandia National Laboratory under sponsorship of the U.S. NRC, MACCS was designed to support evaluations of the off-site consequences from hypothetical severe accidents at commercial nuclear power plants in which a plume of radioactive materials is released to the atmosphere. For such an accidental release, the radioactive gases and aerosols in the plume are dispersed in the atmosphere and transported by the prevailing winds. The fundamental uses of the MACCS computer model for off-site consequence estimates are to track the dispersal of radioactive material away from the accident site, to account for its eventual disposition in the environment, and to estimate potential exposure doses to the surrounding population from plume inhalation, plume immersion, cloudshine, and ground deposition.

The MACCS code also allows for the substitution of default values with values considered more appropriate. Based on current information cited by BEIR V, ICRP Publications, NCRP Reports, NUREGs, and other scientific publications, age- and sex-specific model parameters were selected by which integrated air concentrations were converted to individual thyroid doses and thyroid risks. For the determination of population or collective thyroid doses/risks, the most recent 1990 U.S. population census data were used.

Core Inventory and Source Term

Core Inventory: The radioactive inventory of the core at accident initiation (e.g. reactor scram) is a major input parameter. The core inventory is a function of the type and the operating power of the reactor and the duration of operation after loading fuel.

The core inventory of a pressurized water reactor (PWR) of thermal power of 3050 MW at the end of power cycle was used for the calculation. The inventory of seven radionuclides most relevant to thyroid exposure is given in Table 3. The isotopes Te-131m and -132 are important as they decay into I-131 and -132 respectively.

Table 3. **Core Inventory of Pertinent Isotopes**

Isotope	Inventory (Ci)
Te-131m	1.13E7
Te-132	1.12E8
I-131	7.74E7
I-132	1.14E8
I-133	1.64E8
I-134	1.80E8
I-135	1.54E8

Source Term: The atmospheric source term produced by an accident is defined by the number of plume segments released, sensible heat content, timing, duration, height of each segment of release, and for each important radionuclide, the fraction of that radionuclide's release with each plume of release. Using similar chemical characteristics, MACCS segregates 60 radionuclides into 9 release categories. These categories are represented by noble gas, iodine, cesium, tellurium, strontium, rubidium, lanthanum, cerium, and barium.

For estimates of thyroid exposures and thyroid health effects, radiological source terms were identified for the Surry Nuclear Power Plant, which is considered representative of a U.S.-design LWR. The source terms employed by MACCS correspond to principal reactor accident release categories, which do *not* describe individual accident sequences but rather correspond to distinct *groups* of accidents. A detailed description of reactor release categories for the Surry Nuclear facility is contained in NUREG-1150.

For the Surry plant, the accident sequences that lead to core damage and in the *release* of significant quantities of radioactivity are grouped into four release categories (Table 4).

The principal tool used in NUREG-1150 for characterizing possible scenarios is the Accident Progression Event Tree (APET). The event tree is a computational tool used to display the combination of plant-system failures that can result from an accident initiating event. Initiating events include support-system failures such as electric power or cooling system water faults. From system event trees, combinations of plant-system failures are identified that can result in core damage for each initiating event. An individual path through such an event tree (a specific accident sequence) identifies a unique combination of system successes and failures leading to (or avoiding) core damage. As such, the event tree qualitatively identifies what systems must fail in a plant in order to advance the initiating event toward core damage.

In order to estimate the frequency of individual accident sequences, the failure probability of each system is obtained. The important contributors to failure of each system are defined using fault-tree analysis methods. Such methods allow the analyst to identify the ways in which system failure may occur, assign failure probabilities to individual plant components (e.g. pumps, valves, electrical components, etc.) and human responses to the system's operation, and combine the failure probabilities of individual components into an overall system failure probability. Thus, for a given initiating event, there are many permutations of intermediate events (*i.e.* accident sequences), which may all lead to the common endpoint of core damage.

The four accident release categories identified in Table 4 represent *all* the accidents postulated for the Surry nuclear plant in which significant quantities of radioactivity are released. Important characteristics include the accident frequency, release time(s), release duration(s), and source term (*i.e.* fraction of core inventory released). For the first three categories, the initiating event of the accidents is the loss of off-site power, while for the other category, RSUR-4, the initiating event is containment bypass resulting from a large break in a system interfacing with the primary reactor cooling system. The highest release of iodine is associated with the release category RSUR-1, in which the containment rupture coincides with the breach of the reactor pressure vessel induced by steam explosions. For the RSUR-2 category, the containment failure involves a leak and follows the occurrence of corium and concrete interaction (CCI). For RSUR-3, the containment functions as intended, and a release occurs through a leak that is within the design limits of the containment. The RSUR-3 source term is further mitigated by the operation of a containment spray system, which is not available for the other three categories. For RSUR-4, no containment failure occurs, but two plumes are released by bypassing the containment. For all four accident categories, CCI occurs, and the reactor coolant system is at low pressure (<200 psia) at the breach of the reactor pressure vessel.

Plume Centreline Thyroid Doses by Age and Sex

Tables 5 through 8 present the plume centreline thyroid doses from all applicable exposure pathways in behalf of seven population subgroups located at discrete distances from the reactor facility. Independent of reactor accident release category, a comparison of thyroid doses among the sub-populations reveals that the male child (age 1-12) receives the highest thyroid doses while the adult female receives the lowest. Subgroup differences reflect the impact of age- and sex-specific variations (*i.e.* ventilation rate, iodide metabolism, and thyroid mass) on the thyroid dose. The last column in each of the four tables defines the plume centreline dose to the "average person." This set of values was derived by weighting each subgroup value by its respective percentage of the total population. For near-field residents residing within a five-mile radius, thyroid exposures in the thousands of rads are estimated for RSUR-1, RSUR-2, and RSUR-4. Thyroid doses for RSUR-3 are lower by several orders of magnitude and beyond 10 miles may be considered trivial.

Table 4. Radionuclide Release Characteristics into the Environment for Surry

Source Term	Freq. (yr^{-1})	Rel. Time (h)	Release Duration	Fraction of Core Inventory Released								
				NG	I	Cs	Te	Sr	Ru	La	Ce	Ba
RSUR-1	2.9E-7	6	200 s	1	0.25	0.18	0.08	0.02	0.005	0.001	0.005	0.02
		6.06	2 h	0	0.1	0.13	0.1	0.04	0.001	0.005	0.005	0.04
RSUR-2	2.4E-6	12	3 h	1	0.06	0.03	0.09	0.003	0.001	4E-4	4E-4	3E-3
RSUR-3	3.3E-5	6	10 h	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2E-10	3E-10	4E-10	2.5E-9
		16	10 h	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2E-10	3E-10	4E-10	2.5E-9
RSUR-4	1.6E-6	1	30 min	1	0.075	0.06	0.02	0.005	0.001	3E-4	0.001	0.005
		1.5	2 h	0	0.04	0.06	0.05	0.02	6E-04	0.003	0.003	0.02

Population Thyroid Health Effects

Population thyroid health effects for the reference LWR are estimated by deriving the cumulative population thyroid exposure for each population subgroup and applying the appropriate risk coefficient. The percentage of individuals representing each sub-population for the reference LWR was assumed identical to that of the whole U.S. population, as defined by 1990 census data. By multiplying the age- and sex-adjusted populations at fixed radial distances with the corresponding thyroid dose values of the exposed individuals, population thyroid doses were derived for each distance interval. It is important to point out that the exposed population is limited to individuals within the plume pathway, which based on dispersion parameters may represent only a small fraction of the total population residing 360 degrees around a reactor facility. Additionally, thyroid doses within the plume pathway for any given radial distance are assumed to exhibit a Gaussian distribution whose maximum value approximates the plume centerline values cited in Tables 5 through 8.

Population thyroid doses are converted to thyroid health effects by means of the risk coefficients for thyroid cancer, thyroid nodules, and hypothyroidism. For example, for I-131, the lifetime risk coefficients (weighted for the U.S. population based on age and sex) of 23.2, 2.3, and 44.7 per 10^6 person-thyroid rads were used to estimate total thyroid cancers (fatal and non-fatal), fatal thyroid cancers, and thyroid nodules, respectively. The derived numbers of thyroid health effects estimated to occur within selected distance intervals for the four accident categories are given in Table 9. Estimates of thyroid effects represent a population exposed under normal conditions with no KI. The number of expected thyroid effects is highest for RSUR-1, followed by RSUR-4 and RSUR-2. The small release fraction for RSUR-3 results in small population thyroid doses and yields estimates of less than 0.5 excess thyroid cancers and nodules for all population segments. A less than 0.5 probability of observing a single thyroid cancer or nodule for a population cell is reported as a zero (0) value.

The numbers of cases of hypothyroidism for the four accident categories are also shown in Table 9. Since hypothyroidism is a non-stochastic effect with a dose-threshold, its occurrence is limited to those populations in which individual thyroid doses exceed threshold values. With the exception of RSUR-1, the likelihood of exceeding the threshold value is minimal beyond a distance of 25 miles.

Avoidable Thyroid Health Effects

The potential reduction in the mean number of thyroid effects that would result from the use of KI is governed by the fraction of the thyroid dose from the inhalation exposure of radioiodide. When KI is properly administered, it reduces internal thyroid exposure from radioiodides with a 99% efficiency.

The prophylactic value of KI, however, is limited to reducing *internal* exposure to the thyroid from radioiodides. However, it is important to recognize that *not* all thyroid exposure is mitigated by KI. About 90% of thyroid exposure results from the internal dose of radioiodides, of which I-131 is the dominant form. A small fraction of the thyroid dose comes from the combined inhalation of *non*-radioiodides, and external exposure resulting from plume immersion, cloudshine, and ground deposition.

Accordingly, the number of thyroid health effects that can potentially be avoided if KI is administered under optimal conditions is shown in Table 10. Thus, for RSUR-1 among the less than 5-mile population, 119 thyroid cancers are avoidable through the timely administration of KI among the 137 expected thyroid cancers.

Table 5. **Plume Centerline Thyroid Doses* (rem) for RSUR-1 Versus Distance**

Distance Range (mi)	Infant	Female Child	Male Child	Female Teenage	Male Teenage	Female Adult	Male Adult	Average Person
< 5	2.0E+04	3.4E+04	4.2E+04	2.2E+04	2.6E+04	8.1E+03	1.1E+04	2.0E+04
5-10	7.4E+03	1.3E+04	1.6E+04	8.1E+03	9.8E+03	3.0E+03	4.2E+03	7.3E+03
10-25	1.8E+03	3.1E+03	3.8E+03	1.9E+03	2.4E+03	7.3E+02	1.0E+03	1.8E+03
25-50	3.0E+02	5.2E+02	6.3E+02	3.3E+02	4.0E+02	1.2E+02	1.7E+02	3.0E+02
50-100	6.9E+01	1.2E+02	1.5E+02	7.7E+01	9.3E+01	2.9E+01	3.9E+01	7.0E+01
100-150	3.1E+01	5.5E+01	6.8E+01	3.5E+01	4.2E+01	1.3E+01	1.8E+01	3.2E+01
150-200	1.9E+01	3.4E+01	4.2E+01	2.1E+01	2.6E+01	7.9E+00	1.1E+01	1.9E+01
200-350	8.2E+00	1.5E+01	1.9E+01	9.5E+00	1.2E+01	3.5E+00	4.7E+00	8.5E+00

Table 6. **Plume Centerline Thyroid Doses* (rem) for RSUR-2 Versus Distance**

Distance Range (mi)	Infant	Female Child	Male Child	Female Teenage	Male Teenage	Female Adult	Male Adult	Average Person
< 5	5.6E+03	1.0E+04	1.2E+04	6.7E+03	8.1E+03	2.8E+03	3.9E+03	6.1E+03
5-10	7.0E+02	1.2E+03	1.5E+03	8.2E+02	9.9E+02	3.5E+02	4.8E+02	7.5E+02
10-25	1.3E+02	2.4E+02	2.9E+02	1.6E+02	1.9E+02	6.8E+01	9.2E+01	1.5E+02
25-50	2.2E+01	4.0E+01	4.9E+01	2.7E+01	3.2E+01	1.1E+01	1.6E+01	2.5E+01
50-100	5.1E+00	9.2E+00	1.1E+01	6.1E+00	7.4E+00	2.6E+00	3.6E+00	5.6E+00
100-150	2.3E+00	4.2E+00	5.1E+00	2.8E+00	3.4E+00	1.2E+00	1.6E+00	2.5E+00
150-200	1.4E+00	2.5E+00	3.1E+00	1.7E+00	2.0E+00	7.0E-01	9.6E-01	1.5E+00
200-350	6.1E-01	1.1E+00	1.4E+00	7.5E-01	9.1E-01	3.1E-01	4.3E-01	6.9E-01

* Thyroid dose includes all radionuclides and pathways (i.e., inhalation, cloudshine, plume immersion, ground deposition); exposure condition is for "normal activity."

Table 7. **Plume Centerline Thyroid Doses* (rem) for RSUR-3 Versus Distance**

Distance Range (mi)	Infant	Female Child	Male Child	Female Teenage	Male Teenage	Female Adult	Male Adult	Average Person
< 5	1.8E+00	3.0E+00	3.7E+00	1.9E+00	2.3E+00	6.8E-01	9.3E-01	1.7E+00
5-10	2.2E-01	3.8E-01	4.7E-01	2.4E-01	2.9E-01	8.8E-02	1.2E-01	2.2E-01
10-25	4.5E-02	7.7E-02	9.5E-02	4.9E-02	5.9E-02	1.8E-02	2.4E-02	4.4E-02
25-50	8.5E-03	1.5E-02	1.8E-02	9.3E-03	1.1E-02	3.3E-03	4.5E-03	8.3E-03
50-100	1.9E-03	3.4E-03	4.1E-03	2.1E-03	2.5E-03	7.4E-04	1.0E-03	1.9E-03
100-150	8.1E-04	1.4E-03	1.8E-03	8.9E-04	1.1E-03	3.1E-04	4.2E-04	7.9E-04
150-200	4.7E-04	8.5E-04	1.0E-03	5.2E-04	6.3E-04	1.8E-04	2.5E-04	4.7E-04
200-350	1.9E-04	3.5E-04	4.3E-04	2.2E-04	2.6E-04	7.6E-05	1.0E-04	1.9E-04

Table 8. **Plume Centerline Thyroid Doses* (rem) for RSUR-4 Versus Distance**

Distance Range (mi)	Infant	Female Child	Male Child	Female Teenage	Male Teenage	Female Adult	Male Adult	Average Person
< 5	5.8E+03	9.8E+03	1.2E+04	6.3E+03	7.6E+03	2.5E+03	3.4E+03	5.8E+03
5-10	2.2E+03	3.6E+03	4.5E+03	2.3E+03	2.8E+03	9.0E+02	1.2E+03	2.1E+03
10-25	5.1E+02	8.6E+02	1.1E+03	5.5E+02	6.6E+02	2.1E+02	2.9E+02	5.0E+02
25-50	8.6E+01	1.5E+02	1.8E+02	9.4E+01	1.1E+02	3.6E+01	5.0E+01	8.5E+01
50-100	2.0E+01	3.4E+01	4.2E+01	2.2E+01	2.6E+01	8.4E+00	1.1E+01	2.0E+01
100-150	8.9E+00	1.6E+01	1.9E+01	1.0E+01	1.2E+01	3.8E+00	5.2E+00	9.0E+00
150-200	5.3E+00	9.4E+00	1.2E+01	6.0E+00	7.3E+00	2.3E+00	3.1E+00	5.4E+00
200-350	2.3E+00	4.2E+00	5.2E+00	2.7E+00	3.2E+00	9.9E-01	1.4E+00	2.4E+00

* Thyroid dose includes all radionuclides and pathways (i.e., inhalation, cloud-shine, plume immersion, ground deposition); exposure condition is for "normal activity."

Table 9. **Population Thyroid Effects for Normal Activity with No KI***

Distance Interval (miles)	A - Total Thyroid Cancers				B - Fatal Thyroid Cancers			
	RSUR-1	RSUR-2	RSUR-3	RSUR-4	RSUR-1	RSUR-2	RSUR-3	RSUR-4
< 5	137	58	0	52	14	6	0	5
5 - 10	278	59	0	105	28	6	0	11
10 - 25	432	72	0	157	43	7	0	16
25 - 50	351	58	0	128	35	6	0	13
50 - 100	232	36	0	84	23	4	0	8
100 - 150	174	27	0	63	17	3	0	6
150 - 200	138	21	0	49	14	2	0	5
200 - 350	264	41	0	93	26	4	0	9
350 - 500	449	72	0	153	45	7	0	16
Distance Interval (miles)	**C - Thyroid Nodules**				**D - Hypothyroidism**			
	RSUR-1	RSUR-2	RSUR-3	RSUR-4	RSUR-1	RSUR-2	RSUR-3	RSUR-4
0 - 5	361	155	0	139	150	31	0	33
5 - 10	726	157	0	283	186	11	0	49
10 - 25	1123	193	0	420	146	1	0	21
25 - 50	909	154	0	340	11	0	0	0
50 - 100	594	94	0	220	0	0	0	0
100 - 150	438	70	0	162	0	0	0	0
150 - 200	343	55	0	124	0	0	0	0
200 - 350	635	103	0	230	0	0	0	0
350 - 500	962	168	0	340	0	0	0	0

Table 10. **Potential Net Reduction in Population Thyroid Effects with KI Prophylaxis**

Distance Interval (miles)	A - Total Thyroid Cancers				B - Fatal Thyroid Cancers			
	RSUR-1	RSUR-2	RSUR-3	RSUR-4	RSUR-1	RSUR-2	RSUR-3	RSUR-4
0 - 5	119	41	0	44	12	4	0	4
5 - 10	241	42	0	89	24	4	0	9
10 - 25	374	51	0	133	37	5	0	13
25 - 50	301	40	0	107	30	4	0	11
50 - 100	197	25	0	70	20	2	0	7
100 - 150	148	18	0	52	15	2	0	5
150 - 200	117	15	0	41	12	1	0	4
200 - 350	223	28	0	77	22	3	0	8
350 - 500	388	53	0	131	39	5	0	13
Distance Interval (miles)	**C - Thyroid Nodules**				**D - Hypothyroidism**			
	RSUR-1	RSUR-2	RSUR-3	RSUR-4	RSUR-1	RSUR-2	RSUR-3	RSUR-4
0 - 5	303	103	0	114	99	28	0	32
5 - 10	609	103	0	231	180	10	0	48
10 - 25	937	124	0	342	144	1	0	21
25 - 50	748	98	0	272	11	0	0	0
50 - 100	482	60	0	174	0	0	0	0
100 - 150	355	43	0	128	0	0	0	0
150 - 200	276	34	0	98	0	0	0	0
200 - 350	504	63	0	177	0	0	0	0
350 - 500	769	105	0	261	0	0	0	0

The Monetary Value of Avoidable Health Effects

For cost-benefit analyses, the monetary equivalence of human illness and disease must be assessed for the patient, family, and society. The burden of illness may include financial losses, pain and suffering, reduced quality of life, and premature mortality. At a minimum, the economic benefits must consider the cost of resources used for medical care and the loss of human resources due to morbidity, disability, and premature death. Additional consideration should be given to the impact of disease, injury, or death on the quality of life for the affected individual and family members.

This comprehensive approach, termed the "cost-of-illness" approach, was pioneered by Dorothy Rice, former Director of the National Centre for Health Statistics (Rice 1985). In brief, this methodology is defined by three components that include: direct medical costs, morbidity/mortality costs, and psychological costs.

Direct costs include resources used for medical care from the time of diagnosis until total recovery or death. Morbidity and mortality costs, when combined, are referred to as indirect costs (Hodgson 1984). Indirect costs are the time and output lost or forgone by the individual and/or family members from employment (including imputed earnings for domestic work), volunteer activities, and leisure. Lastly, morbidity and mortality invariably cause patients and family members to incur psychological costs, such as pain and suffering, impaired function in personal relationships, and a general reduction in the quality of life.

Derivation of Direct Costs

Direct cost estimates of radiation-induced thyroid illness include medical costs associated with the initial diagnosis, treatment of the disease, and the long-term management, surveillance, and care of the patient. Estimates of costs for relevant diagnostic procedures, treatments, hospitalization, etc. are based on 1991 U.S. Government and private insurers' reimbursement schedules defined by Physicians' Current Procedural Terminology (CPT) Codes. CPT is a listing of descriptive terms and identifying codes for reporting medical services and procedures performed by physicians under Government and private health insurance programmes. Additional information was obtained from the Health Care Financing Administration Division (HCFA) of the U.S. Department of Health and Human Services.

The following cost estimates were derived for thyroid neoplasms and hypothyroidism:

Thyroid Nodules: Benign nodules may or may not require surgery. In either case, costs include the initial diagnosis, treatment, and long-term follow-up. For long-term follow-up of potential patients resulting from an accidental exposure, an average residual life-expectancy of 30 years is assumed following the initial diagnosis of a nodule. Estimates of costs for long-term patient management and surveillance include routine office visits, hormone replacement therapy, and diagnostic procedures. For a benign thyroid nodule that does not require surgery, lifetime medical costs of $5,148 to $7,375 were estimated. When surgery is required, direct medical costs for a benign nodule range between $11,820 and $14,047. For either situation, the upper value reflects the discretionary use of ultrasound for patient evaluation. For a detailed analysis of these and subsequent cost estimates, the reader is referred to the original NRC-sponsored study.

Thyroid Cancer: The major cost difference between a thyroid cancer and a thyroid nodule is the need for aggressive treatment of the former. Medical costs for a thyroid malignancy are estimated to be $15,413 to $19,348. This range in cost estimates may, nevertheless, be low in instances where residual thyroid tissue is suspected of malignancy following an initial course of treatment. In cases of persistent suspected malignancy, additional I-131 therapies and associated procedures and services are required. It is estimated that each additional I-131 therapy would increase the total cost by about $4,000. In rare instances, up to 10 separate therapeutic treatments may be required for the total eradication of malignancy.

For the 10% of thyroid malignancies that are fatal, cost estimates are adjusted to reflect (1) the reduced follow-up period of medical care and (2) the terminal patient care costs. Based on mean survival times of papillary and follicular thyroid cancers, the mean follow-up period of 35 years assumed for non-fatal cancer is reduced to 9.4 years. It is estimated that the average terminal care of a cancer patient costs about $16,000.

Given the options that are available for the treatment and management of thyroid malignancies and the multiple therapeutic treatments, the following direct costs are assigned to thyroid cancer:

Non-fatal Thyroid Malignancy = $20,000
Fatal Thyroid Malignancy = $32,000

Hypothyroidism: Medical costs in cases of radiation induced hypothyroidism are limited to initial diagnostic tests, which confirm the reduction or loss of thyroid function, hormone replacement and management, and follow-up evaluation of thyroid status. Cost estimates are based on a 35-year life-expectancy following the diagnosis and loss of thyroid function. For hypothyroidism, medical costs are estimated to be $5,669.

Table 11. **Summary of direct medical costs of the radiation thyroid effects under consideration.**

Thyroid Disorder	Total Direct Cost ($)
Thyroid Nodule*	9,600
Thyroid Cancer - Non-fatal - Fatal	 20,000 32,000
Hypothyroidism	5,600

* assumes that 50% of nodules require surgery

Derivation of Indirect Costs

Indirect costs principally reflect the time and output lost or forfeited by the patient due to illness, permanent disability, and premature mortality. Indirect costs may also be incurred by individuals other than the patient who may forego economic activities to accommodate a family member's illness. Economic activities include occupational work that is lost to either the patient or his/her employer, as well as non-occupational (e.g. domestic) work that must be performed by someone else at the expense of the patient. The number of days appropriated to long-term management of the disorder is based on the average remaining years of life following diagnosis and latency periods. A special case involves a thyroid malignancy, which may result in premature death.

In addition to time lost from economic activity due to illness, a patient may also be permanently impaired and/or disabled. Permanent impairment or disability can reduce a patient's ability to be fully effective in occupational or

economic activities and must, therefore, be included in assessing the total indirect cost.

The American Medical Association has published *Guides to the Evaluation of Permanent Impairment (AMA 1990)*. These Guides provide a reference framework within which physicians may evaluate and report medical impairments.

The AMA provides guidelines for evaluating permanent medical impairment of the thyroid due to hypothyroidism from radiation exposure or thyroidectomy as follows (AMA 1990):

Class 1 - A patient belongs in Class 1 when: (a) continuous thyroid therapy is required for correction of the thyroid insufficiency or for maintenance of normal thyroid activity, and (b) there is no objective physical or laboratory evidence of inadequate replacement therapy.

Class 1 Level of Impairment of the Whole Person: 0 - 10%

Class 2 - A patient belongs in Class 2 when, (a) symptoms and signs of thyroid disease are present, or there is anatomic loss or alteration and (b) continuous thyroid hormone replacement therapy is required for correction of the confirmed thyroid insufficiency; but (c) the presence of a disease process in another body system or systems permits only partial replacement of the thyroid hormone.

Class 2 Level of Impairment of the Whole Person: 15 - 20%

In this report, the central value of 5% for Class 1 permanent impairment is applied to the permanent hypothyroid conditions that are likely to result from (1) high radiation exposure doses received accidentally, (2) from the radiotherapy treatment for toxic nodules/cancer, or (3) the surgical removal of nodules/cancer. It will further be assumed that this 5% medical impairment results in a 5% disability for occupational and non-occupational economic activities for the affected individual, family members, and/or society.

The conversion of time lost from economic activities to equivalent dollars was achieved by means of the Gross National Product (GNP). The GNP is considered the most comprehensive measure of the country's economic activity and includes the market value of all goods and services that have been bought for final use during a year. From the Gross National Product of $5,200 billion in 1989, the gross average annual per capita income of about $21,000 is derived. This value of $21,000 per year can be used to determine the equivalent dollar value for the number of days lost over the lifetime of an individual afflicted with a thyroid condition. This value can also be applied to determine the equivalent value of a 5% permanent disability (*i.e.* a 5% disability equates to about $1000 annually in reduced income). Table 12 provides estimates of the total average indirect costs associated with thyroid disorders.

Table 12. **Average Lifetime Indirect Costs Associated with Thyroid Disorders**

Thyroid Disorder	Lifetime Indirect Costs ($)		
	For Time Lost	For Disability (%5)	Total
Thyroid Nodule	3,337	30,000	33,337
Thyroid Cancer			
Non-Fatal	3,625	35,000	38,625
Fatal	619,586	9,400	628,986
Hypothyroidism	3,222	35,000	38,222

Derivation of Psychological Costs

Disease may cause numerous changes and impositions on the lives of the patient and family members that may in part be linked to, but are not reflected in the direct and indirect economic costs identified above. The wide variety of deteriorations in the quality of life (QOL) brought on by illness are frequently referred to as psychological costs. For thyroid neoplasms and dysfunction, a deterioration in the quality of life may be precipitated by the loss of bodily function, a lifetime dependence on medication, hormonal instability, disfigurement from surgical scars, the uncertainty of normal life expectancy, and reduced financial security.

Although psychological costs are consistently identified as a major cost component by health care researchers and economists, no formal attempt has been made to quantify these costs in monetary terms (Hodgson 1984; Rice 1985; Brown 1990). The reason for this omission is obvious. From the forgoing

discussion, it is safe to conclude that the intangible dimensions that define the quality of life are (1) highly subjective; (2) vary greatly among individuals, and in time and space; and (3) are not readily expressed in monetary terms. Independent of these difficulties, past instances of excluding psychological costs may have been justified for conditions in which the health effect is of unknown origin, self-inflicted or unavoidable.

The omission of psychological costs, however, is not readily justified for situations in which the health effect is clearly avoidable, or is the consequence of negligence or wrongful action of a second party. In litigation cases of wrongful injury or death, monetary compensation for psychological cost factors are consistently awarded and exceed those involving medical costs or loss of earnings. The thyroid health effects under consideration in this report must clearly be considered avoidable through the optional administration of KI. Additionally, accidental public exposure to radioiodine is likely to be viewed as the direct or indirect consequence of human negligence or wrongful actions. A complete cost-benefit analysis of KI prophylaxis should, therefore, include estimates of psychological costs expressed in units of dollars.

Based on the monetary awards for the radiation and non-radiation injury claims (see Appendix D of the NRC-sponsored study) and the opinion expressed by a subject matter expert, the psychological cost component for any of the aforementioned radiation-induced thyroid health effect is estimated to be $500,000.

Summation of Thyroid Health Effects Cost

Table 13 summarizes all previously derived values for the direct medical costs, the indirect costs of lost economic opportunities, and the psychological costs attributed to the reduced quality of life for each of the thyroid disorders considered in this report. For all thyroid effects, the direct medical cost for diagnosis, treatment, and follow-up represents the smallest contribution to the total cost.

Table 13. **Average Total Cost Per Radiation-Induced Thyroid Effect**

Thyroid Effect	Direct ($)	Indirect ($)	Psychological ($)	Total ($)
Nodule	9,600*	33,300	500,000	542,900
Cancer				
Non-fatal	20,000	38,600	500,000	558,600
Fatal	32,000	629,000	500,000	1,161,000
Hypothyroidism	5,600	38,200	500,000	543,800

* Value represents the midpoint of the range in direct medical cost estimates.

Estimating the Cost-Benefit Ratio of KI Prophylaxis

In review, a cost-benefit ratio for KI is represented by a dimensionless quotient derived by dividing the programmatic cost of KI stockpiling by the monetary equivalent value of avoided thyroid health effects. In Section 1 of this report, the programmatic cost of KI prophylaxis for the stockpiling option was assumed to be principally determined by the purchase cost of KI and its periodic replacement.

KI tablets, currently available from two FDA-licensed firms, continue to be evaluated by the FDA for residual potency. At this time, a minimum shelf life of 5 years can be assumed for KI under proper storage conditions. At the current retail price and a 5-year replacement schedule, the programmatic cost of stockpiling KI was estimated to be about $0.10 per person per year. Multiplying the number of persons within each population cell by $0.10 yields the *annual* programmatic cost estimates for discrete distance intervals, as was shown in Table 2.

Deriving a monetary equivalence for the thyroid health effects potentially avoided when KI blocks thyroidal uptake of radioiodides with a 99% efficiency was considerably more complex. Section 2 identified four specific accident scenarios with the potential to release large quantities of radioiodides into the atmosphere. By means of the MACCS computer code, atmospheric releases of radioiodides were modeled to yield integrated air concentrations at fixed

distances and then converted to thyroid doses using age- and sex-specific ventilation rates and dose conversion factors.

Also, thyroid doses to individuals in the plume pathway were converted in Section 2 to thyroid health effects by means of risk coefficients. Numbers of thyroid health effects were estimated for the age- and sex-weighted U.S. population for discrete population cells defined by distance intervals.

In Section 3, the monetary equivalence for each thyroid health effect was derived. Estimates of cost equivalence included lifetime medical costs, loss of economic opportunity and psychological costs attributable to pain and suffering, reduction in quality of life, etc. Multiplying the expected number of avoidable thyroid effects in each population cell with their economic worth yielded the economic benefits of avoidable thyroid health effects associated with each of the four reactor accident scenarios.

A cost-benefit ratio in which the KI stockpiling costs are expressed in *annual* terms, however, requires that the economic benefits of avoided thyroid health effects also be expressed in annual terms. The monetary equivalence of avoided health effects resulting from each accident scenario can be expressed in annual terms by incorporating the probability that a given reactor accident scenario may occur in a year's time. Best estimates of accident frequencies for the four release categories analyzed were previously defined in Table 4.

The multiplicative values of (1) the number of expected thyroid health effects, (2) their monetary equivalence, and (3) the accident frequency for each accident scenario yield estimates of the *yearly* economic benefits of avoided health effects through the administration of KI (Table 14). For the population cell defined by the less than 5-mile radius, for example, a yearly economic benefit of $487 is estimated. For illustration, a sample calculation is provided for the less than 5-mile population cell.

Table 14. **Yearly Reduction in Population Thyroid Effects and Their Equivalent Monetary Values**

Distance Interval (miles)	Non-Fatal Thyroid Cancers		Fatal Thyroid Cancers		Thyroid Nodules		Hypothyroidism		Total $-Value
	No. of Cases	Value ($)	No. of Cases	Value ($)	No. of Cases	Value ($)	No. of Cases	Value ($)	
0 - 5	1.84E-4	103	2.05E-5	24	5.18E-4	281	1.46E-4	79	487
5 - 10	2.83E-4	158	3.14E-5	36	7.95E-4	432	1.54E-4	84	710
10 - 25	4.00E-4	223	4.44E-5	52	1.12E-3	608	7.78E-5	42	925
25 - 50	3.20E-4	179	3.55E-5	41	8.89E-4	483	3.32E-6	2	705
50 - 100	2.06E-4	115	2.29E-5	27	5.63E-4	306	0.00E+0	0	448
100 - 150	1.54E-4	86	1.71E-5	20	4.13E-4	224	0.00E+0	0	330
150 - 200	1.21E-4	68	1.34E-5	16	3.18E-4	173	0.00E+0	0	257
200 - 350	2.30E-4	128	2.55E-5	30	5.80E-4	315	0.00E+0	0	473
350 - 500	4.05E-4	226	4.50E-5	52	8.94E-4	485	0.00E+0	0	763

Sample Calculation Derivation of the yearly reduction in population thyroid effects and their monetary values for the < 5-mile population cell.

1. From Table 10, the total number of avoidable thyroid health effects per accident release category for the < 5 population is as follows:

Release Category	Non-Fatal Cancer	Fatal Cancer	Nodules	Hypothyroid
RSUR-1	107	12	303	99
RSUR-2	37	4	103	28
RSUR-3	0	0	0	0
RSUR-4	40	4	114	32

2. Annual reduction in avoidable thyroid health effect = (No. of expected effects) x (Accident frequency):

Release Category	Non-Fatal Cancer	Fatal Cancer	Nodules	Hypothyroid
RSUR-1	3.1E-5	3.5E-6	8.8E-5	2.9E-5
RSUR-2	8.9E-5	9.7E-6	2.5E-4	6.6E-5
RSUR-3	0	0	0	0
RSUR-4	6.4E-5	6.4E-6	1.8E-4	5.2E-5
TOTAL	1.84E-4	2.0E-5	5.18E-4	1.46E-4

3. **Annual equivalent cost estimates = (No. of htyroid effects) x (equivalent monetary cost)**

Non-fatal thyroid cancer:	(1.84E-4 cancers) x ($558,600/cancer)	= $103
Fatal thyroid cancer:	(2.05E-5 cancers) x ($1,161,000/cancer)	= $24
Thyroid Nodule:	(5.18E-4 nodules) x ($542,900/nodule)	= $281
Hypothyroidism:	(1.46E-4 hypothyroids) x ($543,800/hypothyroid)	= $79
	TOTAL	= $487

Total yearly economic benefit for the < 5 population cell = $487

Dividing the annual programmatic cost of stockpiling KI by the average annual economic benefits from avoided thyroid effects represents the cost-benefit ratio of KI prophylaxis. These two parameters and their quotient are presented in Table 15. For example, the annual programmatic cost of stockpiling KI for about 11,000 people living within five miles of the reference LWR is estimated to be $0.10 per person or $1,100. The economic benefits of avoided thyroid effects for this population cell were estimated to be $487 per year, which gives a cost-benefit ratio of 2.26.

The cost-benefit ratio is in effect a measure of the cost-effectiveness of the prophylactic measure. For the < 5-mile population cell, it can be estimated that $2.26 would be spent in order to avoid the economic equivalent cost of $1.00.

The cost-benefit ratios for population cells increase nearly exponentially with distance. This is to be expected inasmuch as the programmatic cost of 10 cents per person per year is a constant while the integrated air concentration, which defines individual thyroid dose, can be expected to drop off exponentially with distance. Thus, the cost-benefit ratio for the 50-100 mile population cell is reduced to 1,051. Within this distance interval, $1,051.00 would be spent for stockpiling to avoid the economic equivalent of $1.00.

Table 15 also provides cumulative cost-benefit ratios, which define the cumulative areas of the circle. If, for example, on the basis of thyroid intervention levels, cost-benefit considerations, logistical factors, etc., a decision was made to provide stockpiles for populations out to a distance of 100 miles, the cumulative cost-benefit ratio of 216 can be estimated.

Limitations and Significance of Data

The principal purpose of the NRC-sponsored study that was briefly summarized here was to provide a comprehensive analysis of the costs and benefits associated with the prophylactic use of KI by the general public in the event of a nuclear accident. The most currently available data were used to define the programmatic costs for stockpiling KI and the equivalent monetary values of thyroid health effects that are potentially avoidable when KI is administered. Dividing the stockpiling costs of KI by the monetary values of thyroid health effects yielded cost-benefit ratios that provide a limited basis for a policy decision.

Although these cost-benefit ratios are as credible and objective as current data allow, some caution must be exercised in using these values in a policy decision. Existing uncertainties in reactor accident frequencies and dispersion modelling could easily change the cost-benefit ratios by as much as one to two orders of magnitude or more.

Additionally, the derived cost-benefit ratios do not represent a total assessment of the cost-effectiveness of KI prophylaxis protective measures. The cost-effectiveness of KI prophylaxis must be assessed in the context of the other protective measures of evacuation and sheltering.

Table 15. The Cost-Benefit Ratio of KI Prophylaxis*

Distance Interval (miles)	KI Cost: Stockpiling		KI Benefits: Reduced Thyroid Effects		Cost/Benefit Ratio	
	Per Distance Interval ($/yr)	Cumulative ($/yr)	Per Distance Interval ($/yr)	Cumulative ($/yr)	Per Distance Internal	Cumulative
< 5	1,100	1,100	487	487	2.26	2.26
5 - 10	5,500	6,600	710	1,197	7.74	5.51
10 - 25	46,800	53,400	925	2,122	50.6	25.2
25 - 50	182,000	235,400	705	2,827	258	83.3
50 - 100	471,000	706,400	448	3,275	1,051	216
100 - 150	786,000	1,492,400	330	3,605	2,382	414
150 - 200	1,100,000	2,592,400	257	3,862	4,280	671
200 - 350	5,184,000	7,776,400	473	4,335	10,960	1,794
350 - 500	8,012,000	15,788,400	763	5,098	10,500	3,097

* Due to the limited scope of this report, in-utero thyroid health effects and their limited impact on the cost-benefit ratio were not included here. However in-utero thyroid health effects and their economic impact were discussed in detail in the NRC-sponsored study, from which the information contained in this report was extracted.

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Session 3

SELECTION OF STRATEGIES

Co-chairman: Iain Todd, United Kingdom
Rapporteur: Colin Potter, United Kingdom

FACTORS INFLUENCING CHOICE OF COUNTERMEASURE STRATEGY

by

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Abstract

There are a number of countermeasures that can be used, singly and in combination, to reduce doses in the short-term following a nuclear accident. Which strategy is adopted will depend on local factors, such as the type of accident, local geography and demography, and the resources available, and on the form of national and international guidance. The purpose of such national and international guidance is to facilitate a consistent level of response to accidents, wherever they occur, whilst at the same time providing for flexibility of response to suit local circumstances.

This paper discusses the influence of all these factors on the choice of protective strategy. The goal of any off-site emergency response strategy should be the protection of the public, not just against radiation, but in the sense of providing overall benefit. To achieve this goal, differing local and national constraints mean that the precise strategy adopted may vary from site to site.

Introduction

Protection against the consequences of accidents should be built into the design of nuclear power plants. The likelihood of a serious accident actually occurring which causes off-site hazards should therefore be very small. However, since the consequences of a very serious accident are potentially so far reaching, it is prudent to develop an emergency response plan as well as to design safeguards into the plant. The purpose of an emergency plan is to provide a framework of rapid response to a radiological emergency.

Following a radiological accident, members of the public may be at risk both from short term, relatively high, intakes and exposures, and from longer term, chronic, intakes and exposures. Generally, in order to be effective, countermeasures intended to provide protection against short term intakes and exposures ('urgent' countermeasures) will need to be taken very quickly. Conversely, decisions on countermeasures intended to provide protection against chronic intakes and exposures ('longer term' countermeasures) may be postponed, at least until there is no further potential for release and a reasonable number of environmental measurements have been made.

A well-constructed emergency plan is mainly concerned with the urgent response to an accident. Its purpose is to define the immediate response structure and arrangements for establishing control. A plan should combine prescription with flexibility, so that appropriate decisions can be taken rapidly, whilst inappropriate decisions can be avoided. The major part of an emergency plan will be concerned with communication channels and responsibilities. Discussion of these aspects is beyond the scope of this paper. However, a clearly important aspect of an emergency plan is the choice of protective strategies, and the specification of events or measurements which will trigger the implementation of these strategies. This paper discusses the factors which influence this choice of protection strategies. The paper begins by considering the generic advice which has been provided by international and national bodies. It then discusses some more detailed factors which need to be considered for individual plants.

International Advice

The Need for Justification and Optimisation

Earlier papers have discussed international advice (1). There is general agreement that no countermeasure should be planned for unless it is expected to achieve greater good than harm (justification), and that effort should be made to implement it in such a way as to maximise the net benefit (optimisation) (2,3,4). These basic principles have important implications for the choice of countermeasure strategies, as discussed below.

First, justification and optimisation should apply to all the consequences resulting from a countermeasure strategy, not just the dose consequences. In other words, the justification and optimisation of a countermeasure must take account of country- and site-specific factors such as the local geography, the availability of resources with which to implement the countermeasure and the number of people likely to be involved in the countermeasure. Whilst, superficially, it may appear reasonable that, whatever the circumstances, all individuals should be guaranteed to be protected to the same degree against radiation risk from the accident, the principles of justification and optimisation recognise that this approach might not lead to the best overall benefit being achieved for those potentially exposed. This means both that a strategy that seems to reduce exposures to pre-accident levels may not actually provide a net benefit to the exposed population and also that a countermeasure strategy that is entirely appropriate for one particular plant or situation may not be appropriate in other circumstances. A good example (albeit concerning long term, rather than urgent response) is the situation that developed in the CIS following the accident at Chernobyl. Some of the relocation policy reflected an aspiration to protect the populations in the contaminated regions to virtually the same levels, in terms of radiation exposure, to which they were subject before the accident. In hindsight, some of these decisions were taken without sufficient regard to the devastating effect this could have on people's lifestyles or on the wider economy. The result is that, for many people, a net harm, rather than a net benefit has been achieved (5).

Second, the decision-making process itself needs to be justified and optimised. With hindsight and full knowledge of the situation, it might be possible to identify what would have been the best countermeasure strategy for response to a particular accident. However, if people are to be protected during the emergency phase of an accident, decisions need to be taken on the basis of best judgement, not certain knowledge. It is not possible, either before or during an accident to know precisely what radiation doses may be averted by a countermeasure. If an urgent countermeasure is delayed whilst sufficient information is obtained to estimate the actual avertable dose, much of the potential benefit of taking that countermeasure may have been lost. Therefore a judgement is required between the likely benefits to be gained from delaying a decision whilst more information is gathered, and the benefits to be gained from taking prompt action. Such constraints have implications both at the emergency response planning stage (see below), and the actual response to an accident. The knowledge that decisions will need to be taken promptly, with incomplete information, may make certain countermeasure strategies more attractive than others, in that their benefits are less sensitive to the exact circumstances of the accident. In fact, in view of this, international and national advice particularly recommends that consideration be given to the use of precautionary countermeasures, that is, countermeasures implemented because a serious release is anticipated, but before it has actually occurred.

Linked to this need for optimised decision-making, is the need to develop a plan that is straightforward to follow, but robust for a wide range of circumstances. Unless this is achieved, unwelcome delays in deciding on the appropriate response are likely to occur, resulting in loss of confidence by the public and a much less optimum response. In other words, it is not intended that the need for mathematical optimisation should take priority over clear planning and rapid response. The advice to optimise response should be interpreted in the broadest sense, *i.e.* to make best use of the available information within an appropriate timescale. This can best be achieved by the development of a single, robust plan for the urgent response to most envisaged accidents and circumstances. The plan should clearly indicate the (few) types of accidents and circumstances for which it is not appropriate, and indicate alternative responses for these. It is recognised that the response dictated by such a plan is unlikely to be precisely optimum for any specific accident. However this disadvantage is offset by the advantages of a fast response facilitated by a clear and straightforward emergency plan. Therefore, a major factor that should influence the choice of strategy is the likelihood that a given form of response will provide adequate protection under a wide range of circumstances.

In summary, then, the need to justify and optimise an emergency response strategy means that no two emergency response plans would be expected to be identical. The need for a plan to be straightforward and robust under a range of circumstances will mean that the strategy adopted for response for one site may appear to be very different from that adopted for another site. However, what is important is that a planned response will protect the public, not just against radiation, but in the sense of providing an overall net benefit. There are many ways of achieving this goal, and it is quite reasonable that different sites will adopt different strategies for this.

Factors to be Considered in the Optimisation of Response

In order to develop countermeasure strategies that are both justified and optimised, it is necessary to identify and, at least to a limited extent, quantify the potential consequences of implementing different countermeasure strategies. International and national guidance lists a number of factors that should be

considered when deciding upon urgent countermeasure strategies (e.g. 6). The most important ones are:

Health Factors:

Averted individual risk from exposure to radiation;
Averted collective risk from exposure to radiation;
Individual physical risk introduced by the countermeasure;
Collective physical risk introduced by the countermeasure;
Risks incurred by workers implementing the countermeasure;
Monetary Cost Factors.

Social Factors:

Reassurance provided by the countermeasure;
Anxiety caused by the introduction of the countermeasure ("countermeasure anxiety");
Disruption to the individual;
Disruption to society.

The influence each of these may have on the choice of strategies is discussed below:

Individuals and Populations: Before discussing each factor, some general comments are useful concerning those factors which relate to individuals and those which relate to populations (collective factors). The relative importance attached to these two types of factor depends primarily on the level of individual harm (or benefit). Here the terms harm and benefit are used in the widest sense, encompassing the risk of radiation-induced health effects, physical risk, disruption and reassurance. Generally, at high levels of individual harm or benefit, it is the individual related factors which most strongly influence any decision on countermeasures. Conversely, where individual levels of harm or benefit are very low, a decision on countermeasures is likely to be dominated by consideration of the collective risks or benefits.

The magnitude of any collective harm or benefit is dependent upon the population group considered. Many countermeasures affect a larger number of people than those directly subject to the countermeasure. For example, a decision to evacuate has implications, not only for the evacuees, but for all those required to manage the evacuation, for those providing food, accommodation and medical attention for the evacuees, and for all those who had planned to visit the area or make contact with individuals within it. If consideration were restricted to the collective harm experienced by the evacuated population only, then the total collective harm caused by the countermeasure could be significantly underestimated. Therefore, a strategy developed solely to optimise the consequences of a countermeasure for the people directly subject to the countermeasure could be different from a strategy that took account of the consequences for the whole of society. (Equally, the definition of 'the whole of society' could affect the decision. For example, the optimum strategy for the UK only, might be different from that for the whole of Europe.) It is beyond the scope of this paper to recommend how widely the optimisation should be carried out. However, it is clear that since the size of the population group considered will affect the choice of strategy, it is important that an explicit decision is taken concerning the importance of different population groups when developing it.

Averted Health Risk: Clearly, the principal reason for implementing urgent countermeasures is to avert doses that would otherwise be received. However, the importance that should be attached to this depends very much on the levels of doses involved. Clearly every effort should be made to avert doses that would otherwise cause very serious deterministic injuries (2,3,4). On the other hand, the likely harm caused by disruption and the other 'non-dose' factors mentioned above should play a major role in decisions where the averted dose is likely to be small. Referring again to the longer term experience after Chernobyl (which is acknowledged not to be directly comparable with the consequences of urgent countermeasures), it became clear during a series of decision conferences held in the contaminated CIS republics, that the anticipated reduction in radiation-related health injuries achieved by the relocation strategies had only a small influence on the choice of relocation criteria. Social concerns and monetary costs were far more influential factors (5).

A second point about averted health risk is that, in general, urgent countermeasures should be designed to protect against individual exposure. Strategies planned to achieve a large dose saving to a few individuals are likely to be more appropriate than those planned to achieve a small dose saving for a large population group. This is clearly a different situation from longer term countermeasures. This means that, within the constraints of prompt decision-making and practical issues, urgent response needs to be targeted at those likely to be most at risk.

Physical Risk: Generally, at least in the UK, and therefore probably in western Europe, the physical risks associated with countermeasures are small. A survey of individuals in south-west England concluded that most people would shelter for 1 or 2 days with little difficulty (7). For the administration of

stable iodine, a UK Department of Health working group concluded that, generally, the health risk from this countermeasure was very low (8). Even for evacuation, which is carried out frequently for hazards other than radiation, there have been very few documented injuries either in the UK or in the USA (9). However, it is always possible to postulate scenarios where the individual physical risks might become a dominant factor in determining the appropriate strategy for a site. For example, in very hot weather, prolonged sheltering of the young or elderly might pose health problems, whilst in very bad weather conditions, evacuation might endanger lives.

Even though the individual physical risks involved in early countermeasures may be small, the collective risks may not be trivial. The magnitude of the collective risk is, largely, dependent on the number of people affected by the countermeasure, while the magnitude of the individual risk is less strongly affected by this. This means that as the intervention level for a countermeasure decreases (resulting in an increasing number of people being involved), the collective physical risk increases proportionately. At some low level of individual risk, the collective physical risk may become a major factor in deciding on an appropriate countermeasure strategy.

Individual Disruption, Reassurance and Countermeasure Anxiety: These three factors are very difficult to quantify, and they may well be very different for each individual. Moreover, the dissociation of reassurance and countermeasure anxiety is convenient for the discussion in this paper; it is unlikely to be so clear-cut in reality. However, it is also clear that these are very important factors for all decisions where the individual radiation risk is not extremely high. Socio-psychological issues are dealt with in a separate paper (10), so it is necessary only to outline a few major points here.

The level of disruption experienced by individuals will be related, to some extent, to their lifestyle, health and intended activities during the period of the countermeasure. For example, the advice to shelter for a few hours, given to parents of several young children on a wet and cold winter evening may cause them negligible disruption. The same advice to those parents on a very hot summer's day might cause significant disruption, particularly if their house were small. However, evacuation will always be very disruptive.

The reassurance afforded to individuals by the introduction of a countermeasure depends on their perception of the risk to which they are exposed and the extent to which they perceive the countermeasure will protect them from that risk. If the protective strategy proposed accords with the level of protection which the individual judges necessary then they are likely to be more reassured than if it differs significantly from their judgement. Individuals who judge the risk to be high will not be reassured by advice that little protective action is required. An individual's perception of the risk will be determined by a complex set of interacting factors, including the general nature of the risk (in this case, exposure to ionising radiation). The problem with a radiological accident is that individuals have little opportunity for directly assessing the seriousness of the risk; they must rely upon information supplied to them by a third party. In this case, the reassurance afforded will be strongly influenced by the level of control and competence the authorities are perceived to have in the management of the accident, and the level of trust that exists between the individual and those providing the information (11). For example, advice to shelter from authorities who are trusted will provide more reassurance than advice to evacuate from authorities who are perceived to have lost control of the situation.

It is likely that countermeasure anxiety will be strongly influenced by the level of risk that would exist in other circumstances where the countermeasure would be implemented. For example, evacuation is a typical response to bomb-scares, hurricanes and flooding - *i.e.* situations in which there is a significant risk of direct serious injury or death. Generally, it is only for rare types of accident (involving the release of, for instance, radioactive or carcinogenic substances) that plans are made for urgent countermeasures to protect against late, stochastic health effects. Therefore it is likely that if countermeasures are taken after a nuclear accident, individuals will overestimate the health risk to which they are exposed.

Consideration of each of these factors indicates that estimations of social consequences should play an important role when decisions on appropriate countermeasure strategies are taken.

Monetary Cost: Monetary cost is a factor which some might argue should not be taken into account when developing a strategy for emergency response. Clearly, for situations where the individual health risks are high, the monetary cost of introducing countermeasures will not be a major factor in such decisions. However, for many situations, monetary cost forms a very significant contribution to the harm introduced by a countermeasure. Moreover this cost is rarely borne solely by those benefiting from the countermeasure, nor is it necessarily shared equitably throughout the wider population. For the countermeasure of evacuation, the decision to implement it will involve a significant monetary cost, however few people are evacuated. This is because a decision to evacuate people requires the organisation and mobilisation of a number of supporting services; personnel to organise the evacuation and to

ensure the security of property in the evacuated region, transport, accommodation, food supplies, counselling services, monitoring services and general administration. This sharp increase in monetary cost is much less significant for the other early countermeasures, although the decision to implement any countermeasure is bound to require the mobilisation of some support services. Therefore, at intervention levels of dose which do not represent a major individual health risk, it is reasonable that evaluation of the monetary cost is one input in the choice of countermeasure strategy.

A separate paper will deal with economic factors in more detail (12).

Social Disruption: Social disruption is the collective disturbance to the normal or expected lifestyles of those affected by the countermeasure. It is likely to be experienced by a larger population group than those benefiting from the introduction of a countermeasure. As with monetary cost, social disruption is likely to become a significant factor in determining emergency response strategies where relatively low doses are involved.

Worker Risk: The factor "worker risk" encompasses individual and collective health risks incurred by workers as a result of exposure to radiation and also any physical risks involved in implementing the countermeasures. ICRP has recommended that, except for life-saving actions, all doses to workers involved in mitigating the consequences of the accident should be kept below 0.5 Sv (2). In the UK, the National Radiological Protection Board (NRPB) further recommends that workers involved in implementing off-site countermeasures should, in general, have their dose restricted below the statutory annual dose limit (4). If this advice is followed, then the individual radiation risk to off-site workers should not be a major factor in decisions on countermeasure strategies.

Although the individual dose received by off-site workers is unlikely to be a major consideration in the determination of countermeasure strategies, consideration should also be given to the collective dose they might receive. For example, it would rarely be justified to ask emergency services personnel to experience a greater collective exposure in the course of introducing a countermeasure than the collective dose averted by that countermeasure.

Some accident situations may be hazardous for workers (e.g. very bad weather conditions). It is therefore important to take account of the level of physical risk faced by emergency workers. Where this is significant, then the expected individual risk saving in the exposed population should be at least commensurate with it, or else the countermeasure will not be justified.

The purpose of international advice on countermeasure implementation is to provide a degree of commonality in the response to radiological accidents, wherever they occur. If international advice is followed then this will strongly influence the choice of countermeasure strategy adopted for a particular accident, in terms of both the level of response and the way in which it is implemented. However, no two accident situations will be identical, and so it is important that international advice is formulated in a way which leaves flexibility of response for accident- and site-specific features. In the following section the influence of some of these more detailed, local factors is addressed.

Developing Planning Strategies

There is a wide range of countermeasures which can be applied to avoid stochastic and non-stochastic effects (see, for instance, Ref. 13). The countermeasures are not really alternatives as some may need to be carried out simultaneously. These include:

- sheltering
- evacuation
- iodine prophylaxis
- prevention of access to the area
- respiratory protection
- body protection
- personal decontamination
- relocation
- food control
- decontamination of the area

The countermeasures which are of most interest in this paper are sheltering, evacuation and the administration of stable iodine. Some of the other countermeasures may be carried out in conjunction with these (e.g. personal decontamination of exposed and evacuated people). Factors which influence the circumstances in which these countermeasures may be employed are discussed in the following sections.

Sheltering

There is a wide range of factors to be considered in the adoption of sheltering as a countermeasure. The factors include, for instance, the type of shelters available, the timing and nature of the release, and the local weather.

In developing a strategy for sheltering the following points need to be considered:

i) Type and availability of shelters: There may be a wide range of buildings within which people could shelter in the emergency planning zone. These might include permanent residences, industrial premises, schools, hospitals, public buildings etc. There may also be a significant number of less substantial shelters available eg. mobile homes and tents. Emergency planners should be familiar with the number, type and distribution of all permanent and semi-permanent accommodation and be aware of the likely numbers and distribution of any non-permanent accommodation (mobile homes, campers etc.). Consideration should also be given to the capacity for public buildings to provide sheltering for transient populations caught in the open (eg. on beaches or attending sporting events).

ii) Shielding characteristics: The dose reduction factor[1] will vary widely depending on the structure of the shelter and on how well it can be sealed. Generally the protection offered by shelters from groundshine is likely to be better than from cloudshine as walls are usually thicker than roofs. Table 1 taken from an IAEA publication (14) gives representative dose reduction factors for various types of structure and location. There is a wide range of construction codes and standards between different OECD countries and the degree of shielding provided will therefore need to be assessed for the types of shelter available locally.

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1 Dose reduction factor = dose that may be incurred with sheltering/dose in open. Thus the shielding effectiveness of a shelter can range from 0 (maximum effectiveness) to 1 (no shielding).

Table 1. **Representative reduction factors for desposited activity**

Structure and/or location	Reduction factor
1 m above a hypothetical infinite smooth plane	1.00
1 m above ordinary ground	0.70
1 m above centre of 50-ft (ca. 16 m) roadway half-way contaminated	0.55
Cars, pickups, buses and trucks on 50-ft (ca. 16 m) road:	
Road fully contaminated	0.5
Road 50 % contaminated	0.5
Road fully decontaminated	0.25
Trains	0.4
1 & 2-storey wood frame homes (no basement)	0.4
1 & 2-storey block or brick homes (no basement)	0.2*
Home basement 1 or 2 walls fully exposed	0.1*
1-storey less than 2 ft (60 cm) of basement walls exposed	0.05*
2-storey less than 2 ft (60 cm) of basement walls exposed	0.03*
3 or 4-storey structures, 5000-10 000 ft² (ca. 500-1000 m²) per floor:	
First and second floors	0.05*
Basement	0.01*
Multi storey structures > 10 000 ft² (ca. 1000 m²) per floor:	
Upper floors	0.01*
Basement	0.005*

Representative reduction factors for cloud source

Structure location	Reduction factor
Outside	1.0
Vehicles	1.0
Wood frame house, no basement	0.9
Masonary house no basement	0.6
Basement of wood frame house	0.6
Basement of masonary house	0.4
Large office or indusstrial-type building away from doors/windows	0.2 or less

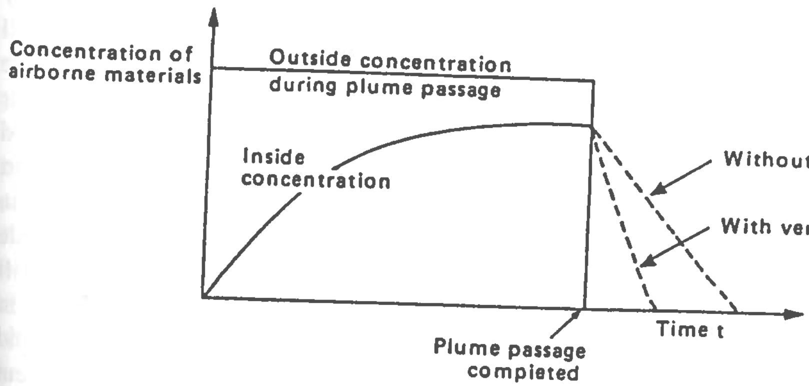
* Away from doors and windows.

Source: Ref. 14

The protection given against inhalation or ingestion of active materials (gases and particulates) will depend on the ventilation rate of the shelter. Depending on the building structure, this will be due to natural or forced ventilation or both. For purpose-built shelters the type and efficiency of any installed filtering system will influence the rate of build up of active materials inside the shelter. The natural ventilation rate will also depend on national construction practices. In colder countries, for instance, residential accommodation will generally be better sealed. The natural ventilation rate will depend on the local wind velocity and direction, the rate increasing with the wind speed. However, a higher wind speed will also disperse the release more quickly.

Figure 1 shows the way in which activity may build up inside a building. The protection will clearly diminish with time as the concentration of radioactivity increases. It is important, therefore, not only to seal the buildings effectively but also to ventilate thoroughly once the plume has passed.

Figure 1. **The increase of the inside concentration of airborne materials in a closed building for a fixed outside concentration and a given ventilation rate (Reference 22).**



iii) Nature and timing of the release: Sheltering, as a countermeasure on its own, is likely to be most effective for:

- releases which consist primarily of radioisotopes of noble gases;
- situations where there is little or no time to organise comprehensive evacuation (*i.e.* a short or non-existent threat phase);
- releases which take place at night (when most people are already in their homes);
- short, puff, releases which are likely to lead to relatively low radiological doses.

iv) Other factors: Other factors may be important in deciding on sheltering as a countermeasure, for example:

Extreme weather: People will be less willing to leave the apparent security of their homes in extreme adverse weather (e.g. freezing fog or deep snow). The risks of evacuation in these circumstances may well outweigh dose savings to be achieved in evacuation. On the other hand, advice to put out domestic fires and close chimney dampers (to reduce natural ventilation), could eliminate the main source of heating and make sheltering less attractive. In very hot weather, the need to avoid using ventilation systems may lead to extremely uncomfortable sheltering conditions and might lead to people choosing to leave the shelter early or to self evacuate.

The duration of sheltering: Apart from the progressive build up of radioactive concentration inside buildings, sheltering beyond a few hours may lead to high levels of stress and anxiety in the sheltering population. Stress will be related not only to fear and uncertainty about the health effects of the accident but also to the degree of personal disruption that sheltering causes. For example, farmers will be less willing to shelter for long periods if there is a need to attend to livestock. This may be alleviated by advising people that short periods spent outside to attend to important matters, will not usually result in high exposures. This may be particularly true for an emergency where stable iodine has already been administered. The willingness of people to shelter will also depend on the prevalence of purpose built public and domestic shelters. In countries with a high provision for purpose built sheltering such as Switzerland or Finland, public confidence in the ability of the shelters to afford them protection will mitigate against other concerns. A UK survey (7) showed that most people would be willing to shelter for longer than one day without significant disruption, although the IAEA (3) recommends sheltering for no longer than two days.

Pre-publicity: It is vital that any population which may be called upon to shelter has been provided with clear instructions in advance. This is can be achieved by issuing (and periodically reissuing) written instructions to homes, places of work and public buildings within the emergency planning zone. It is a particular problem for areas with significant transient populations such as tourists and visitors. As a minimum, those responsible for the management of camp sites, trailer parks, recreation areas etc., should be provided with information on the emergency planning arrangements for the area. This could include information on what advice should be transmitted to transient populations to facilitate application of countermeasures.

Notification to shelter: The potential communication channels from the decision makers to the public include personal notification (through door-to-door visits), loudspeakers, public address systems, radio, television, telephone and sirens. The decision to advise sheltering must be based on a high probability that the majority of people will receive, understand and act upon the instructions issued. Transient populations are less likely to receive and understand warning messages than residents. The likelihood of significant mis-interpretation of instructions, and possible counter-effective actions (such as self-evacuation) needs to be considered in selecting sheltering as a countermeasure. Research carried out in the US has indicated that between about 50% and 66% of people are likely to comply with advice to shelter (15, 16). In sub-populations (e.g. racial, ethnic and political groups) and in transients (e.g. tourists) the compliance factor may well be significantly lower unless warning messages are specifically aimed at these groups.

v) Costs: ICRP recommendations (13) state that costs used in the justification and optimisation analyses for sheltering should include consideration of monetary losses to both individuals and society, monetary losses to industry, trade and agriculture and cost in dose to those responsible for implementing the countermeasure (e.g. the police). Depending on a variety of factors, including means of alerting the population, the time of day when sheltering is recommended and its duration, such costs are likely to be quite small. The ICRP report recommends that an averted effective dose of 50 mSv will always justify sheltering as a countermeasure. Optimised levels may be up to a factor of 10 lower when consideration is given to specific accident conditions and sub-groups of the population.

Stable Iodine

The accumulation of radio-iodine in the thyroid gland due to inhalation or ingestion can be blocked or reduced if stable iodine is administered before or soon after exposure. If stable iodine is administered orally in the six hours before exposure, the protection provided is about 98%. If administered at the time of exposure the protection is about 90%. The effectiveness of the countermeasure decreases with delay but may still be about 50% even if administered within four to six hours of inhalation (17). From this, it is clearly desirable to administer stable iodine as soon as possible, preferably before any exposure has occurred. In considering stable iodine as a possible countermeasure a number of factors need to be considered:

i) Type of accident: The administration of stable iodine is only of benefit if an accident has the potential to cause exposures to the thyroid in excess of the appropriate intervention level (13). In general only accidents in operating nuclear reactors have this potential. Used fuel in storage or reprocessing plants will normally have been cooled for a sufficient period for its radioactive iodine content to be reduced to insignificant levels. For accidents with a significant threat phase, there may be sufficient time to complete the distribution of the stable iodine before the release occurs (see (iii) below).

ii) Dosage: The WHO (17) recommended quantity of stable iodine for adults is 100 mg. This is normally in the form of potassium iodide (130 mg) or potassium iodate (170 mg). WHO recommends smaller doses for children and neonates but makes no distinction for pregnant or lactating women. The WHO recommended doses are considered to carry a very low risk even to people in countries where there is a marked iodine deficiency in the diet. In the short term, a single dose should be planned for but if exposure to radio-iodine continues beyond about 2 days a further administration may be required. However, for such an extended release, a combination of a single dose of stable iodine combined with evacuation is likely to provide the optimum level of protection.

WHO make additional recommendations regarding the administration of stable iodine to people with known thyroid problems which may be adversely affected by the intake of stable iodine. National health advisory bodies will need to develop guidelines for such cases based on the WHO or other recommendations.

iii) Distribution: In order to maximise the effectiveness of stable iodine as a countermeasure, it is important that it is administered as soon as possible. Emergency planning authorities therefore need to give careful consideration of the most effective means of supplying stable iodine to the affected population. Pre-distribution within the emergency planning zone might form part of the planning strategy. Pre-distribution could be to individual homes, to places of work, to public buildings or to all of these. For certain types of institution (eg. schools, hospitals, residential nursing homes, evacuation reception centres, police stations etc), pre-distribution is probably always justified. Pre-distribution to places of work is also probably justified if there are adequate roll-call facilities available and if the iodine tablets are under the control of nominated responsible persons. In addition, stockpiles of tablets may be held in reserve by the operator's organisation, or at national or regional government offices.

The question of pre-distribution to individual households is more difficult. Some people will almost certainly mislay the tablets and be unable to find them if they are needed. Others will not follow the dosage instructions and will administer either too much or too little. In addition, householders may not have spare tablets for visitors. Medical authorities may also be wary of pre-distributing drugs (albeit fairly innocuous drugs) to the general public. These objections may be outweighed by the fact that at least a large proportion of affected people will have immediate access to the tablets. Distribution during the accident will take some time, particularly to isolated buildings and will also pose a potential radiological hazard to those who carry out the distribution. In the UK, the general policy is not to pre-distribute to individual households but it has been done in some remote areas where there are few residents. If pre-distribution is carried out, there will be an ongoing need periodically to supply new tablets and withdraw old ones.

A further consideration is whether stable iodine should be available for purchase by the general public. A wide range of potentially harmful drugs is available without prescription in most OECD countries. For most people, inappropriate consumption of stable iodine will not cause any particular harm and, on that basis, there would seem to be no reason why people should not be able to purchase supplies if they so wished. On the other hand there is a danger that large numbers of people would consume tablets whenever any radiation accident was reported in the belief that they would be protecting themselves, regardless of whether there was any danger from radioactive iodine or not. The decision of public availability is one which has to be decided by national medical advisers in consultation with emergency planning authorities. In the UK, potassium iodate and iodide are not available for purchase by the general public.

iv) Costs: Monetary costs are likely to be reasonably small. Stable iodine tablets are relatively cheap to buy and the costs of limited pre-distribution and stockpiling will also be fairly low. The costs in radiological dose to persons distributing the tablets during an accident could be significant, however, and this needs to be taken into account in any planning strategy.

Evacuation

Evacuation is the temporary moving of people from an area to avoid significant short term exposures. It is distinct from relocation which is the removal of people from an area for extended periods of time such as weeks, months or even years. Evacuation has the potential to prevent virtually all exposure to a release if it is carried out before the release occurs. However it can also be implemented at various stages in the development of an accident. Of the countermeasures discussed in this paper, evacuation is the most disruptive and, potentially, carries the most cost, especially if the numbers involved are large. Decisions about evacuation must therefore be based on very careful consideration of the potential benefits and detriments. Among the factors to be considered are the following:

Accident Scenario: Evacuation can be an effective countermeasure following a wide range of accidents. NRPB (6), has identified five main accident situations in which evacuation is likely to be the optimum early countermeasure:

i) precautionary evacuation in response to a threatened release of unknown magnitude. Additional factors such as adverse weather conditions may preclude this;

ii) in response to a large release of predictable duration and size, particularly one for which there is sufficient time for evacuation to be completed before it begins. As an example, a ruptured tank containing a known amount of radioactive material; the evolution of the accident can be predicted with confidence and dose savings compared with appropriate intervention levels;

iii) in response to an accident for which the release to the atmosphere may be prolonged, and the magnitude of the release is very uncertain and potentially large. In this case the potential dose saving is likely to outweigh the exposure incurred during the evacuation;

iv) after the cessation of a large release to atmosphere, to avoid doses from short-lived radionuclides deposited on the ground;

v) after the cessation of any release, to avoid exposure while short-term decontamination is carried out.

Logistics: Evacuation may present considerable logistical problems. It is important that these are considered, so far as possible, in developing plans which call for this countermeasure. Experience has shown that pre-defined evacuation areas or sectors are valuable in ensuring efficient and timely evacuation. The evacuation following the Mississauga train derailment (Canada, 1979) showed the importance of an adequate supply of suitably marked maps for personnel directing the evacuation. The following factors are among those that could affect the efficiency of an evacuation:

Communication channels: Instructions to the public must be clear and should not conflict. Sufficient resources are required for issuing instructions, eg. by calling at individual houses, over loudspeakers or via the media. Conflicting information may cause unnecessary self-evacuations. People will require detailed information on, for instance, choice of escape route, destinations, what to do about children at school, family pets, members of the family at work, what they should take with them etc. If the public have been well informed prior to the emergency, then the demand for such information during the evacuation may be greatly reduced. Nevertheless, instructions will need to be repeated frequently.

Special groups: These may include the elderly, disabled, pregnant women, hospital patients, schoolchildren, farmers, tourists, and people at work in offices and industrial premises. Consideration should be given to the special needs of these groups and any delays this may cause in completing the evacuation. It may be appropriate to give priority to some of these groups if evacuation is to be carried out using public transport. Farmers will need guidance on the welfare of their animals and the arrangements that can be made for them to return periodically to carry out milking etc. Some industries may be unable or unwilling to close down their operations completely. Where possible, these should be identified in advance and suitable advice issued on alternative protective measures for staff remaining at work.

Resource requirements: Planning for evacuation needs to consider the means by which people will be moved from the area. Sources and procedures for obtaining the transport necessary for organised evacuation should be identified in advance. If privately owned transport vehicles are to be used, advance contractual arrangements should be made. In an area with a significant number of private cars and with a good road system, self evacuation may be an efficient means for many people to leave. However, for resource planning purposes, it is better to assume that most people will be evacuated using mass transport arrangements. There is, in addition, a need to identify who will organise and carry out the evacuation from the area. The police, the military, local government personnel, private contractors and volunteers should all be considered. Radiological protection and monitoring requirements for such personnel also needs to be taken into account if evacuation cannot be achieved before the release starts.

Traffic management: Planning should take into account the number and nature of roads leaving the emergency planning zone. To achieve a smooth flow and avoid traffic jams the information given to the evacuating population should identify recommended routes. Ideally, major escape routes and routes to evacuation reception centres should be signposted as soon as possible. Traffic patrols and road blocks may be necessary to ensure that certain routes are kept clear for access by the emergency services and by public transport vehicles. In addition, large numbers of the media could be expected to converge on an affected area and steps may need to be taken to ensure that key routes are not obstructed by them. The use of helicopters to monitor traffic movement should be considered. The use of check-points on routes out of the area would enable valuable information to be gathered on the numbers of people self-evacuating, although this could slow the movement of traffic and lead to a delay in the completion of the evacuation.

Evacuation time: In order to assess the practicality of an evacuation strategy, estimates are needed if the time taken to evacuate various sectors around the site. Estimates can be based on professional judgement derived from information about actual evacuations and on detailed knowledge of the geography and demography of the area. However, there are a number of evacuation models available which allow the factors affecting evacuation rates to be investigated in a more rigorous manner for individual sites (18, 19). A UK study (20) identified four components to the time taken for people to evacuate an area:

i) Decision time: this starts from the moment a threat is identified and continues to the point at which the relevant authorities decide to recommend evacuation;

ii) Notification time: this starts from the point at which the first evacuation warning is issued and ends when 100% of the target population has received the intended warning. (Of course, 100% may never receive a warning);

iii) Preparation time: this commences from the time individuals receive the warning and ends when the they are ready to leave. It includes such behaviour as obtaining information on reception centres, waiting for official transportation and collecting family members who are not present.

iv) Evacuation time: This starts once people actually start to leave and ends (theoretically) when 100% of the target population leave the evacuation zone.

The time distributions of some of the above factors will inevitably overlap.

The following conclusions from the UK study are relevant:

1. There is likely to be a significant over response amongst the population at risk from a nuclear accident. At Three Mile Island, for instance, approximately 1% of the population with 8km were advised to evacuate, whereas over 60% actually evacuated.

2. The delay between people receiving the instruction to evacuate and actually starting evacuation after a toxic release is typically about 1 hour. If clear and unambiguous instructions are given to the public, the delay time for nuclear accidents could be expected to be similar.

3. Families tend to evacuate as units. Individual family members will therefore be less inclined to evacuate during normal working or school hours when the family may not be together.

4. In a theoretical situation, about 20% said they would not evacuate even if advised to do so.

5. Most people evacuating in their own vehicles will seek destinations in excess of 80 km from their homes.

6. Evacuation rates show a dependence on the total numbers evacuated. Based on a comparison of data from 25 cases, the mean evacuation rate (numbers per hour - R) was found to be given by R= 14 N0.5 where N is the number to be evacuated.

Reception centres: In planning for evacuation, suitable and sufficient reception centres should be identified in advance. To reassure evacuees that they are no longer threatened by the release, reception centres should be a considerable distance outside any area that is likely to be significantly affected by the accident. Schools or other large public buildings are suitable. Because of the likely short duration for which they will be used, reception centres do not need to be specially equipped in advance but it is important that they can be rapidly equipped once the decision has been made that evacuation should take place. As a minimum the reception centre should be warm, with adequate space for the expected number of evacuees plus a number of self evacuees from outside the evacuation area. People will require food and drink, blankets, bedding etc. Medical attendants and social workers should also be available. It is also essential that an accurate register is kept of those evacuated persons arriving at the centre. If evacuation commenced after the start of the release, radiation monitoring will probably be required for reassurance. There may be special religious and cultural needs which will also need to be considered.

Risks: A UK study (9) indicates that physical risks associated with evacuation are small. However, weather conditions, time of day or night, road capacity and traffic density will all affect the risks involved. In addition, special groups such as the elderly or ill may be at particular risk, if not from physical injury, then from the stress caused by the disruption to their daily lives.

Costs: Of the three countermeasures considered in this paper, evacuation is likely to be the most costly. Costs include the transportation out of the area and back, the provision of reception centres or other accommodation, additional living costs (e.g. food, medical care, reassurance monitoring and counselling, schooling etc), compensation for loss of income and inconvenience and the costs of surveillance of evacuated properties.

Combining Countermeasures

The previous discussion has highlighted some of the factors to be considered in the application of sheltering, evacuation and the administration of stable iodine. Whether the countermeasures are applied singly or in combination depends partly on the pre-determined plan and partly on the circumstances prevailing at the time of the accident. However, for reactor accidents, it is unlikely that sheltering within the emergency planning zone would be contemplated without also planning for the administration of stable iodine. Likewise, evacuation from an area already affected by the plume would probably need to be supplemented with the administration of stable iodine. Flexibility in

the countermeasure strategy is essential if the principles of justification and optimisation, discussed earlier, are to be applied.

Table 2, taken from a UK study (21), gives an indication of the possible effect on thyroid and whole body doses of various combinations of countermeasures for a particular release. For a different release, the same countermeasure strategies will not necessarily have the same effects on the dose saved and may lead to different conclusions about the optimum combination.

Although flexibility should be built into a countermeasure strategy, there are practical issues which need to be taken into account in applying the strategy. For instance, sheltering followed at a later time by evacuation may cause problems for the organising authorities, especially if advice to the public is primarily by way of visits to individual streets and houses. In addition to the extra demands on resources, the public might be confused if they were advised first to shelter and then later to evacuate. The situation would be even more confused if sheltering was succeeded by evacuation in some sectors and not others. A decision to carry out a later evacuation may also have to be delayed if the evacuation routes would entail passing through the plume. It would also probably be unwise to terminate the evacuation of a sector once it had started, even if it was considered no longer justified. In this event, it may be judged better to return evacuees to their homes in an organised and orderly manner after the evacuation had been completed rather than risk the considerable confusion that would be likely to ensue if a change was made while the evacuation was in process. Local weather conditions may also influence the decision on how and when to combine countermeasures.

Table 2. **The effect of different countermeasures on radiological dose from an extended release**

Table 2a. Effect on Thyroid Dose

Countermeasure(s)	Without Iodate	Iodate at 3 hours	Iodate at 6 hours
No countermeasures	1.0	0.052	0.164
Plume exposure for 3 hours then shelter	0.57	0.04	0.112
Immediate shelter	0.5	0.026	0.082
Immediate shelter - evacuation at 3 hours	0.067	0.013	0.06
Plume exposure for 3 hours then evacuate	0.14	0.027	0.1
Prior evacuation	~0	~0	~0

Table 2b. Effect on Whole Body Dose

Countermeasure(s)	Without Iodate	Iodate at 3 hours	Iodate at 6 hours
No countermeasures	1.0	0.46	0.52
Plume exposure for 3 hours then shelter	0.55	0.25	0.29
Immediate shelter	0.48	0.21	0.25
Immediate shelter - evacuation at 3 hours	0.065	0.034	0.043
Plume exposure for 3 hours then evacuate	0.13	0.07	0.089
Prior evacuation	~0	~0	~0

Source: Ref 21

Note: There numbers should only be taken to be indicative of the effects of various combinations of countermeasures. They do not represent a rigorous application of current UK radiological protection strategy.

Extendibility

In the preceding paragraphs it has been assumed that for each nuclear site there exists a pre-defined emergency planning zone in which the countermeasures strategy can be planned in detail. Emergency plans need, however, to be extendible to respond to an accident more serious, but less likely than the accidents for which the plan was developed. Planning authorities will need to strike a balance between ensuring that plans are flexible enough to respond to a more serious accident and avoiding the waste of resources that could occur through excessive planning for extremely improbable events. As a

minimum, there should be outline plans for the extension of countermeasures to an area larger than the emergency planning zone. In assessing the extendibility of the detailed plans, use can be made of existing severe accident scenarios.

Factors to be considered in assessing extendibility of plans include:

"cliff-edge" effects. Extending the area of application slightly may bring in areas of very high population density, or include installations that could present particular difficulties (eg. airports, military bases, harbours etc)

- the identification of additional possible evacuation reception centres
- stockpiles of additional stable iodine tablets
- arrangements for mutual assistance from neighbouring regional authorities or states
- the means of warning and informing the public in the wider area.

Other Influencing Factors

The preceding discussion of short term countermeasures has highlighted some of the factors which may need to be taken into account in developing a countermeasures strategy. There may be additional factors, for instance, local and national legislation and policy decisions, which may form a major element in strategy development. As an example, the legal requirements for relevant organisations to take part in the planning process, or in the actual emergency response, may have a strong influence on the detail of the emergency plan. In a country where there is a national emergency response organisation with wide ranging legal powers, a plan based on large scale evacuation, for example, may be easier to implement than a plan based on voluntary agreements between the various organisations involved.

As a further example, the size of the detailed emergency planning zone (EPZ) varies widely from country to country and sometimes from site to site. The size of the zone is generally a matter of national policy and is sometimes specified in legislation. Developing a countermeasure strategy may depend crucially on the size of the detailed planning zone and the number of people covered by it. In general, there will be more flexibility in the development of a strategy for a smaller, sparsely populated EPZ than for a larger one. The difficulties in planning for the evacuation of a very large EPZ, for instance, may influence the priorities given to in-situ sheltering and the administration of stable iodine.

Finally, at the risk of stating the obvious, countermeasures strategy cannot be developed without taking account of national and regional cultural and sociological attitudes. In an area where authorities are trusted and respected a countermeasures strategy is more likely to be successful than where the public has little confidence in those charged with implementing such a strategy. It is unfortunate that public perceptions of the events following the two best known accidents, at Three Mile Island and Chernobyl, have done little to enhance international confidence in the ability of emergency planners to provide people with the protection they expect and demand. Regaining that public confidence is probably the most difficult task that those of us involved in the emergency planning process have to face.

Concluding Remarks

This paper has considered both the principles and practicalities of developing a strategy for applying short term countermeasures following a radiological emergency. It has not been possible to consider all of the relevant factors in detail, but the preceding sections should, at least, indicate the range of considerations that may influence the planning process. Other publications (e.g. Refs. 3, 13, 14 & 22) contain useful detailed advice and guidance on planning strategies. How far the points raised in this paper are applicable in different countries will depend on national and regional emergency planning practices. Socio-economic, political and regulatory factors will also play an important part in the development of any national strategy for such countermeasures.

Note: The views expressed in this paper are those of the authors and should not be taken to be those of either the National Radiological Protection Board or the Health and Safety Executive.

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PSYCHOLOGICAL AND SOCIAL FACTORS INFLUENCING THE CHOICE OF STRATEGY AFTER A NUCLEAR ACCIDENT

by

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The analysis of the post-accident situation in Chernobyl provides information that focuses on social and psychological factors in the management of nuclear accidents, both during short and long term accident management. This paper will concentrates on the short term countermeasures.

Many characteristics of the post-accident situation are determined by the behaviour of the decision-makers during the first stage of the accident. Consideration must therefore be given to the close link between short, medium and long term problematics, all the more so since the logic underlying the emergency plans generally leads to an arbitrary separation between these different phases. The proposals below are based in particular on the results of studies[1] carried out in Ukraine by Mutadis as part of an EEC programme to assess the consequences of the Chernobyl accident.

Psychological and Social Consequences of the Chernobyl Accident: Main Conclusions of Field Surveys

Extent of post-accident response at Chernobyl

Seven years after the accident at Chernobyl in the Ukraine, an analysis of its socio-economic impact at national level has confirmed the extent of the post-accident response. In administrative terms, this involved almost 3 million people

[1] Girard P. and Hériard-Dubreuil G. "Conséquences sociales et Psychiques de l'accident de Tchernobyl" a MUTADIS Report of May 1994
Heriard Dubreuil G. "Un premier bilan des effets psychiques et sociaux de l'accident de Tchernobyl", to be published in "Radioprotection" - Paris

(those relocated, people who had helped bringing the accident under control (liquidators), inhabitants of the contaminated territories. In financial terms, the post-accident management system proved a source of serious difficulties for the Ukraine, with 1/6 of the Ukrainian state budget being dedicated to it. This amount is levied by a 12% tax on wages and is administered by a special department, the "Chernobyl ministry". In political terms, Chernobyl remains a major factor in the process of institutional change initiated after the demise of the soviet state.

A General Mood of Anxiety; Worries over Health

A general mood of anxiety has been noticed in the various groups of population studied (those relocated, inhabitants of contaminated land and liquidators). This anxiety derives from the effects of the Chernobyl accident on the health of the persons surveyed and on that of their immediate family. This takes the more specific form of worries over the health of children. This anxiety is expressed in several forms; in the interviews, many references are made to the various somatic effects encountered by the population and systematically attributed to the Chernobyl accident, including constant references to thyroid problems and the mention of frequent sudden deaths in adults without any apparent specific reason.

The studies also show that this high degree of psychological distress is clearly linked to a feeling of partial loss of control by individuals over their existence which leads to an attitude of passivity toward their environment.

One Over-riding Concern: Contamination

Contamination of the environment is an over-riding concern for all interviewees. All of the persons questioned expressed their concern over the effects of this contamination on their health and the health of their immediate family. An examination of the interviews carried out by Mutadis shows that this fear does not conform with a clinical phobia. It is associated with a lot of distrust with regard to the statements made by the authorities and by the scientific and medical bodies.

Concern over the Future: "The Catastrophe is a Growing Tree"

The people interviewed expressed their deep concern over the future. "The catastrophe is a growing tree" is a recurring image showing the typical feeling which was expressed during the interviews. The future effects of the accident seem to be especially feared, even more so than past ones. This feeling is

fuelling a pessimistic and fatalistic vision of the future, most obvious in the children of those who have been relocated. The conviction that the situation can only get worse seems to strengthen the passivity of those interviewed.

Complexity of the Post-accident Situation

The detailed interviews have shown the complexity of the post-accident situation in the field. Multiple explanatory factors (historical, physical, political, cultural etc.) seem to be at the origin of the situation prevalent in the field today. All of these factors contribute in varying degrees in giving an understanding of this situation, but no single one can explain it. These factors themselves interact, which leads us to speak of systemic complexity[2]. In particular, account must be taken of the fact that this situation results from a concatenation of various earlier events which have occurred in succession since the accident, and which all seem, albeit to varying degrees, to contribute to the current situation.

A reconstruction of the various phases in accident and post-accident management and an analysis of their characteristics and their impact on the population is hence a necessary step in any approach to understand the accident situation. Once this reconstruction is complete, it will be possible, using the various factors identified, to attempt to interpret the situation encountered in the field and to suggest a way of modelling the various factors interacting to produce this complex situation, in order to put forward possible courses of action with the prospect of future nuclear accident situations.

Interpretations, an attempt to model those factors interacting to produce the 1993 post-accident situation

In order to single out the various explanatory factors, the effects of accident management must be distinguished from those of post-accident management. More specifically, we suggest distinguishing on the one hand the physical effects of the accident in the short, medium and long term and the consequences of the type of accident or post-accident management on the other (see Figure 1).

2 In the sense developed by various research teams in the USA and in France (Herbert Simon, Jean Louis Lemoigne).

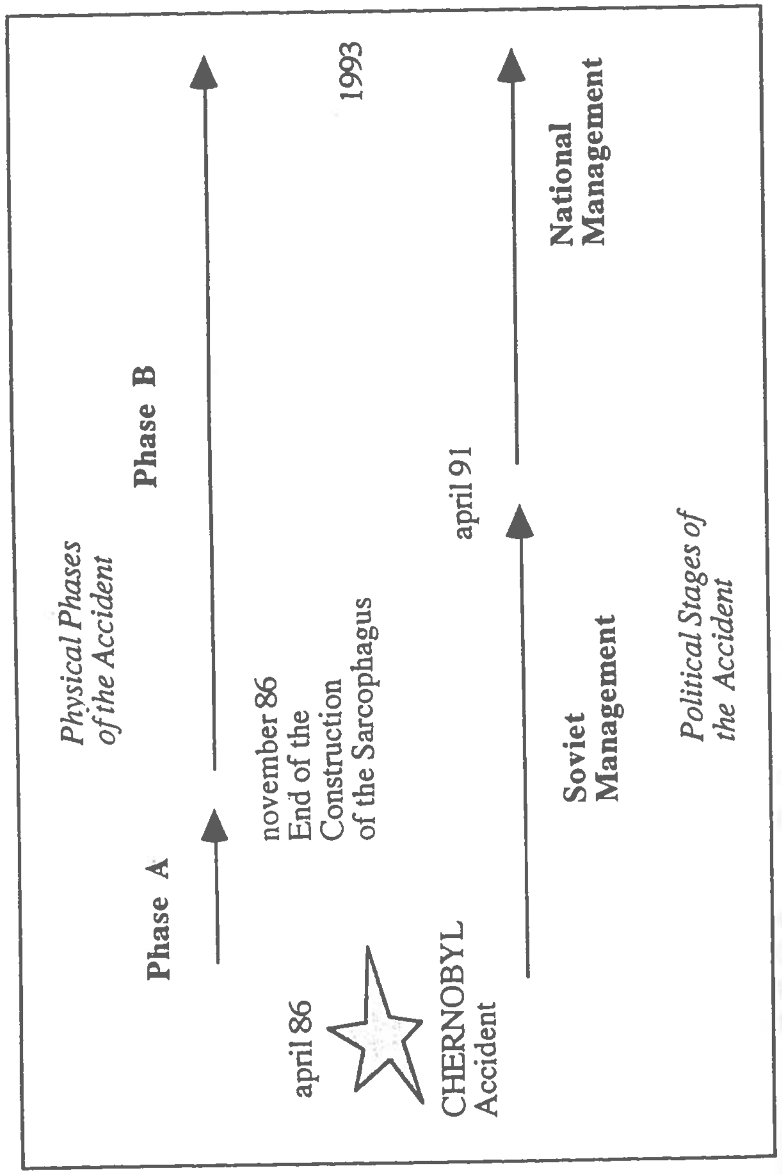

Figure 1. The Physical and Political Stages of the Chernobyl Accident
Mutadis Consultants - May 1994

Differentiating the Causes of Direct Somatic Effects in Phases A and B

The radiation-induced effects of the accident are not all of the same type, and so we suggest that a distinction be made between the effects of the accident phase (which we shall call Phase A), and those of the post-accident phase (which we shall call Phase B) in which there is still residual contamination (that currently observed), but with only a fraction of the radioisotopes present in Phase A. By convention, we shall take Phase A to refer to the time elapsed from the start of the accident to the end of sarcophagus construction (April to November 1986) and we shall take Phase B to refer to the period beginning with the end of Phase A. The somatic effects of these phases differ with the physical causes (variety of radioisotopes, intensity of exposure, nature of the contamination etc.). These effects are only partially known today, since a latency phase can arise between the accident phase and appearance of the effects of this phase.

The effects of Phase A are the result of a physical environment which no longer exists. Some of the effects appeared very rapidly (determinist effects of Phase A), but delayed effects are, it seems, presently in the process of appearing, as shown by the recent results of research carried out by the various teams (OMS, EEC, Ukrainian and Belorussian public health specialists) into the medical consequences of Chernobyl[3], which all seem to point to a significant increase in the frequency of thyroid cancer.

The potential effects of Phase B would be the result of residual contamination. These effects are evaluated in stochastic terms and are, according to the specialists, difficult to pinpoint in a population.

It should be noted, in particular, that the problematics associated with these two phases differ greatly. They are of different lengths (six months for Phase A which is now over, and soon over seven years for Phase B, the length of which will be proportional to the half-life of the radioisotopes remaining). In some ways, the problematics associated with Phase A are problematics of the past, even if delayed effects might still appear. The effects of Phase A are the result of an earlier attack on the health of the population. Conversely, the problematics associated with Phase B are current and of the future, insofar as its effects are

3 See the report EUR 15248 EN "Thyroid Cancer in children living near Chernobyl" and also OMS communication of 29 October 1993 concerning the results of research into the consequences of the Chernobyl accident on health, which indicates a "spectacular increase in the incidence of thyroid cancer" in Ukraine and in Belorussia, and also the various reports by the Ukrainian and Belorussian public health specialists.

the result of a physical cause which will only very gradually disappear. It should also be noted that the risks associated with Phase A vary greatly between individuals within the population. They depend on the behaviour of these individuals during this phase, on their proximity to the accident, on the type of work they carry out (outdoor, indoor), on their access to preventive measures (preventive instructions, iodine distribution, information regarding the contaminated areas, evacuation etc.).

Differentiating the Soviet and Post-soviet Management of the Accident

Historically speaking, there is a need to draw a clear line between "soviet management" of the accident (from 1986 to 1990) and the "national management efforts" (Ukrainian, Belorussian and Russian) which succeeded it; these national efforts differed in practice and in their consequences.

The interviews carried out as part of the Mutadis study in Ukraine highlight different features of these two stages which have left a deep impression on the picture the public had of the accident and of its consequences for them.

The first stage ("soviet management")

As regards the first, or "soviet management" stage, the study highlights three major characteristics which seem to be the cause of direct or indirect effects at both the somatic and the psychological levels.

- The first characteristic concerns the absence of efficient protection for the population during Phase A (with the exception of measures for evacuation which were often delayed, especially in the case of rural populations) and in particular the absence of iodine distribution, with a few rare exceptions. These observations made by the population, if confirmed, could explain the appearance of pathologies of the thyroid. Our understanding of the situation encountered will vary greatly depending on whether the somatic effects are real or imagined and whether or not they are directly related to the accident.

  In the current state of our knowledge, we have formed the hypothesis that the population is clearly suffering from real somatic effects, and that

these effects, at least[4] in the case of the pathologies of the thyroid, are delayed effects from Phase A. We base this hypothesis partly on the medical observations mentioned earlier, and partly on our own observations regarding the absence of phobia within the population.

- The second characteristic of the "soviet management" stage was the use of censorship and secrecy by the soviet authorities until about 1990. Interviews show that the official statements made during Phase A were systematically euphemistic. Several studies have shown that information likely to reveal the scale of the accident and its consequences to the public was kept secret. In particular, the measurements of the doses received by the population and by the liquidators of the accident were hushed up by the authorities. The authorities' attitude will have decisive psychological consequences. These will take the form of an absence of representation and conception of this Phase A by the population; this will in turn lead to a confusion of the effects of the two phases (A and B) of the accident, to focusing on Phase B, and therefore to ignoring the possible impact of Phase A.

- The third characteristic of this first phase was the high numbers of people taking part in accident management (almost 600,000 liquidators in the CIS), followed by their release into the population, without, apparently, any serious evaluation of the risk being made. It should be noted that, in view of the size of this group (almost 200,000 people for Ukraine), any deterioration in the state of its health combined with uncertainty over the root cause of this deterioration (no clear distinction between Phase A and Phase B) can be a major cause of confusion and worry in the public as a whole.

The second stage of post-accident "national management" (after 1991)

As far as the second stage of post-accident "national management" is concerned (from 1991 onwards), the study carried out by Mutadis also highlights several factors which explain the present state of affairs. The first factor is the political context in which responsibility was transferred to national level. The

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4 Account must certainly also be taken of the various factors likely to aggravate a poor state of health, such as the high degree of psychological distress which can be the root cause of psychosomatic effects, but also such as the worsening economic climate in the countries of the CIS (drop in the quality of foodstuffs, shortage of medicine). Account should also be taken of factors likely to reveal a deterioration in health, such as the development of medical surveillance and epidemiology for certain categories of the population following the accident.

collapse of the Soviet Union opened the way for Ukrainian independence and institutional transition to a democracy. In this context, the post-accident management of the Chernobyl accident became even more important as a political issue because demands for information and for public debate over the consequences of Chernobyl were being made in an atmosphere of censorship and secrecy (see earlier). Defending the rights of the "victims" and the implementation of a compensation system became major political issues, which would bring to power a new wave of politicians. This culminated in the passing of the law of 16 April 1991. Following a period of silence, the issue of Chernobyl became a battleground of political overbid and came to embody the clamour for self-determination and separation from a weakened central system[5].

This should be borne in mind, when considering that the public debate which developed over the consequences of the accident concentrated on the effects of Phase B. This tendency is evident in the Ukrainian law (april 1991), which attempts to assess all of the effects of the accident (Phase A and Phase B) using the figures for Phase B contamination[6].

The Ukrainian law (april 1991) is based on concepts of post-accident management which generate many adverse social and psychological side effects. They will not be developed here.

Suggested Modelling of the Interplay of Factors Accounting for the Post-accident Situation in the Ukraine in 1993 (Figure 2)

We listed a certain number of factors accounting for the situation in the field. These factors are of different types. They come into play, depending on the individual cases, at the various stages of the accident and post-accident process, the successive physical phases of the accident, Phase A then Phase B,

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5 This is the reason why the Ukrainian parliament passed very generous guidelines for compensation which was to be funded by the central soviet authorities (this draft law was vetoed by the soviet authorities, resulting in the decision by the Ukrainian State to suspend payment of its share of the central budget etc. right up until the declaration of independence).

6 This law defines the zones of contaminated land (there are four types of zone), which are delimited in terms of evaluations of the lifetime dose which will be received by the populations living in these zones, taking into account present and future contamination of the land on which they live (Phase B). Qualification for compensation is dependent on the amount of time spent living there in the past (Phases A and B) and in the future (Phase B) by persons (liquidators, those relocated and inhabitants of contaminated land) in a zone, and the classification of this living zone (between 1 and 4).

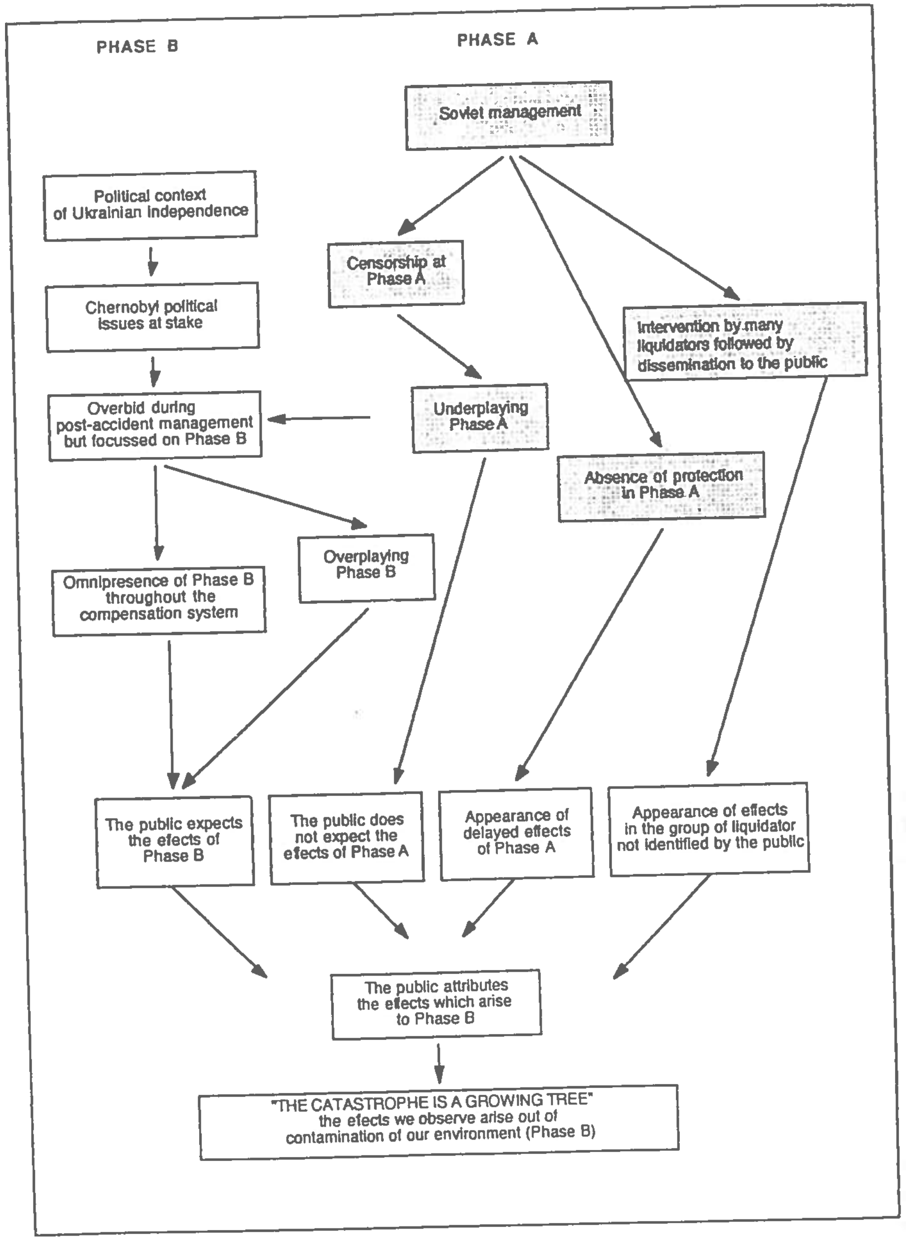
or successive organisational stages, soviet management or national management (by the Ukraine, Belorussia or Russia). The factors cited are the following:

- censorship during Phase A (soviet management),
- absence of efficient protection of the population during Phase A (soviet management),
- high number of liquidators and their subsequent return to the population (soviet management),
- political context of national independence (national management),
- the Chernobyl accident becomes a political issue (national management),
- overbid on post-accident countermeasures and compensation, but focused on Phase B (national management),
- adverse effects of the compensation system (national management).

A model of the interplay between these various factors is put forward in Figure 2. It shows that the interplay of factors leads to the emergence of delayed effects from Phase A and to the attribution of these effects to Phase B by the population. This situation, the result of an adverse combination of the various factors, is extremely harmful socially and psychologically insofar as it leads to a confusion between the effects of Phase A and those of Phase B.

We mentioned earlier that these two phases were very different in nature, and in particular that the problematics associated with Phase A were of the past, whereas those associated with Phase B were problematics of the present and the future. The confusion between the effects of Phases A and B brings about the projection of a past situation (which appears to have quite considerable risks) into the future. The delayed effects of Phase A are experienced as effects of Phase B, in other words, as effects of residual contamination which would take a long time to disappear. Needless to say, the public sees no reason for these effects to disappear, but rather feels that they must increase.

Figure 2. **Post-accident situation at Chernobyl in the Ukraine Mutadis Consultants -May 1994**



Draft Guidelines for Intervention Giving more Consideration to Social and Psychological Factors in the Short-term Coutermeasures

Introducing criteria of openness and automatic triggering of measures to inform and protect sections of the population during the accident phase.

It should be pointed out here that, contrary to popular opinion, the implementation of measures to protect and inform the population during the accident phase is a difficult decision for the people in charge of accident management and one which can be postponed because of the concern not to spread panic among the population: to inform and implement protective measures is in part to recognize at the very least the potential severity of an accident and hence to run the risk of worrying the public[7]. It seems that we should insist on the danger and adverse nature of this logic of preventing panic, which can lead to serious social and psychological problems, not to speak of medical effects.

In this context, it seems that the difficulties and hostilities with which the decision-makers are faced should be taken into account, for example:

- by introducing criteria for automatic triggering of the procedure for implementing measures to protect and inform the public,
- by introducing principles of openness when evaluating situations, including, for example, the participation of independent experts.

The Public Must Clearly Identify Phase A and Distinguish it From Phase B

The various considerations set out above have led to the recommendation that measures be taken at the start of the accident in order to prevent the onset of confusion among the public concerning the problematics associated with Phase A on the one hand, and Phase B on the other. The public must clearly identify Phase A and distinguish it from Phase B. Several practical guidelines for this can be laid down. A distinction can notably be made between Phase A and Phase B from the point at which the first information is released to the public, at the start of the accident.

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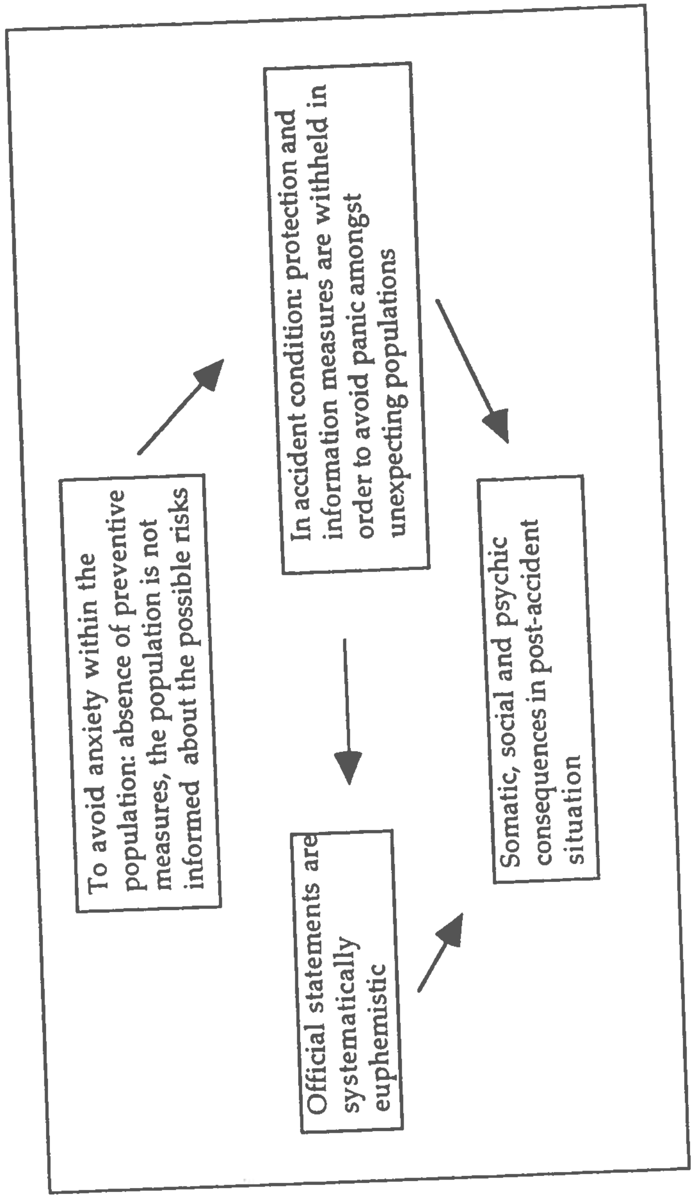
7 The decision-makers' concerns are, furthermore, increased where no prior information was given to the population as part of the emergency plans.

Figure 3. The dangerous logic of preventing panic



The risks associated with Phase A must be assessed individually; this implies an evaluation of the doses received (by direct measurement if possible, or if necessary by reconstruction). Individual evaluation is recommended since these risks can vary greatly. A principle of openness must be introduced in all approaches evaluating the effects and associated risks in Phase A. In particular, the public should be informed, if necessary, of the potential for delayed effects very soon after the end of Phase A. It is essential that the population have a clear picture of the risks associated with the accident phase.

Reduce Stress on the Population by Reshaping Preventive Measures

It should be noted that, as a preventive measure, one can help limiting any element of surprise caused when implementing protective measures by developing the practice of drills in normal situations.

Some research into cognitive psychology carried out by the French military, has shown that stress can be reduced in an emergency by a certain type of behaviour which will allow the subject to feel in control again, for instance:

- actively controlling the situation, instead of being a passive participant in it;
- searching around for information and checking the consistency of it;
- anticipating events by foreseeing any eventualities.

It should also be noted that the emergency response plans are generally designed to leave as little room for individual initiative as possible (using instructions which are generally written to be passive). It is by exercising his or her individual ability to act that an individual[8] is able to overcome his fear when faced with a risk and thereby reduce any temptation he might have to panic. It should be noted that designing the emergency response plans in such a way as to give greater room for individual action when faced with risk in an accident situation would reduce the effects of panic.

8 See the relevant study by Mutadis from February 1993, which puts forward a model for the process of perceiving individual and collective risks and showing the importance of the ability to take individual actions thereby instilling a feeling of risk control.

CONSIDERATIONS ON THE ECONOMIC CONSEQUENCES OF SHORT-TERM COUNTERMEASURES AFTER A NUCLEAR ACCIDENT

by

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Introduction

The conceptual framework for the management of short-term countermeasures is now well established and the assessment of their effectiveness in terms of dose reduction can be performed with reasonable confidence (1). As far as economical consequences are concerned, the situation is more debatable. Methods for the estimation of costs are restricted to the direct impacts of countermeasures and the use of the optimisation approach is still limited.

The objective of the paper is to present the various dimensions of economic consequences of the short-term countermeasures. The first part is devoted to the description of the different costs with emphasis on the main methods for their calculation. The second part is dealing with the total costs of short-term countermeasures and mainly with the distinction between "direct costs" and "indirect costs" of an accident. The third part presents the general framework for the implementation of the optimisation procedure. It should be noted that only few formal experiences exist in the application of optimisation for the choice of strategy for short-term countermeasures while this procedure is the core of the definition of strategy when dealing with long-term consequences (2).

Economic Consequences of Short-term Countermeasures

Six components are generally considered for the costs associated with the earlier phase of the accident: *i.e.* population evacuation or sheltering, temporary interdiction, food ban of directly contaminated products, distribution of stable iodine, decontamination, and health effects (3).

Population Evacuation or Sheltering

The direct costs associated with the evacuation of the population include the transportation costs of the population defined as a function of distance, number of people, and type of transport (public/private). This leads to a cost per person.km in the range of 0.03 to 0.08 ECU (1 ECU = 1.2 US$) or a cost per person.day in the range of 1 to 3 ECU (3). The other elements to be considered within the direct costs are accommodation and food. They are a function of the number of days of evacuation and persons as well as the type of premises (public/private). The cost per person.day is in the range of 5 to 15 ECU (3). The organisation of evacuation and the monitoring of people also imply additional costs because of the involvement of personnel during the emergency phase.

The evacuation of the population and the sheltering induce indirect costs on the economic system (3). These reflect the income and production losses caused by the shutdown of industry and commerce activities in affected areas. The calculation of these costs are based on the gross value added (except for the agricultural sector where a detail evaluation on market price is done). According to the area considered (size of the area, industrial/agricultural level...), this component should be quite large. One of the key element of this evaluation is to know how workers will be affected by the evacuation or sheltering: do they have to stop or not their occupational activities? Especially, around certain nuclear installations, "sensitive" industries should be concerned with short-term countermeasures and if the duration of countermeasures is greater than a few days, this shutdown of activities may cause large economic consequences at the regional level as well as in terms of loss of asset.

Temporary Interdiction

The temporary interdictions may have an incidence on the economical valuation of affected area. That means that the implementation of short-term countermeasures may decrease the cost per unit of area of farmland or the value of properties in urban area because of the loss of use (for example: acceleration of depreciation rate for the buildings...). Nevertheless, this component is a marginal aspect as far as short-term countermeasures are concerned.

Food Ban Costs of Directly Contaminated Products

The calculation of the costs associated with food ban are of great importance because of the large areas which may be affected by an accident. The impact of this countermeasure depends on the intervention levels adopted by national and/or international organisations.

Generally, three elements are considered for this cost: the loss of agricultural production, the lost services of agricultural capital, and the disposal of contaminated products. The calculation is based either on the contribution to GDP or on the market prices.

Health Effect Costs

In order to evaluate the benefit associated with the different short-term countermeasures, one of the main component is the reduction of the collective exposure to ionising radiation. Thus the calculation of the health effect cost becomes a key indicator. The health effects may differ according to the level of exposure (deterministic/stochastic effects), the time of expression (immediate/late), and the severity (death/incapacity or disease).

This economic evaluation, mainly depends on the value of life. It should be noted that the value of life is really specific to the country considered and there is no real consensus in economics about the value to be used as well as the methodology to be adopted. Basically, two approaches exist: the human capital approach and the "subjective" valuation of life.

The first one includes medical treatment costs and compensations for disability as well as the loss of human capital (generally based on GNP/inhab. which is about 15,000 ECU for European countries). Thus, assuming 15 years of life lost associated with radiation-induced fatal cancer, the loss of human capital is about 225,000 ECU per cancer (4).

The second approach is based on contingent valuations which are really dependent on the environment considered for the survey as well as the level of risk concerned. A review of the literature has pointed out a range of value between 80,000 to 26,000,000 ECU for the value of life corresponding to the amount that people are willing to pay in order to reduce the risk of death (5). Such a range of values demonstrates the ambiguity of the results and of the valuation of the benefit of the countermeasures.

As mentioned, the distribution of the effects according to time has to be taken into account in the case of stochastic effects associated with exposure to ionising radiations. Figure 1 provides the distribution of potential effects for an exposed population according to the time after exposure.

Figure 1. **Relative frequency of occurrence of a cancer for a French population after one year of exposure**

Because of the time-distribution of these effects, a discount rate has to be introduced when the cost of the health effect is considered. As far as non market good is concerned, there is a wide range of values for the discount rate and no real consensus exists among the economists about the value to be selected. Table 1 presents a set of discount rates adopted in Europe and in the USA (6).

It should be noted that the value of discount rate may have a large effect on the effectiveness of the countermeasures. In the field of economics of environment, discount rates in the range of 1 to 3% have been generally adopted for non market good such as health or the environment.

Table 1. **Evolution of discount rates in Europe and in USA**

COUNTRY	YEAR	RATE (%)
Belgium:		
Public investments	1969	7.0
Public investments	1982	4.6
Life-insurance	1992	4.75
United States:		
Electricity companies	1990	5.0
Medical	1990	0.0 to 5.0
Office of Management & Budget	1990	10.0
Environment	1990	1.0 to 3.0
France:		
Public investments	1970	10.0
Public investments	1992	8.0
United Kingdom:		
Public investments	1989	6.0
Sweden:		
Electricity companies	1989	5.0

Direct Costs Versus Indirect Costs

Although the methodology adopted for the calculation of direct economic consequences associated with a nuclear accident is now well-established, the potential for a large disturbance on the national economy has also to be considered. First attempts have demonstrated that the indirect costs may increase the total costs of an accident of about 30 to 50 % (7).

The Total Direct Cost of a Nuclear Accident

The calculation of economic consequences of nuclear accident are now really easily obtained, especially with the distribution of PC-codes including an economic module such as COSYMA and MACCS (3, 8, 9). In the framework of the calculation of external costs associated with different fuel cycles within a joint EU/US programme, the following calculation has been performed for an hypothetical nuclear accident (10). This calculation is based on the COSYMA code and its economic module.

The scenario adopted assumes a 10% of releases of the core, from a 1,200 MWe NPP located in central Germany[1]. For the estimations of the consequences, the evacuation lower criteria from ICRP 40 were adopted (*i.e.* lower dose level: 50 mSv whole body, and 500 mSv to the thyroid) (12). It should be noted that these calculations have been performed before the ICRP Publication 63 (13). This publication defines the intervention level of averted dose for which evacuation is 'almost always justified' (*i.e.* 500 mSv whole body dose, and 5 Sv equivalent dose to skin). Furthermore, it specifies that the 'range of optimised values' is 'not more than a factor of 10 lower than the justified value'. The duration of the evacuation was three days and food bans were adopted above 1,000 Bq/kg. Table 2 presents the direct costs for this scenario.

Table 2. **Direct costs derived from the economic module of COSYMA**

	Cost (MECU)	% of total cost including long term
Population evacuation (44 000 people)	78	0.25
Health effects: - immediate morbidity (138 people) - immediate mortality (9 people) - late morbidity - late mortality	 0.6 3 nd nd	0.01
Food ban: - local - regional	890 28 870	2.8 91

nd: not defined because mainly associated with long term countermeasures

It should be noted that the main cost is due to food ban at the regional level. This component is partly associated with short term consequences and moreover, there is no direct relationship between food bans and countermeasures such as evacuation, sheltering and distribution of iodine. The total social cost of this scenario (including long term consequences, and willingness to pay of the

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[1] This rather pessimistic scenario has been selected by OECD/NEA and CEC as an example for the comparison of computer codes (see source term TS2) (11).

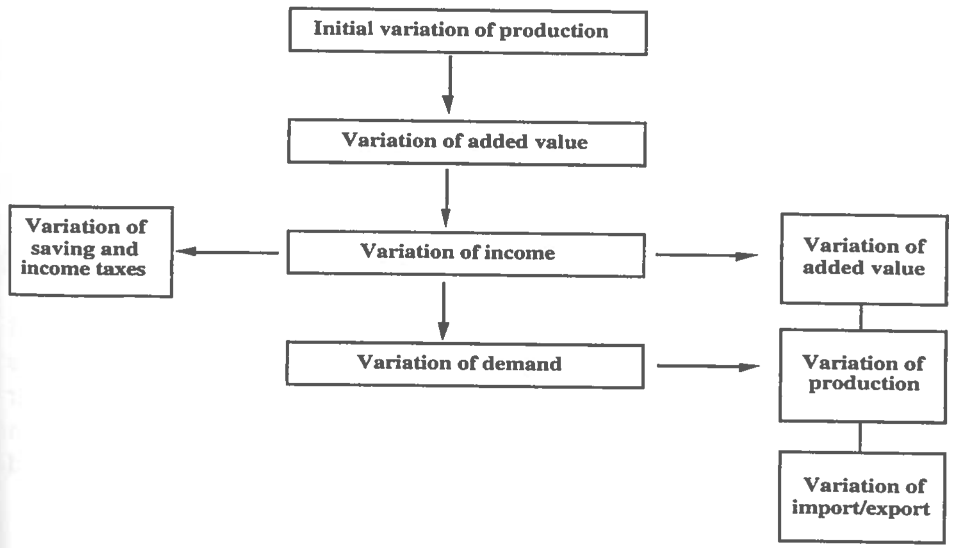
population for the valuation of health effects) is about 30,000 MECU while the direct compensation cost is only in the range of 2,000 MECU.

Above the difficulty to clearly delineate the categories of costs of an accident (*i.e.* local/regional, short term/long term, direct costs/indirect costs), a large variation should appear according to the location of the site as far as the evacuation is concerned. Sensitivity analyses on French NPPs lead to one order of magnitude for the number of people to be evacuated (and thus for the cost of evacuation) according to the site considered.

Towards the Integration of Indirect Costs

According to the duration of the countermeasures, especially if there is a need to evacuate a large area for a week or more, indirect consequences could appear on the economic system. In order to evaluate this kind of consequences, it is necessary to analyze the "input/output" matrices of the regional economy. Figure 2 describes the logical framework for such an analysis (7).

Figure 2. **Framework for the calculation of indirect costs on economic activities**



The Evaluation of Compensation Costs

Beyond the distinction between direct and indirect economic consequences of a nuclear accident, one of the major concern is the delineation of the compensation associated with these consequences. Although insurance systems have been adopted at both national and international levels for the compensation in the case of a nuclear accident, there is still a lack of detailed analyses concerning the categories of consequences to be compensated as well as the practical criteria for compensation.

The Role of Optimisation

The interest of the optimisation procedure appears in areas where action has to be taken and the question is to know how far to go in the implementation of countermeasures. Based on the model of acceptability developed by the HSE in United Kingdom (14) and the last ICRP recommendations (15), this optimisation procedure should provide information for the selection of optimised intervention levels for the implementation of countermeasures (see Figure 3) (13). In the case of post accidental situations, the limit of tolerance has to be considered with cautious, and should referred to the upper value of intervention level.

In order to allow the selection of the optimum level, a cost-benefit analysis is performed implying the definition of a system of monetary values of the man-sievert. Figure 4 presents the system adopted in the International Chernobyl Project for the optimisation of long-term countermeasures (2) taken into account both avertable collective dose and the individual residual level of exposure (4). This system is also used for occupational exposures in France and UK (4, 16) and could be adapted for short-term countermeasures. An aversion factor is introduced to reduce the dispersion of individual exposures, in accordance with the last ICRP recommendations.

The evaluation of the monetary value of the man-sievert can be based either on the human capital approach or on the willingness to pay approach. In France, the values adopted are in the range of 15,000 ECU to 3 MECU per man-sievert according to the level of individual exposure. Various valuations of the man-sievert should be adopted for the protection of the public after a nuclear accident. The adoption of this system is necessary in order to determine, within an a priori evaluation, the optimum levels for short-term countermeasures and to choose the strategy according to the situation considered.

Figure 3. **The model of acceptability of risk**

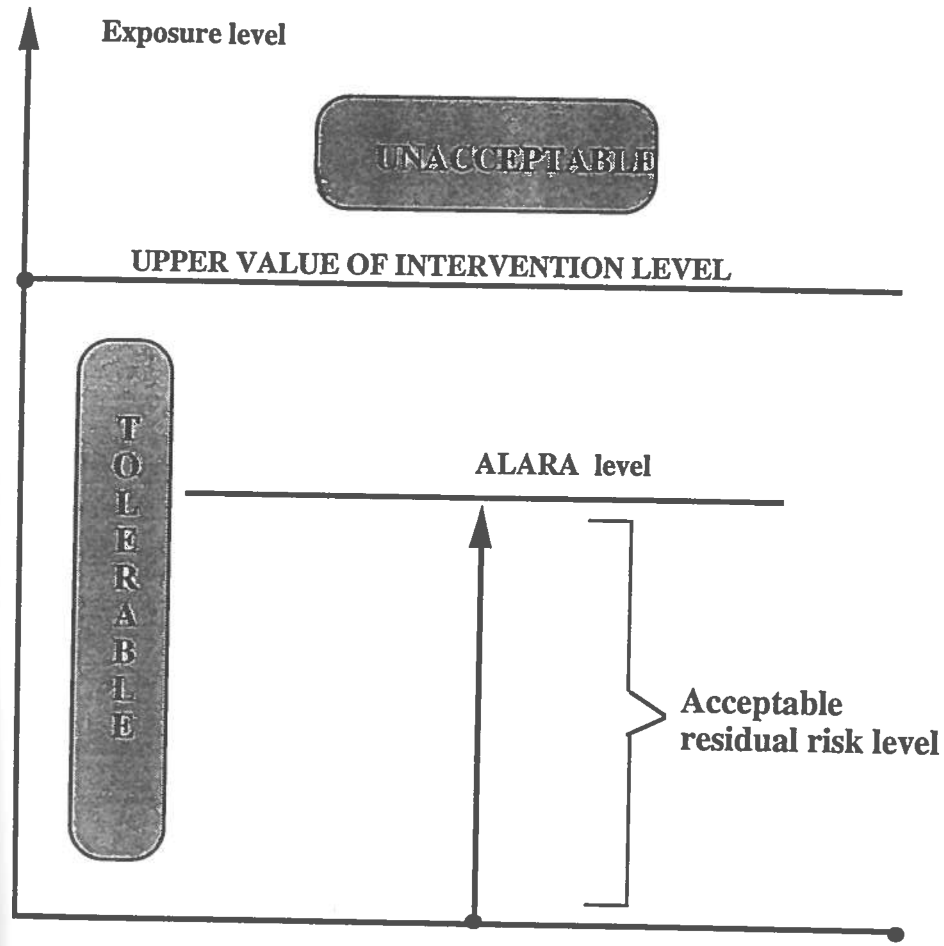
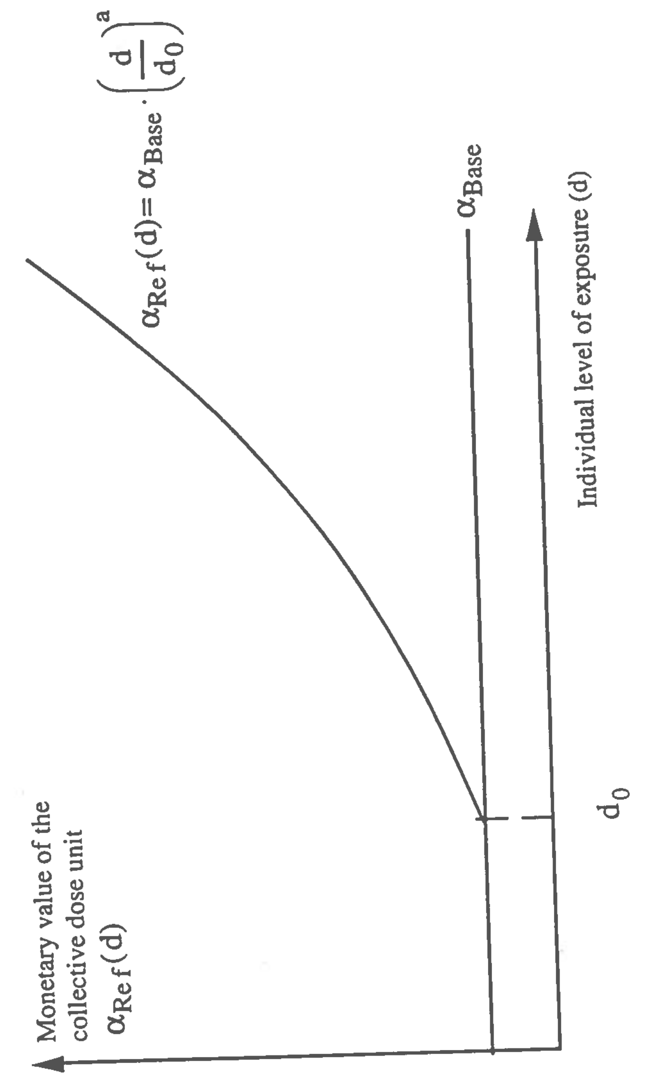


Figure 4. The system of monetary values of the man-sievert



Conclusion

The direct costs associated with short-term countermeasures are relatively well delineated and represent only a small part of the total costs of an accident. The food ban costs are really the main component of these direct costs.

Furthermore, it appears that the indirect consequences on the regional economy has never been studied in details and should be addressed in the future as far as it may represent a significant part of the total costs according to the "size" of the initial impact on the economic activity. Moreover, it would be of interest to better define the part of costs to be potentially covered by the insurance system.

Finally, there is a need to introduce social considerations for the valuation of health effects as well as for the determination of a specific value of the man-sievert for public protection associated with the definition of short-term countermeasures. In this perspective, the objective should be to performed surveys based on the recent developments in the field of revealed preferences and to define a consensus on the values of the man-sievert to be used in the decisional process allowing for the adoption of intervention levels which will decide about the choice of strategies for short-term countermeasures.

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Session 4

IMPLEMENTATION OF STRATEGIES AND NATIONAL PRACTICES

Co-chairman: Hans Brunner, Switzerland
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NUCLEAR EMERGENCY PLANNING IN BELGIUM

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1. International Recommendations Supporting Decision-making

The countermeasures provided for in nuclear emergency planning, their medical background, as well as the related reference intervention levels are characterized by a fair level of international consensus on the approach of the matter.

However, a similar approach can not conceal that some stumbling blocks still remain; trying to remove these was one of the reasons why this workshop was organized.

When comparing the available documents, we should bear in mind the possible differences in the field of radiological risk evaluation. Some of these documents were indeed published before the latest re-assessment of the risks, while others were drawn up afterwards.

In fact, the whole system is based on the evaluation of the magnitude of these radiological risks, and, taking this into account, on the economic and public health price that society as a whole is willing to pay, in order to reduce or dispose of the risks involved.

One critical matter has to do with the radiation hazard before birth, more particularly with the risk of brain damage.

Yet, the attitude towards pregnant women in a nuclear emergency situation depends upon the basic approach or hypothesis agreed on: either we accept a threshold value for radiation-induced effects on the brain or we consider that the existence of such a threshold level has not been established yet, the latter involving that stochastic radiation-induced brain damage cannot be excluded.

Moreover, some conceptual problems also remain unsolved. They can be explained by the following considerations: although a broad scientific consensus – which, in itself, would be an encouraging achievement – seems to exist, not everyone is aware of the fact that this consensus is not a purely scientific one, but comprises choices in the political, ethical and socio-cultural fields, choices that are rarely being explicated.

We should focus on two concepts: first on the meaning of lower Emergency Reference Level (ERL) and, second, on the concept of "net benefit".

In international recommendations the lower ERL value is often regarded as the dose level below which a countermeasure *is not justified* – or is *probably not justified* – for reasons related to *radiological protection.*

But is it really so ?

If the risk of a countermeasure in terms of public health is low or nonexistent (e.g. some preventive measures in the field of agriculture or recommendations to the public), and if, for ethical or other reasons, society as a whole accepts to pay a higher financial price to reduce the risks for some well-defined categories of individuals, it is perfectly acceptable – on the ground of scientific as well as strictly human considerations – to suggest lower ERL levels than those usually set forward in the available recommendations.

But the conceptual ambiguity remains and the myth of threshold levels as far as long-term radiation-induced effects are concerned, is matched here, *mutatis mutandis*, by "justification thresholds" of the countermeasures.

Obviously, we do not argue that there should be no threshold at all in view of responsive actions such as evacuation; what we do like to stress, though, is that it could never be a threshold, below which no harm can be expected (even in the broader sense, after weighing advantages and disadvantages). Decisions in that domain are always influenced by ethical and economic arguments.

There is another questionable conceptual item : the "net benefit". The question is: a benefit for whom? In the classical formula ($B = \Delta Y - (X+R)$), the avoided radiological damage and the risks linked with the countermeasures, relate to individuals exposed to the risks; but the price of the countermeasures and the public health costs related to radiation-induced effects, concern the State or society in general.

Examples abound of situations where health interests of an involved group clash with financial interests of society.

Even if all international recommendations agree on the principle that the term "cost" goes beyond its purely economic meaning, the fact remains that the above formula cannot be applied without a common unit. And if we refer to practical examples in the literature, we notice that the concept of "cost" is nearly always reduced to its mere financial aspect.

An ethical approach of post-accidental decision-making could consist in doing away with this exclusively mathematical and financial approach of the problem, and in opening up the debate to concepts such as "benefit" and "the conflict between individual and social benefit", with solidarity as a background. It may be incorrect to state that health is priceless, but it is truly immoral to claim that the health of individuals should not cost anything to society as a whole (we are only paraphrasing the financial translation of the "net positive benefit").

Society may be perfectly willing – provided it has the necessary means – to bear certain costs as an expression of solidarity. By doing so, it is no longer referring exclusively to the purely mathematical approaches of the justification and optimisation concepts, but it is paving the way for solidarity-minded decisions.

Let us briefly discuss another conceptual difficulty: the distinction between justification and optimisation. Distinction is not as clear-cut as one would believe at first sight. The I.C.R.P. (International Commission on Radiological Protection) states that protection should be optimized by modulating the scale of the intervention; the fact is that the dimensions of the response area, and particularly the integration of big cities in this zone, are an essential component of the ... justification process. Both concepts thus intersect.

2. The Belgian Approach

The main features of the Belgian approach can be summarized as follows:

- to take account of the most recent evaluations of the risk coefficients for radiation-induced effects;
- to reject, for ethical reasons, any purely financial cost/benefit analysis and, as far as possible, give priority to protecting public health;

- to give, also for ethical reasons, priority in decision-making to the justification concept, which requires a gradual, step-by-step and upwards analysis of intervention reference levels;

- to give priority to the protection of the most vulnerable subgroups of the population, probably through specific recommendations in the media;

- to integrate countermeasures aiming at preventive protection of the food chain in the large set of possible interventions;

- to include exceptions in the application of countermeasures for "special groups" whose presence is mandatory;

- to reduce the range of recommended guide levels for intervention in a process of "cold pre-justification" – *i.e.* justification prior to any emergency situation, on the basis of scenarios –, to take account of national realities and of the potential gravity of the higher dose levels (possible thresholds of fetal effects clearly exceeded, absence of low dose reduction factors for long term effects, possibility of acute effects due to incorrect modelling...).

3. Main Problems

Working out emergency plans in Belgium proved to be a long and arduous process. This is partly due to some of the conceptual problems mentioned above. Another factor should be stressed here: part of the nuclear "world" has still some doubts about the reality of the risks involved. Some people are still convinced that accidents are highly improbable in the light of the type of nuclear power plants that are operational in our country; or they question the gravity of the dangers linked with exposure to ionising radiation (at least when only low or medium doses are involved). That lack of motivation could explain, at least partly, why it took so long to work out those plans.

Now that emergency planning exists, exercises confirm that not all problems have yet been overcome.

The main difficulty is related to the information available at the time when a decision is to be made: is this information sufficient or not? This is a typical example of decision-making in a context of uncertainty. This line of argument raises the problem of the feasibility of preventive actions: for instance, measures intended to protect the food chain, or the absorption of stable iodine (our plan

only provides for the distribution of iodine pills within a 10 km radius of nuclear power plants, and an even smaller radius for other installations), or preventive evacuation, limited or not to a specific group.

Centralisation, continuous evaluation, and modelling are the key concepts of our system: decisions are taken at the national political level after evaluation by experts. In practice, decision-making in the area of urgent countermeasures largely boils down to dose projections based on models.

However, recent tests have shown that, using the same parameters, the Belgian models yield quite different results from those used in other countries.

For the measurements to be reliable, they must reach a certain "critical mass"; waiting for them implies giving up every possibility of preventive action.

Finally, the principle of a political discussion on decision-making following expert meetings, holds the danger of generating inefficient decisions or decisions that are no longer adapted to the current situation.

We advocate a "cold" analysis of different possible scenarios and a final decision based on "cold political arbitration". It is important that decision-makers are involved in this preparatory stage because it allows going to the heart of the matter.

Another problem is the concept of "phased response".

The proposed countermeasures are often put forward as "mandatory" measures: "the whole population is being evacuated"; "everybody has to stay indoors", etc.

This mandatory aspect ipso facto generates complications that balloons both the risks and the social or financial costs, and these effects, in turn, require higher dose levels for intervention.

We are convinced of the usefulness of "recommendations" through the mass media; this system crystallizes the idea that each individual has **the right to be informed and is free** to follow the recommendations or not. It is a possible solution to the problem of dealing with sensitive groups (especially pregnant women). Along the same line, we should also provide for exceptions to the countermeasures, for examples in favour of certain groups whose presence on the spot is absolutely required (certain industries,...).

The public is becoming aware of the principle of "sensitive" or "vulnerable" persons (for example the risks for pregnant women taking certain drugs). The concept of "relative" risk is also getting better known. Guidelines recommending to stay inside "if possible" in heavy storm are an example of this. They could be used as a model for recommendations to be issued at low radiation doses.

We will have to make the public become familiar with these concepts if we want to convince them of the fact that key-industry personnel has to continue to work when other people stay indoors.
The risks linked with the absorption of stable iodine will be reduced if sensitizing campaigns inform people in due time of possible contraindications.

If we want to avoid the "all or nothing" situation and try to cut the facts down to size, there is no alternative than to issue accurate information aimed at a correct assessment of risks.

THE FINNISH MODEL FOR SHORT-TERM COUNTERMEASURES AFTER A NUCLEAR ACCIDENT

by

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Summary

A short description on the radiation surveillance and on the intervention policy in a radiological emergency in Finland is presented. The Finnish Centre for Radiation and Nuclear Safety (STUK) is the national contact point in emergency situations in Finland. It collects all data about the event of an accident and about the radiation situation. It also makes assessments of health effects and gives recommendations for countermeasures to the executive authorities.

The first concern in the event of a radiological emergency is to assure that the radiation exposure to individuals from all pathways will be below thresholds for serious deterministic health effects. In an operational intervention, the aim of every countermeasure is to keep the stochastic health effects in all population groups as low as reasonably achievable. When considering a specific countermeasure or a set of countermeasures, it has to be taken into account that the countermeasure will do more good than harm, *i.e.* it is justified, and the form, scale, and duration of the countermeasure should be optimized so that the net benefit of the countermeasure is maximised.

The basic short-term countermeasures to be implemented in emergency situations are described, together with the proposals for the generic operational intervention levels to be applied with countermeasures. STUK proposes that operational intervention levels in Finland would be given in external dose rates in outdoor air, because it is the only real-time monitored quantity in the country-wide surveillance networks. Practical problems with using directly measurable

quantities to trigger an operational intervention in the acute phase of an accident is discussed.

STUK recommends the following operational intervention levels to be adopted in Finland: external dose rate of 10 μSv/h for protection of cattle and its feed in the acute phase of an emergency situation, 100 μSv/h for sheltering, for prophylactic administration of stable iodine and for control of access, and 500 μSv/h for preventive evacuation. These operational intervention levels are generic in nature, *i.e.* they can be changed either downwards or upwards as soon as the authorities have got adequate data about the severity of the situation.

Radiation Surveillance in Finland

Several organisations are participating in radiation surveillance in Finland. The Ministry of the Interior maintains the country-wide monitoring network of external dose rate. This network contains about 250 automatic stations which can be read and managed in real-time by the radiation experts at the Ministry of the Interior, the Finnish Centre for Radiation and Nuclear Safety (STUK), the Meteorological Institute, the General Staff of the Defence Forces, and at the county governments.

STUK has its own country-wide surveillance network for airborne radioactivity (high-volume air samplers and laboratory measurements) and for radioactive deposition (dry and wet deposition and laboratory measurements). STUK also has a mobile laboratory for rapid measurements of external dose rate, airborne radioactivity and deposition.

The Meteorological Institute supports the radiation surveillance by supplying meteorological data, making weather forecasts and trajectory calculations. The institute also has its own network for measuring airborne total beta-activity.

The Defence Forces measure airborne radioactivity by a gammaspectrometer installed in an airplane or a helicopter, or take high-altitude air samples and measure them in the laboratory. The Seismological Institute of the University of Helsinki participates in radiation surveillance by informing the other organisations about observations of nuclear explosions and seismic events near nuclear installations.

STUK is the central organisation in case of nuclear or radiological hazards. In emergency situations, STUK collects all technical data concerning the accident, makes estimates of the development of the accident, makes dose

estimates, collects all data on radiological situation, gives recommendations for countermeasures to executive authorities, provides advices to industry, trade etc., and informs the public.

Generic Intervention Levels for Short-Term Countermeasures

In accident situations, an intervention for protection of the public may consist of several different countermeasures. The first concern in an event of a radiological emergency is to assure that the exposure to individuals from all pathways will be below the thresholds for serious deterministic health effects. In an operational intervention, the aim of every countermeasure is to keep the stochastic health effects in all population groups as low as reasonably achievable.

When considering a specific countermeasure or a set of countermeasures, it has to be taken into account that the countermeasure will do more good than harm. In other words the dose reduction and other benefit due to the countermeasure should be sufficient to justify the harm and the costs, including social costs, of the countermeasure. Secondly the form, scale, and duration of a countermeasure should be optimized so that the net benefit of the countermeasure is maximised, *i.e.* the gross benefit less the detriment associated with the countermeasure, is maximal.

In a radiological emergency, countermeasures for protection of the public are almost always justified if the projected individual doses from a specific pathway or a combination of pathways may approach thresholds for serious deterministic health effects.

The key concept for an intervention, used by the ICRP and the IAEA, is the averted dose, which is the dose saved by implementing a protective action. These international organisations have given their recommendations (1, 2) for generic intervention levels in averted doses. The averted dose, in the acute phase of a radiological emergency, however, is not very practical quantity for the short-term countermeasures. Operational intervention levels given in directly measurable quantities, will be needed for a rapid implementation of short-term countermeasures. These operational intervention levels should also be generic in nature. That is, they are chosen to be reasonable for the majority of situations, and they can be changed either downwards or upwards as soon as the severity of the situation has been settled.

STUK has started to develop the operational intervention levels for different short-term countermeasures needed in a nuclear accident. These operational intervention levels should fulfil the following criteria: 1) they have to be suitable for the Finnish conditions, and 2) they should be measurable by the real-time radiation surveillance network used in Finland. In addition, they should not lead to remarkable deviations from the international recommendations on generic intervention levels. External dose rate in outdoor air has been chosen for the operational quantity of the generic operational intervention levels, because the real-time surveillance network in Finland is based on monitoring of external dose rate.

In connection with short-term countermeasures there always is the problem that the countermeasures should be implemented before the radioactive plume arrives to the area to be protected. Therefore, decisions in protective actions must be based on a prejudgment of possible release and radiation situation. If a radioactive plume already has affected one area, results of the real-time radiation monitoring network together with the weather forecasts can be used when estimating the spreading of the plume to another area.

Proposals for Operational Intervention Levels

The operational intervention levels have been studied for the following short-term countermeasures after a nuclear accident:

• **Sheltering**: advising people to stay or to go indoors, to close and to tighten doors and windows, and to turn off the ventilation systems, before an arrival of radioactivity plume. Sheltering usually lasts not more than for one day.

• **Prophylactic administration of stable iodine**: advising people to take KI tablets according to instructions given in advance, if high intakes of radioactive iodine are expected to occur or is occurring.

• **Preventive evacuation**: urgent removal of people from a specified area for periods of the order of days before any radioactive release of radionuclides into the environment.

• **Control of access**: limitation of access to an area to be affected by a radioactive release or to an contaminated area. Access is only allowed to workers undertaking rescue or recovery operations.

• **Protection of cattle and its feed**: advising farmers to keep the cattle sheltered and to protect the feed before arrival of radioactive plume.

The operational intervention levels have been calculated for a radiological emergency where the composition of radioactive plume is not known. Therefore a conservative scenario of the origin of the radioactive plume has been used. In the scenario used, the main part of the projected dose (>80%) during the passage of the plume is received through inhalation. This kind of plume is estimated to occur after a severe reactor accident where radionuclides are released to the environment without any filtration. The external dose rate, in this kind of radiological situation, is not the best possible quantity to trigger an intervention, because it describes a small part of the total potential exposure. If estimates e.g. on airborne iodine concentrations are available, they should be used instead of external dose rate.

The projected doses are calculated to an "average" member of the public in his/her normal living conditions. This individual is a person whose age is the weighted mean of the age distribution of the Finnish population and who is more probably indoors than outdoors at the moment of the accident. The house where he/she is staying during the emergency situation has average shielding and filtrating factors against external dose rate and airborne radioactivity. So the projected doses and the efficiencies of countermeasures are not estimated to individuals who are most sensitive to radiation and who are staying outdoors at the moment of arrival of the plume. Population groups being more sensitive to radiation (e.g. children, pregnant women etc.) can be considered as separate subgroups if it is possible in practice.

Table 1 gives the proposals for the generic operational intervention levels for the short-term countermeasures in a radiological emergency. The countermeasures to be performed at sites where people are staying at the moment of need for protection (sheltering, prophylactic administration of stable iodine and control of access) are grouped to the same intervention level (100 μSv/h) for practical reasons. The estimates on individual avertable doses in sheltering and prophylactic administration of stable iodine shown in the table are at the same level recommended by the ICRP and the IAEA. On the other hand, in the area where people are advised to stay indoors, it is reasonable to control other people to access the area.

The operational intervention level of 500 μSv/h is proposed for the preventive evacuation. STUK recommends that in Finland the word "evacuation" should always be used for the preventive and urgent removal of people from a threatened area. This countermeasure is foremost intended for being implemented only in close areas of the domestic nuclear power plants. If the removal of people is necessary to be performed after the passage of a radioactive plume, STUK proposes the "temporary relocation" to be used. Preventive evacuation should always be performed in good time before a radioactive release.

Protection of cattle and its feed is an efficient countermeasure to protect the food chain. It is especially important to protect milk from contamination with radioactive iodine during the first few weeks after the deposition. Seasonal and local circumstances have great influence on the effectiveness of protective actions. The operational intervention level of 10 μSv/h for the acute phase of a radiological emergency is recommended on the basis of the experiences achieved from the Chernobyl fallout in Finland.

Table 1. **Proposals for generic operational intervention levels for the short-term countermeasures in Finland after a nuclear accident**

Protective action	Operational intervention level as an external dose rate	Avertable dose
Protection of cattle and feed	10 μSv/h [a)]	depends on circumstances
Sheltering	100 μSv/h [a)]	few mSv/h [1)]
Iodine prophylaxis	100 μSv/h [a)]	few tens mGy [2)]
Control of access	100 μSv/h [b)]	depends on the duration
Preventive evacuation	500 μSv/h [a)]	about ten mSv/day [1)]

a) Predicted external dose rate in outdoor air
b) Predicted or measured external dose rate in outdoor air
1) Effective dose
2) Absorbed dose in thyroid

These intervention levels are intended to be used in a radiological emergency where the composition of radioactive plume is not known. In specific accident conditions where the nature and the severity of the radiological situation are known, it is reasonable to define the accident-specific intervention levels.

References

1. ICRP Publication 63. *Principles for Intervention for Protection of the Public in a Radiological Emergency*. Annals of the ICRP, 22, No 4. Pergamon Press, Oxford; 1991.

2. *Generic Intervention Levels for Protecting the Public in the Event of a Nuclear Accident or Radiological Emergency*. IAEA-TECDOC-698 (interim proposals). International Atomic Energy Agency, Vienna; 1993.

THE GERMAN PRACTICE WITH SHORT-TERM COUNTERMEASURES
(Stable Iodine; Sheltering and Evacuation)

by

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1. Introduction

The Federal Republic of Germany is, as its name suggests, a federal country with 16 constituent states (Länder). Both, the federal government and the states have tasks and responsibilities in the emergency management.

Disaster response is within the responsibility of the states. It is based upon the Atomic Energy Act (1) as well as the disaster planning legislation of each state and has been developed since the initial construction of commercially used nuclear power plants (in Germany: end of sixties/early seventies). Disaster response includes all measures which prevent acute damage to health, such as sheltering, evacuation, the distribution of iodine tablets, the sealing off of areas and other traffic control measures as well as the decontamination of individuals. Disaster countermeasures are planned and prepared for a distance of 25 km from a particular installation.

Long range precautionary radiological protection, on the other hand, is within the overall responsibility of the federal government. It is based on the "Act on Precautionary Protection of the Population Against Radiation Exposure (Precautionary Radiological Protection Act)" (2) which was drawn up after the Chernobyl accident. Precautionary radiological protection measures are designed to prevent chronic exposure, in particular in connection with the commercial trade of food and feedstuff, relocation or large scale decontamination.

Concerning this workshop on short-term countermeasures (sheltering, evacuation and stable iodine), we are going to talk about disaster countermeasures only.

2. Disaster Response Management

2.1 *Basic Recommendations*

In order to ensure that, as far as possible, the same principles for organisational regulations and the planning for emergency countermeasures by the individual disaster response authorities are applied all over the Federal Republic of Germany, federally oriented guidelines were named. The latter were considered in the "Basic Recommendations for Emergency Preparedness in the Environment of Nuclear Facilities" (3) jointly prepared by the Federal Government and the Federal States. In supplement hereto, "Radiological Bases for Decisions on Measures for the Protection of the Population against Accidental Releases of Radionuclides" (4) were issued by the Federal States Committee for Nuclear Energy as a decision making aid to radiological protection experts.

The "Basic Recommendations" apply exclusively to the disaster response in the environment of German nuclear facilities, including reprocessing plants and foreign plants which, because of their location near the frontier, require planning measures as defined in the above mentioned recommendations to be carried out on German territory. The "Basic Recommendations" do not apply to precautionary measures in the area of preventive medical care or other government measures in compliance with the "Precautionary Radiological Protection Act" for which the governmental as well as the federal state environmental ministerial authorities are signing responsible. The "Basic Recommendations" do likewise not apply the on-site emergency protection for which separate recommendations are valid.

The competence for disaster response in the environment of nuclear facilities is differently distributed in the various federal states. In some of the federal states, the county district magistrates and the district authorities are responsible as a lower disaster response authority while in other federal states such competence is assigned to the regional government as an intermediate authority.

2.2 *Principles for Setting Up Special Disaster Response Plans for the Environment of Nuclear Facilities*

Basically, the environment of the nuclear facility is subdivided into the following zones in order to locate preparatory measures:

- Central Zone,
- Intermediate Zone and
- Outer Zone.

The Central Zone surrounds the nuclear facility directly. Its outer limit must be adjusted to the local conditions and not exceed a distance of 2 km to the facility.

The Intermediate Zone surrounds the Central Zone. Its outer limit is a circle with a maximum radius of about 10 km. In order to be able to respond fast and flexibly the Intermediate Zone may be subdivided into further sub-areas.

The Outer Zone surrounds the Intermediate Zone. Its outer limit is a circle with a maximum radius of 25 km.

The Intermediate Zone and the Outer Zone are subdivided into 30° sectors which are numbered clockwise with sector 1 in general symmetrically oriented towards the north (see figure 1).

The necessary countermeasures must be prepared for each zone. In principle, special disaster response plans in relation to the nuclear facility concerned are not required outside of the referred zones.

2.3 *Remarks on the Disaster Response Plan*

The disaster response plans for the environment of individual nuclear power plants are prepared by each proper federal state in compliance with the Basic Recommendations.

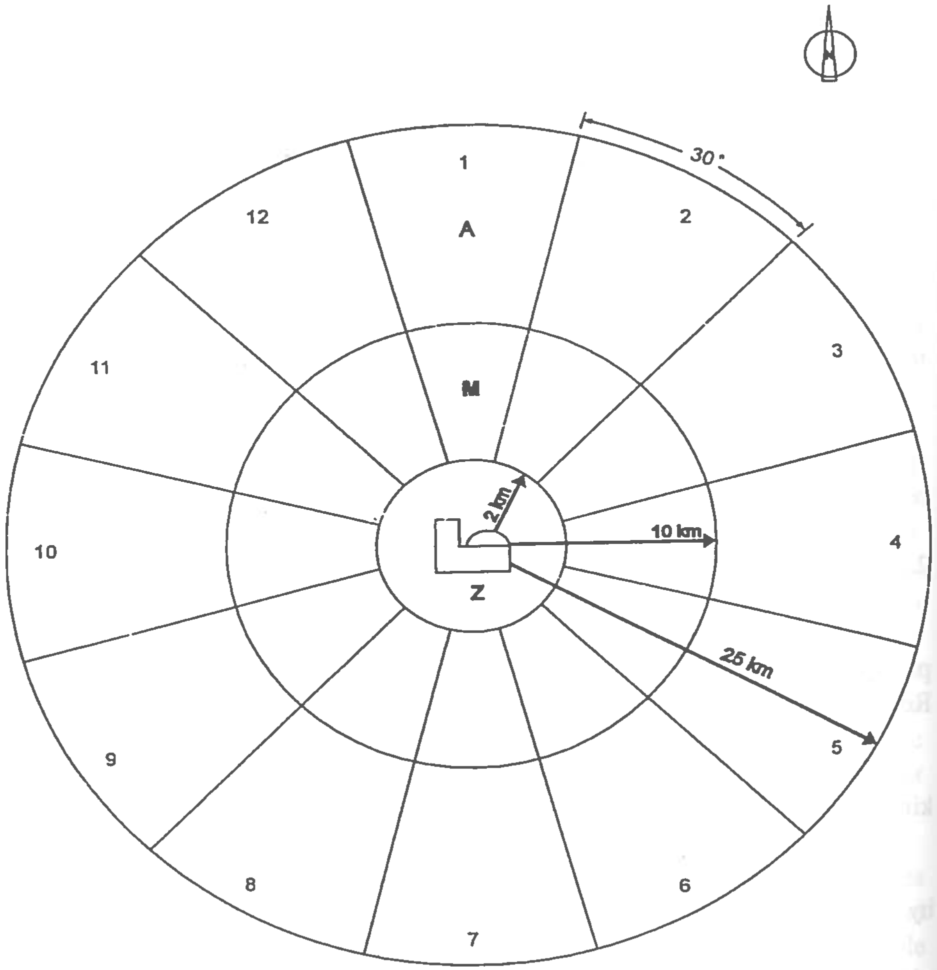
When such plans are prepared, special population groups (e.g. schools, kindergartens, hospitals, prisons, etc.) are considered.

Also included is alerting campers or anglers outdoors. They would be alerted by helicopters or public address vans.

Likewise considered is the time needed to implement the individual measures. Among others, the prevailing weather conditions (black ice, snow, etc.) will also be taken into account.

The financial costs arising from these measures are generally not included in the planning. For instance, if an evacuation should become necessary, it would be done independent of the costs.

Figure 1. **Subdivision of the nuclear facility environment**



Z: Central Zone
M: Intermediate Zone
A: Outer Zone

The financial costs for the measures may be regulated differently in each of the federal states. In the federal states of Rheinland-Pfalz and Baden-Württemberg the facility operators will have to carry the costs for the individual disaster response measures and also for the precautionary initiation of such measures (particularly the distribution of iodine tablets). In Bavaria, the federal state will carry those costs.

The disaster response plans are generally coordinated with the neighbouring federal states, particularly in cases where nuclear power plants (e.g. the nuclear power plant Philippsburg in Baden-Württemberg) are located near the border with another federal state. The plans are usually not coordinated with other countries since the distance between German nuclear installations and the national border is in excess of 25 km in each case, so that other countries are not within the applicable range of disaster response plans.

The only exception is the nuclear power plant Emsland in the federal state of Niedersachsen. The outer planning zones for this nuclear power plant is touching the Netherlands. Accordingly, the Netherlands are considered in the plan and advised of it. Additionally, annual meetings are held where among others the plans concerning the nuclear power plant are discussed (among others, also within the scope of German-Dutch Commission meetings).

In addition there are disaster response plans for foreign nuclear power plants close to the German border, as for example the nuclear power plants Leibstadt and Beznau in Switzerland. These plans are agreed on by the various authorities.

2.4 Emergency Workers

Emergency workers are needed to protect against the dangers arising from a nuclear accident.

For the emergency workers of the police and the fire department, dose limits are set (Table 1) in compliance with the guideline "ABC-Wesen LF 450" (5) and the "Fire Department Regulation 9/1" (6) respectively. Originally, the application of these limits is intended for other events (e.g. after accidents in radionuclide laboratories, transport accidents, and others). Their application in a nuclear accident – possibly in reference to an eventual excessive exposure – should be handled in a manner avoiding a conflict between the reference intervention values for the population in an actual case. Here it may also be taken into account that emergency workers are usually persons whose health is in good condition and that special risk groups (e.g. children, pregnant women) are not included.

Table 1. **Permissible radiation exposure (total body dose) of emergency workers on the basis of FwDV 9/1 and LF 450**

Operations for the protection of material goods: Maxium total of:	15 msv 15 mSv/a
Operations for the rescue of persons, to avoid injury expansion and to perform high priority measurement tasks:	100 mSv/injurious event
Operation to save human lives:	once per lifetime of an emergency worker 250 mSv*
Exceeding the maxium limit permissible?	only when considered as justified by a radiation protection expert

* According to LF 450 - Supplement of 1992, a total maximum value of 100 mSv/a may not be exceeded for an emergency worker of the police.

3. Disaster Response Countermeasures

Short-term countermeasures serve for the defense against acute dangers, that means the prevention or limitation of deterministic effects from the impacts of nuclear accidents on the population, and in particular early effects and high individual risks. They can only be taken on the basis of a close knowledge about the condition of the facility and after the radiological situation has been assessed. These countermeasures may be applied, if necessary. The following short-term countermeasures are mentioned in the Basic Recommendations:

- warning and information of the population,
- regulation, control and restrictions of traffic in accordance with a prepared plan,
- staying indoors (sheltering),
- precautionary clearing or evacuation in accordance with a prepared plan,
- distribution of iodine tablets in accordance with a special plan - possibly in conjunction with evacuation,
- decontamination of the population and task personnel involved,
- medical care and treatment of the population and task personal involved,

- warning of the population against the ingestion of newly harvested foodstuffs,
- warning of the population against the use of water, against aquatic sports and fishing,
- information of the river navigation, warning against the use of water and
- initiation of traffic restrictions for rail traffic, river navigation and air traffic.

The additional measures (like barring from contaminated water catchment areas, barring from heavily contaminated areas, if necessary relocation of people, ensuring the supply of foodstuffs and drinking water and so on) follow the short-term countermeasures and serve as a precaution, and for the elimination or mitigation of dangers that may still exist. As these measures depend on the circumstances of the individual case, they cannot be planned in advance.

In the following, only the measures "sheltering, evacuation and stable iodine" are discussed. Here, it must be explicitly stated that Germany has no practical experience in the application/implementation of such measures since a nuclear accident has so far not occurred, nor did any consequences of this type of accident (e.g. Chernobyl), by which Germany was affected, sufficiently justify the initiation of such measures as evacuation or the distribution of iodine tablets.

3.1 *Reference Doses for Staying Indoors, the Distribution of Iodine Tablets and Evacuation*

The dose to be expected during a continuous stay outdoors has to be estimated for deciding on the implementation of measures. This dose shall be determined as the dose commitment to be expected within 7 days from external radiation and the inhalation of radioactive materials.

Based on ICRP-Publication No. 40 (7) and to a far-reaching extent on the proposal from an EC Group of Experts (8), reference doses for the above mentioned measures are contained in Tables 2, 3 and 4. They have to be considered during the early and intermediate phases of an accident.

3.2 *Sheltering*

Remaining indoors may be the first and most practical protective measure taken after a sudden or temporary release of radioactive material. This is also applied if the expected exposure is relatively low and a precautionary evacuation of the affected region would not be warranted.

According to chapter 3.1, the following reference dose values apply to sheltering (Table 2):

Table 2. **Reference doses for Sheltering**

Dose in mSv					
Whole Body (external irradiation and inhalation)		Thyroid (inhalation)		Lungs or any preferred irradiated individual organ* (external irradiation and inhalation)	
lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose
5	50	50	250	50	250

* with the exception of the skin

The upper reference dose for this measure was set to be 50 mSv (whole body dose). This reference dose is oriented on risk estimates as specified in Section 28, paragraph (3) of the Radiological Protection Ordinance (9).

The lower reference dose for the countermeasure sheltering was set to be 5 mSv. It is of an order of magnitude for which the additional radiation risk is considered small in accordance with internationally recognized views. (For comparison purposes: In Germany, the mean effective dose caused by natural radiation sources is 2 mSv/year, with considerable regional variations between 1 and 6 mSv/year).

During an actual accident situation it has to be checked at which "intervention level" within the dose range defined by upper and lower reference doses the measures concerned have to be initiated, considering the existing conditions. At radiation doses below the lower reference level, measures are, in general, no longer justified. In the case of radiation doses above the upper reference doses the respective measures have to be initiated.

The measure will be rescinded if the ambient radiological conditions are below the lower intervention levels.

To inform the public, respective announcements/proclamations with instructions for the affected population are prepared for use in the actual event. In addition, the population in the vicinity of nuclear installations will receive a booklet with informations about the countermeasure. By this, the public will be instructed about the reason and the benefit of the countermeasure (shielding effect of buildings, reduction of the direct contact with radioactive substances). Guides on the shutting of windows and doors and the turning off of ventilation and air-conditioning systems are also included. The booklet also points out to continuously listen to the official situation reports on the radio while remaining indoors to hear, among others, when the countermeasure will have been rescinded.

3.3 Evacuation

The evacuation of the population is the most extensive (extreme) countermeasure of disaster response. An evacuation may be necessary for two reasons: for one as a precautionary measure if, due to the situation in the nuclear installation, a subsequent and essential release of radioactive material cannot be excluded or if the amount of radioactivity released can no longer be counteracted by staying indoors but demands a consecutive evacuation. This is mainly the situation when a dangerous amount of radioactive substances will have been deposited in a specific area.

According to chapter 3.1, the following reference dose values apply for evacuation (Table 3):

Table 3. **Reference doses for Evacuation**

Dose in mSv					
Whole Body (external irradiation and inhalation)		Thyroid (inhalation)		Lungs or any preferred irradiated individual organ* (external irradiation and inhalation)	
lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose
100	500	300	1500	300	1500

* with the exception of the skin

When specifying the actual intervention level, it has to be taken into account that this measure will become more difficult with an increasing number of persons needing to be evacuated in connection with a low reference dose. Apart from the increase in the risk connected with the measure, an additional radiation exposure resulting from longer evacuation times has to be taken into account. Therefore, in summation, the protective effect of the evacuation measure cannot be fully achieved.

For the decision on the type and extent of an eventual evacuation it is important for the disaster response management to be informed about the following factors next to the extent and characteristics of the event and the actual meteorological conditions:

- the immediately or consecutively affected region,
- the number of persons needing to be evacuated and their living conditions,
- special provisions for the evacuation of schools, hospitals, homes, institutions and other facilities from which people need to be evacuated by means of public transportation,
- densely populated regions, conurbations, geographical difficulties,
- suitable evacuation roads,
- the receiving regions and availability of emergency receiving centers,
- the time needed for
- providing emergency receiving camps,
- providing means of transportation,
- relocation into the receiving regions,
- registration of evacuated persons (reunification of families),
- traffic control measures,
- securing the evacuated area.

The evacuation is following a specific plan. Such plans were prepared e.g. in Baden-Württemberg up to 8 km distance around a nuclear installation and up to 10 km in Rheinland-Pfalz, Hessen, Niedersachsen and Bayern.

Moreover, in the federal state of Bayern, there are three types of evacuation, as explained in greater detail in the following. In evacuation type I, the central zone (2 km) and the immediate area with 3 sectors (90°) in the direction of expansion up to a distance of 5 km is evacuated; evacuation type II comprises the area of the central zone and partial areas of the intermediate zone up to a distance of 10 km in which evacuation reference dose values are reached according to Table 3; evacuation type III comprises additional areas of the outer zone (10 to 25 km) and, possibly, in further distance, if evacuation reference

dose values are reached also in those areas. Respective preparations for evacuation type I are meant to guarantee the clearance of this immediate area to be accomplished within about two to three hours. The local situation where traffic roads, river crossings, proximity to the dangerous site are concerned must be particularly considered and is important for time element. The actions must be prepared in a manner (task sheets) that will allow for their immediate application by zones and sectors. The task includes emergency teams and personnel deployed by the local county administration authority. Should these forces not suffice, the aid possibilities of the adjacent county authorities are included, unless these are not themselves endangered within a predictable time by an unfavourable wind direction and developing damage. Evacuation phase II must be initiated if other countermeasures such as sheltering and the ingestion of iodine tablets are exhausted; and, furthermore, if there is any danger of reaching reference dose values according to Table 3 during the course of damage development. The release of this evacuation phase requires also the assistance of extra-regional forces for transport into the receiving regions and the care of persons in need of aid. The transport capacities of local and regional bus companies, community transport enterprises, the federal railway and postal systems as well as the transport capacity of the Armed Forces must be known. In cooperation with the local railway authorities it must be checked in which time intervals trains may be available for evacuation purposes. The evacuation measures of phase III need not be prepared by plan. (10)

The basic principles of evacuation planning are:

- If possible, members of the population should leave the endangered areas in their own vehicle after the disaster response authority decided to evacuate (ordered evacuation).
- The police must direct traffic in a manner permitting the speediest and most unencumbered evacuation. Roadblocks prevent incoming traffic from entering the danger area and guarantee a free flowing evacuation process unobstructed by other traffic movements.
- People without own transportation are evacuated from the danger area by busses and taxis leaving from assembly points.
- A collective evacuation is planned for schools, hospitals and old-age homes.

If the time factor allows, the director or other responsible person of a specific institution (hospitals, old-age homes, etc.) will be ordered to immediately send the persons belonging to such institutions home, unless the institution involves persons incapable of walking and/or sick persons. In such case or if the time factor is insufficient, the respective director will be ordered to prepare for a collective evacuation in busses at a specified time.

Included in the evacuation plans is the possibility of large parts of the population attempting to leave the actual or assumed danger area on their own accord and by their own means before the competent authority has decided on an evacuation.

The population in the vicinity of the nuclear facilities Philippsburg, Biblis and Mühlheim-Kärlich will, for instance, be informed on respective evacuation routes and assembly points by the prior distribution of booklets containing such information. The population is additionally advised to drive to an emergency centre before looking for an assembly point where persons likely to have been exposed can be examined and decontaminated, if necessary.

The appropriate emergency reception centres are planned to be situated outside of the outer zone (25 km) up to a distance of about 50 km. Suitable objects for receiving a larger number of persons are schools, sports complexes, homes and similar facilities. To equip and furnish such emergency reception centres could be done, apart from own supplies, by supplies from local aid organisations, among others from the stores of such federal aid organisations as, for example, the German Red Cross.

The population is informed about its imminent evacuation by prepared notices which are announced locally and by the radio networks. Such notices include information about the hazard potential, which protective measure to take and on the anticipated length of the evacuation as well as information required for a fast evacuation (e.g. evacuation routes and receiving communities, recommendations to look for private quarters when possible, etc.). Furthermore, the notices include important information on necessary items needed while being evacuated (taking along drugs, personal documents, etc.).

3.4 *Stable Iodine*

Iodine tablets will saturate the thyroid with nonradioactive iodine and thus prevent an accumulation of radioiodine in the thyroid, if taken in time. If required, both the task personnel and the population concerned will receive iodine tablets as soon as possible.

According to chapter 3.1 the reference doses for the distribution of stable iodine are as shown in Table 4.

Table 4. **Reference doses for the distribution of stable iodine**

Dose in mSv					
Whole Body (external irradiation and inhalation)		Thyroid (inhalation)		Lungs or any preferred irradiated individual organ* (external irradiation and inhalation)	
lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose	lower ref. dose	upper ref. dose
-	-	200	1000	-	-

* with the exception of the skin

The lower and upper reference doses for this measure were increased by a factor of 4 to 200 and 1000 mSv, respectively, in comparison to those suggested by the EC Group of Experts, since the greatest part of the Federal Republic of Germany is an iodine deficiency area. The intake of iodine tablets is thus connected with an increasing risk of undesirable side effects (see Iodine Reference Sheet in Annex).

In connection with the countermeasure "Stable Iodine" three "Iodine Instruction Sheets" were prepared (see Annex):

A: Instruction sheet concerning the application of iodine tablets in the case of a nuclear accident (instruction sheet for distribution with the tablets),
B: Specimen of advance information for the public regarding the application of iodine tablets in the case of a nuclear accident and
C: Instruction sheet for physicians (regarding the application of iodine tablets in the case of a nuclear accident).

Instruction sheet A contains particular instructions on dosage as well as on intolerances and side effects. In the dosage of iodine tablets, a difference was made between adults (including pregnant women), children (up to a weight of 40 kg), children below 6 years of age and infants (up to a weight of 20 kg). Persons who are hypersensitive to iodine should not take the drug. Instruction sheet C is also naming possibilities of blocking the thyroid by other medication than potassium iodide, as for example by perchlorate which competitively inhibits the intake of iodine (e.g. potassium perchlorate baer or Irenat^R).

Each tablet contains 0.1 g potassium iodide. The basic package of potassium-iodide tablets produced in accordance to an uniform pattern contains 10 tablets per 100 mg. The limited storage period under favourable conditions (cool and dry) is 10 - 15 years. Upon expiration of the storage period (controls), withdrawal from supply and appropriate replenishment are initiated.

In Baden-Württemberg, for example, 10 tablets per person are kept on supply by the local authority. Iodine tablets were procured by this federal state since 1978 and 1979. This was followed by a first procurement of expired tablets during 1990 and 1991.

The collective package which is also the smallest unit for dislocated storage contains 100 basic packages (= 1 000 tablets). The forwarding packages contain 50 or 100 collective packages (= 50 000 or 100 000 tablets) and are intended for regional supply and as a Federal State reserve.

Aside from an instruction sheet (iodine instruction sheet A) contained in each package, additional information is prepared for the involved physicians and the population.

The centrally procured potassium-iodide tablets are distributed by the competent authorities of the respective federal state, e.g. in Bavaria by collaboration between governmental and county administrative authorities and health offices, to the communities in the vicinity of nuclear installations up to a distance of 10 km. To assure a timely distribution in case of need, the distributed potassium-iodide tablets should be locally stored by the communities in a decentralized manner at public facilities, pharmacies, hospitals, old-age homes, schools, kindergartens, industrial plants, etc., which will also serve as distributing points. Special arrangements for orderly and ready storage should be made with the competent authorities for police, border police and armed forces personnel quarters.

Appropriate instruction signs should be set up at the designated distribution points. The distribution to persons who are incapable of collecting their tablets by themselves is intended to be done by assisting personnel.

In Bavaria, for example, people incapable of collecting their own tablets, are directed to identify their residence by a white piece of cloth on the streetside of the building, so that fire department personnel may deliver the tablets.

The potassium-iodide tablets intended for the active forces of local fire and disaster protection units, emergency aid organisations and emergency aid units

of the police must be distributed to the organisational offices for a central ready supply. There are no provisions for a precautionary distribution to emergency aid personnel. Enforcement and substitute emergency personnel must be considered.

Disaster response authorities within a radius of 25 km from the nuclear facility must establish a local supply of iodine tablets meant to mainly cover the need of other than local emergency personnel.

For state police radiation detection units and nuclear/chemical detection teams of disaster protection units, iodine tablets are to be separately carried in emergency vehicles for ready supply.

Within the range of disaster response authorities where no iodine tablets are being stored, such tablets may be requested in case of an accidental radiological event (e.g. transport accidents and fires involving the release of radioiodine) from the authorities of the regional reserve depot.

The general rule is that iodine tablets kept on supply for protection in nuclear emergencies may only be distributed by order of the corresponding disaster response authority to the population and to emergency workers in charge of protection. A precautionary distribution to the population is not planned.

The countermeasure "stable iodine", which in any case can only be an attending measure, is currently discussed in Germany by the Radiological Protection Commission. The pick-up of tablets is rejected by the working group on emergency radiation protection since it is in controversy with the countermeasure "sheltering". Proper organisational measures (clearly defined competence and procedural plans) will have to assure a safe distribution. In this context, other points are discussed, such as

- reference value/dose range,
- intervention dose values (age groups, pregnant women),
- dosage as well as
- single dosage/multiple dosage.

Currently it is also discussed to which extend Germany will also adopt the international recommendation concerning iodine blockage. At the moment it is proposed to conform with the WHO (11) Recommendations for iodine prophylaxis.

4. Exercises

At this point, it should be emphasized again that the Federal Republic of Germany has no practical experience of any kind in the application of the discussed measures.

To guarantee readiness in case of emergency protection measures needed to be applied in nuclear events, regularly programmed additional training is necessary. Therefore, aside from technical training courses, planning discussions, table top – exercises and command post – exercises are taking place along with training by field exercises.

Within the scope of such exercises which, depending on the federal state and the type of exercise, are taking place in regular intervals from one to four years, newly developed or modified disaster response plans are tested – communication pathways, etc. – according to the type of exercise.

Exercises within the range of disaster response are, of course, not involved in the practical application or testing of the measures discussed here, since the exercises are held without public participation. Evacuation is not exercised for reasons of accident prevention.

5. Information of the Public

Advance information

In advance, the public is informed about these disaster response measures largely by means of specific booklets as they are distributed in the individual federal states among the population in the vicinity of nuclear installations. Next to general information on radioactivity, these booklets contain partially very extensive information on principally organisational rules of planned catastrophe protection together with instructions and guidelines on personally applied protection measures (e.g. booklet on "Emergency protection in the surrounding area of the nuclear power plant Biblis" (12), which includes 13 maps with evacuation routes as well as a list of assembly points and iodine tablet distribution points).

Aside from verbal descriptions, the attempt is made in this booklets to also explain individual protection measures by means of graphic demonstrations.

Furthermore, the booklets contain also practical hints and suggestions which aspect of such countermeasures should be particularly considered. For example, in reference to "sheltering" it is pointed out that, while staying indoors, the radio broadcasts of the authorities should be continuously followed to, among others, learn about how long the recommended conduct should be kept up. Or also the urgent recommendation in connection with this measure, to keep windows and doors shut and to be certain to turn off ventilation and air conditioning systems.

In reference to "evacuation", some booklets contain practical advice (e.g. "Emergency protection in the vicinity of the nuclear power plant Philippsburg. A public guide") (13) in reference to how this information can be passed on to need-to-know persons in the neighbourhood (elderly fellow citizens, sick and handicapped persons) and also where the packing of an emergency case is concerned and the care of domestic animals by providing a proper supply of food.

Concerning the countermeasure "stable iodine", in addition to the information given in the booklets, there is advance information in the form of "iodine information sheets" (see chapter 3.5, Annex).

Planned is the publication of a standardized booklet for the information of the public in the vicinity of nuclear facilities all over Germany by the current Ministries of the Interior of each Federal State. These standardized booklets should include a general part as well as a special plan tied to the locality of each nuclear facility (e. g. information of evacuation routes, iodine tablet distribution centres, etc.).

In the actual event

In the actual event of a nuclear accident, the population will be alerted by a widespread sounding of sirens, where available. Civil defence sirens have generally been removed by Federal order. In some Federal States, however, the sirens were retained and modernised for use in the area of the intermediate zone around nuclear installations or in the vicinity of installations with a high danger potential. As a warning signal, a siren is sounded for the length of one minute with the meaning to "turn on radios and listen to the announcements". The individual announcements are adapted to the actual situation and repeated by broadcast.

Certain elements of the broadcast content in case of an actual event have already been prepared. Accordingly, a respective broadcast in reference to picking up iodine tablets might be as follows:

> "You will receive tablets at distribution points (pharmacies, schools, kindergartens, fire department facilities) which are accordingly identified. To prevent unnecessary traffic activity, please collect the tablets also for neighbours and other residents living in your building. Citizens who are unable to collect the tablets will identify the streetside of their houses by a white cloth. Fire department personnel will then bring you your tablets.
>
> You are also asked to inform your neighbours or non-German speaking persons of this announcement as accurately as possible".

In support of the information by radio broadcast or additionally to the locally limited sounding of alarm, public address vans of the police or fire department may also be used.

The public is not only informed by radio announcements but additionally by video instructions repeating the radio announcement in writing. Video text is a television aided telecommunication service introduced in the Federal Republic of Germany by the official public television institutions on 1 June, 1980. Video text communications are a particularly practical tool in nuclear events because of the great amount of information and recommendations involved.

6. Summary

Countermeasures such as "sheltering, evacuation, stable iodine" are disaster response regulations according to German law and, therefore, within the competence of the individual Federal States.

The planning and the adaptation of the individual measures conform with federally uniform skeleton recommendations introduced as being binding for all Federal States.

Disaster response countermeasures such as evacuation and distribution of iodine tablets are to be prepared only for the central zone (2 km) and the intermediate zone (10 km) surrounding a nuclear installation.

Decisive for the initiation of the individual measures is the fact that the respectively set reference dose has been exceeded. Reversely, the reduction to

a dose value below the specific reference dose is the decisive criterion for the respective measure to be rescinded.

The countermeasures "sheltering" and "evacuation" may be described as independent measures whereas "distribution of stable iodine" is to be regarded more in the sense of a supplemental or supportive measure.

The population is alerted primarily by the sounding of sirens. Radio broadcasts, loudspeaker announcements and video text instructions are additionally applied.

7. Conclusions

Discussions in reference to the here described countermeasures are expected in Germany within the near future. The debate will be, among others, on whether the latest international recommendation, ICRP 63 (14), and thus the proposal of a single intervention reference level, should be adopted rather than a dose range concept.

Furthermore it will have to be discussed, for example in reference to the "distribution of stable iodine" measure, if the tablets should be distributed to the individual households as a precautionary measure and to which extent international recommendations, e.g. the WHO-recommendation, should be adapted in Germany.

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from: TRANSLATIONS-SAFETY CODES AND GUIDES

Annex 1

Iodine Instruction Sheets
(as published in the Gemeinsames Ministerialblatt 1984, page 232)

IODINE INSTRUCTION SHEET A

Instruction Sheet for Distribution with the Tablets

Instruction Sheet concerning the Application of Iodine Tablets in the case of a Nuclear Accident

Formula

Each tablet contains 0.1 g potassium iodine.

Important Note

These iodine tablets are for the purpose of safeguarding against the dangers of radioactive iodine in the case of radiation accidents and are only to be taken after public and specific instructions of the responsible authorities. The authorities alone are in possession of all the details concerning the situation that enable a decision to be taken regarding the necessity and advisability of taking iodine tablets.

Properties and Purpose of Application

When taken in the dosage indicated, the iodine tablets saturate the thyroid and thus prevent the accumulation of radioactive iodine.

This application is particularly effective when the tablets are taken shortly before the possible absorption of radio-active iodine or within two hours after such absorption. However, the retention time of radioactive iodine in the body is also shortened if iodine tablets are taken even several hours after absorption and thus radiation exposure is reduced.

Iodine tablets do not protect against the intake of other radioactive substances by the body, nor against external radiation of the body.

Intolerance and Risks

Persons suffering from a hypersensitivity to iodine (a very rare iodine allergy) must not take iodine tablets.

Persons suffering or having suffered from hyperthyroidism should continue their treatment whilst taking iodine tablets. However, they should see their physician after the termination of the emergency.

Persons beginning to suffer from disorders such as palpitation, loss of weight or diarrhoea one week to three months after the intake of the tablets, should see their physician.

Accompanying Symptoms

In general, iodine tablets are well tolerated. Side effects (gastric disturbances may occur in individual cases, but these disappear of their own accord when medication is discontinued. A physician should be consulted if the symptoms continue over a longer period of time.

Dosage

Adults, including pregnant women: Initial dose 2 tablets, then 1 tablet approximately every 8 hours, up to a total of 10 tablets within 3 or 4 days.

Children (up to a weight of 40 kg): Initial dose 1 tablet, then 1/2 tablet approximately every 8 hours, up to a total of 5 tablets.

Children under 6 years and infants (up to a weight of 20 kg): 1/2 tablet daily, up to a total of 2 tablets.

The duration of application may be extended and the total number of tablets increased if so directed by the authorities.

As far as possible, the tablets should not be taken on an empty stomach. To facilitate taking the tablets, they may be dissolved in any preferred beverage (to be consumed immediately as the solution is unstable).

Note: The tablets are to be stored away from light and humidity. Only sealed tablets can be kept for longer periods of time.

IODINE INSTRUCTION SHEET B

Specimen of Advance Information for the Public Regarding the Application of Iodine Tablets in the Case of a Nuclear Accident

Radiation accident involving the release of radioactive iodine

Accidents are possible in places where radiation and radioactive materials are in use (for example, in engineering, in the medical field, or in nuclear facilities). In this respect, there is no difference between the use of radiation and the use of other technologies or, perhaps, road traffic.

In particularly unfavourable although extremely rare circumstances, in the case of accidents in operations that involve radiation and especially in the case of nuclear power plants, radioactive materials could be released in quantities which make countermeasures necessary. Radioactive iodine (a special form of the iodine that is present everywhere in foodstuffs, etc.) plays a particular role in this respect, since it is accumulated in the thyroid in the same way as non-radioactive iodine. This accumulation in the thyroid is the distinctive property which sets iodine apart from the great number of other radioactive elements.

How does radioactive iodine get into the body?

Like other substances in the human environment, iodine theoretically has three ways of getting into the body:

firstly, through the skin;
secondly, with food and beverages; and
thirdly, with the air, through the respiratory system.

In our case, absorption through the skin is so minimal that it can be disregarded. The intake with water or foodstuffs can be considerable if, for example, grazing cows absorb radioactive iodine from a large pasture area and then discharge it in their milk. It is, however, very easy to prevent this intake in the case of a radiation accident: milk and fresh vegetables from areas where corresponding amounts of radioactive iodine may have precipitated are withheld from immediate consumption until, after a few weeks, they are practically free of radioactivity as a result of normal radioactive decay. The observance of any warning issued by the Emergency Control Management against the consumption of certain foodstuffs from certain areas is quite sufficient to keep such intake of radioactive iodine under control.

It is more difficult when radioactive iodine is in the air that is breathed. Here it is difficult to prevent absorption by the body completely. However, it is possible to do something to reduce the effect of the radioactive iodine in the body by eliminating it as quickly as possible. This is best done by taking iodine tablets.

How do iodine tablets work?

Iodine absorbed by inhalation or with food is accumulated by the thyroid until it is "saturated". If more iodine is absorbed than the body can hold, the excess iodine is eliminated from the body. Therefore the "saturated" thyroid absorbs iodine only in small amounts, further it is largely "blocked" against the absorption of radioactive iodine. Such a blockage is achieved by means of iodine tablets.

Why are iodine tablets taken as a preventive measure?

It must be emphasized that the taking of iodine protects exclusively against the effects of radioactive iodine, and not against the effects of other radioactive materials.

The earlier this protective action is taken, the more effective it is. The tablets are most effective of all when taken shortly before or practically at the same time as the inhalation of radioactive iodine. However, a certain protection is still achieved if they are taken within a few hours after inhaling radioactive iodine.

Where and when are iodine tablets obtainable if needed?

The Federal States have adequate supplies of iodine tablets in stock which, if there is a suspected need, can be distributed immediately to those members of the public who may be affected. In this case, "suspected need" means that an accident may develop in such a way that the application of iodine tablets may become desirable. The tablets would then be distributed already. However, distribution is merely a precautionary measure and does not mean that the tablets should be taken immediately. Should it in fact become necessary to take them, the members of the public affected would be requested to do so, by means of announcements over the radio or public address systems, for example.

Since only the authorities have the necessary overall view of the situation which may require the application of iodine tablets, the tablets should in no circumstances be taken on one's own initiative or because of apprehension. It could then happen that no further tablets are available when they are really needed.

It is also absolutely unnecessary and even absurd to buy iodine tablets – that are available at pharmacies for other purposes – on one's own initiative. They may deteriorate if improperly stored. Indiscriminate and uncontrolled application also increases the possibility of undesirable side effects.

How should iodine tablets be taken, and how many?

A reference sheet will be distributed with the tablets themselves containing exact indications of how they are to be taken. The indicated dosage is the optimum amount required for the desired purpose of a largely "blocking" the thyroid. A higher dose does not increase effectiveness and a lower dose in no way prevents the possible side effects that may occur in certain rare cases.

What side effects may iodine tablets have?

Like all medicines, iodine tablets may also produce side effects in those persons whose metabolisms exhibit special peculiarities. Although rare, there are persons who are hypersensitive to iodine (however, most of those who are classified as "hypersensitive to iodine" at the time of and X-ray examination are in fact not hypersensitive to iodine but to the X-ray contrast medium). In the case of genuine iodine hypersensitivity, the person's life may even be endangered if iodine is taken. Persons who believe to be hypersensitive to iodine should consult their physician. He can recommend alternative preventive measures, if necessary.

There are also persons who react to an increased supply of iodine with increased hormone activity of the thyroid. However, the symptoms of hyperactivity of the thyroid (hyperthyreosis) do not appear while iodine is being taken but occur days or even weeks after the intake of iodine. This may also occur if the hyperthyroidism has not been known. Therefore, persons suffering from a known hyperthyroidism and persons observing signs of hyperthyroidism such as palpitation, loss of weight or diarrhoea one week to three months after the intake of the tablets, should see their physician. If necessary, the physician can initiate medical attention.

Iodine tablets during pregnancy?

Pregnancy does not stand in the way of a short-term intake of iodine that does not continue for weeks. On the contrary, both the mother and the unborn child would be protected by the iodine tablets. Nor does the optimum dosage change because of pregnancy. No particular side effects are to be feared for either the mother or the unborn child. After the birth, however, the mother should inform the physician of the fact that she took iodine tablets during pregnancy, since this knowledge may in certain cases be important for the physician's conclusions.

What do iodine tablets not protect against?

Iodine tablets do not protect against radiation from outside the body nor against radioactive materials other than iodine that have been absorbed by the body. Other protective measures that are designed for these cases, such as remaining in a closed room, are not rendered superfluous by the taking of iodine. In your own interest, therefore, you should follow the instructions issued by the authorities, since only they are in a position to judge the situation and, consequently, to know what is to be done.

Instruction Sheet for Physicians
Regarding the Application of Iodine Tablets in the Case of a Nuclear Accident

Preliminary Remarks

Iodine tablets (0.1 g potassium iodatum) are held in stock by the authorities responsible for emergency preparedness that they can be distributed to the public if needed. This brochure is intended to inform the physician about the fundamental problems associated with the blockage of the thyroid with iodine, and to provide him with the means to advise his patients properly and to treat them if necessary. In this connection, attention is drawn to the advance information given to the public by means of Iodine Instruction Sheet B.

Why block the thyroid?

Among the fission products that are generated during the operation of nuclear reactors are the various radioactive isotopes of iodine. Because of the biological peculiarity of iodine, i.e. its incorporation in the biological peculiarity of iodine, i.e. its incorporation in the thyroid hormone, these are of special importance. Since the temperatures in nuclear reactors are such that the iodine is present in gaseous form, the possibility must be faced that, in the case of accidents occurring under favourable circumstances, radioactive iodine may be released into the air of the environment. Most of this radioactive iodine would precipitate on to the ground and plants. From there it can be absorbed by humans by way of foodstuffs, and in particular through milk.

However, in case of an accident, attention must above all be paid to the fact that radioactive iodine can be inhaled and completely absorbed in the lungs. After being absorbed, the radioactive iodine reacts in exactly the same way as we have experienced in the case of stable iodine and the radioactive iodine used to test thyroid activity.

It is dispersed in the extravascular area, then there is a temporary concentration in the salivary glands and the mucous membrane of the stomach and, in particular, long-lasting accumulation in the thyroid. The extent of accumulation in the thyroid depends on the functional state of that organ and, in the case of euthyroidism, especially on the iodine supply in the diet. The lower the amount of iodine in the diet, the higher the percentage accumulated in the thyroid. In the Federal Republic of Germany, the daily intake of iodine from foodstuffs is generally under 70 µg and it is therefore probable that in the case of euthyroidism more than 50 % of the radioactive iodine absorbed would be accumulated in the thyroid.

When is an iodine blockage advisable?

The blockage of the thyroid with iodine is only to be considered if the release of a considerable quantity of radioactive iodine must in fact be feared as a result of the particular emergency situation. It may be of interest to know that there has been no known nuclear reactor accident in the whole world where iodine blockage was necessary. This includes the Windscale incident in England a few years ago and the TMI incident at Harrisburg, USA, in March 1979.

The release of radioactive iodine to the extent that an iodine blockage must be considered advisable for the population living in the vicinity, does not happen suddenly. It is one of the later stages in an unfortunate chain of circumstances that takes at least 1 to 2 hours, if not days, to develop. There is consequently a warning period, during which the authorities can give the necessary instructions, based on the information available to them and their judgement of the situation.

Please point out to your patients repeatedly that it would be useless and even absurd to proceed with an iodine blockage on their own initiative, without being requested to do so by the authorities. They would merely expose themselves to the risk of side effects, even if these are minimal.

Is a blockage of the thyroid permissible in the case of pregnant women and nursing mothers?

Foetuses take iodine into the thyroid no earlier than the 13th week of pregnancy. From the 6th to the 9th month the accumulation of iodine in the foetal thyroid is considerable. It is therefore also necessary to block the thyroids of more advanced foetuses and this is achieved by means of the iodine content in the mother's blood, with no specific increase in the dose being necessary.

Occasionally, the sensitive foetal thyroid can develop a goitre with hyperthyreosis. However, this can be cured post partum with thyroxine. However, more pregnant types of goitre may develop which may require a tracheotomy.

It should therefore be pointed out to women who are treated with iodine during pregnancy that they should inform their obstetrician of this fact, so that his attention is drawn to the thyroid of the new-born child.

How is the thyroid blocked against radioactive iodine?

The accumulation of radioactive iodine in the thyroid can be prevented by the administration of a large quantity of non-radioactive stable iodine before the intake of radioactive iodine. By means of this increased supply of stable iodine, and because the thyroid can only take in a limited amount of iodine, only a fraction of the radioactive iodine absorbed is accumulated. The iodine that is not accumulated is eliminated through the kidneys, with a biological half-life of approximately 6 hours.

Since the accumulation curve is very steep at the beginning, a blockage with iodine is most effective if the stable iodine is already present in the system before the radioactive iodine is absorbed. However, a reduction in the amount accumulated is still achieved during the first few hours after the intake of radioactive iodine, whereas approximately 8 hours after inhalation or ingestion the intake of stable iodine no longer has any appreciable effect on this accumulation nor, consequently, on the radiation exposure of the thyroid caused by the radioactive iodine.

What should be the dose of potassium iodide?

Not only the timing of its administration, but also the quantity of stable iodine is of decisive importance in reducing the accumulation of radioactive iodine. Since it is important that the blockage be as complete as possible, a high concentration of stable iodine in the blood plasma must be obtained initially. This is achieved with an initial dose of 200 mg potassium iodide with which, in general, no digestive intolerance is to be feared.

A lower dose does not reduce the possibility of side effects and a higher dose, although not harmful, produces no further reduction in the radiation exposure.

In the case of an accident, the release of radioactive iodine may be spread over a period of several hours or even several days. During this whole period, in which there is the risk of radioactive iodine being absorbed, a correspondingly high concentration of stable iodine must be maintained in the blood plasma. Since the iodine, with a half life of approximately 6 hours, is eliminated through the kidneys, it is advisable to administer a further 100 mg potassium iodide approximately every 8 hours, so that a more or less constant level is maintained in the blood plasma.

The following doses are recommended

Adults, including pregnant women: Initial dose 2 tablets of 100 mg each, then 1 tablet approximately every 8 hours, up to a total of 10 tablets within 3 or 4 days.

Children (up to a weight of 40 kg): Initial dose 1 tablet, then 1/2 tablet approximately every 8 hours, up to a total of 5 tablets.

Children under 6 years and infants (up to a weight of 20 kg): 1/2 tablet daily, up to a total of 2 tablets.

As far as possible potassium iodide should not be taken on an empty stomach.

The period of application may be extended without hesitation, thus increasing the total number of tablets taken, should the authorities consider this necessary under the circumstances of the emergency and issue instructions accordingly.

What health risks are involved in the blockage of the thyroid with iodine?

In very rare cases, signs of a hypersensitivity to iodine (iodine allergy), for example iodic rhinorrhea or iodic rash, can be observed. However, the possibility of an intolerance to iodine should not be overrated. The iodine effect can be mitigated by sodium bicarbonate or neutralized by sodium thiosulphate.

In the case of an existing disease of the thyroid, even if its course has so far been asymptomatic, a hyperthyroidism may be triggered within weeks or months of the intake of iodine.

Newborn children and infants are especially susceptible to hyperthyroidism if iodine is taken over protracted periods of time.

The induction of hyperthyreosis

A healthy thyroid has several regulatory mechanisms that enable it to tolerate an over-supply of iodine without any harmful increase in the production of thyroid hormones. The pathological mechanism by which an increased supply of iodine leads to a clinically manifest hyperthyreosis is not yet fully clear. Nevertheless, it is known that this transition to hyper thyreosis occurs mainly in areas where goitres are endemic.

This possibility has to be anticipated in the Federal Republic of Germany.

A hyperthyroidism may develop on one of the following bases:

1. Diffuse autoimmuno processes (type M. Basedow)

2. Nodular autonomous adenomas

3. Multiple autonomous microadenomas (so-called diffuse autonomy).

All three diseases of the thyroid may also exist as latent diseases not showing any clinical signs of hyperthyroidism.

Contra-indications for the blockage of the thyroid with iodine

Unfounded contra-indications occasionally mentioned in publications are cardiac insufficiency and the various forms of tuberculosis. Pregnancy and the lactation period, as well as hyperthyreosis and thyroiditis, are mentioned but these do not represent true contra-indications.

The intake of iodine should be waived if there is a known disposition to an iodine allergy. This should not be confused with an allergy to X-ray contrast media which in most cases, is not due to the iodine they contain.

Patients suffering from the very rare Dermatitis Herpetiformis Duhring must not take iodine under any circumstances.

Patients being treated against hyperthyroidism have to continue their treatment besides the intake of iodine. All patients suffering from hyperthyroidism, whether or not undergoing treatment, have to be seen by a physician at short intervals following the termination of the emergency giving rise to the intake of iodine.

Possibilities of blocking the tyroid with other medication

Since the aim of the blockage is to prevent the thyroid as far as possible from accumulating radioactive iodine, the most suitable medication other than iodine is perchlorate, which competitively inhibits the intake of iodine (e.g. potassium perchlorate Baer or Irenat[R]).

The following dosage is recommended:

Potassium perchlorate (Baer) - initially, 3 tablets of 200 mg each, followed by 1 tablet every 5 hours, or Sodium perchlorate (Irenat[R]) - initially, 30 drops (450 mg), followed by 15 drops (200 mg) every 5 hours.

The duration of administration corresponds to that of iodine tablets.

EMERGENCY PLANNING IN ITALY

by

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1. Introduction

The emergency situations which could arise are strictly connected with the possible accident types and strongly depend on the facilities existing in the country. After the Chernobyl accident, the Italian Government, following a referendum for a nuclear moratorium, stopped the nuclear power production programme. Four nuclear power plants have been built in Italy (see Figure 1), two of them are now in shut down conditions; the nuclear fuel has been partially removed from the reactor core in the Trino plant, while in the Caorso plant, the fuel is still present in the core. The remaining two reactors are in the decommissioning phase. Other than the above mentioned plants, in Italy there exist nuclear research reactors, fuel and waste storage facilities (Figure 2), that could give rise to a radiological emergency situation.

The utilities, around 3 500, using radioactive substances and radiation sources employed for different purposes, i.e.medical, research, industrial, etc., as well as the transport of radioActive materials, may give rise to incidents which are handled case by case according to general provisions set up at local levels. National Authorities could give their advice, if the case.

2. Pre-Chernobyl Situation

In Italy the protection of workers and general public against the risks of ionising radiation is regulated by the Presidential Decree n.185, february 1964. In this decree the actions to be taken following an accident in a nuclear installation are set out.

Figure 1. **Nuclear Power Plants**

Figure 2. **Nuclear Research Reactors**

The procedure established in the regulations is the following:

- The utility has the responsibility to make an analysis of the possible accidents.
- The regulatory control body reviews the analysis, which is then approved by a technical committee.
- The Ministry of the Interior receives the final analysis supported by a technical annex containing the main provisions to be followed in case of emergency.
- A Committee of Experts appointed by the Prefecture where the plant is located is charged to set up the emergency plan. Members of the Expert Committee are local and national Authorities, the Control Authority and the Director of the installation.

The final approval of the emergency plan is given by the Ministry of the Interior. The main objective of an emergency plan is to minimize the radiation population exposure, well below the threshold for harmful health effects.

2.1 *Definition of Accident Situation and Provisions to be Taken*

The utility shall perform the evaluation of the Design Basis Accidents, under pessimistic assumptions. Typical DBA are:

Steam Line Break Accident (SLBA) outside the containment;
Control rod accident;
Spent fuel handling accident; Loss of Coolant Accident (LOCA) inside the containment.

These types of accidents may give rise to radiological releases of the order of 37 TBq ^{131}I and associated radionuclides and about 37 PBq noble gases. These releases shall be considered as an upper limit.

The law foresees two situations: prealarm and alarm.

Prealarm, when the radiation level at the plant fence is 10 times higher than the alarm threshold set for the radiation area monitors or LOCA occurs, which requires the intervention of the emergency cooling system. The prealarm situation is notified to local Authorities and plant personnel is informed by acoustic means.

Alarm, when the radiation level at the plant fence is higher than 10 microSv/h, or SLBA, LOCA with malfunction of ECCS or of emergency ventilation, etc, occur. The alarm situation is notified to plant personnel and to population living within 2-3 km from the plant by means of acoustic devices. The information is also passed to local authorities. The Prefect is charged of the declaration of the emergency situation and is the Authority responsible for whatsoever action to be taken. After the declaration of emergency the Prefect and the Committee of Experts provide the implementation of the emergency plan. Population living further away 2 km from the plant is alerted by means of vehicles using loudspeaker, or by telephone, or couriers.

2.2 *Emergency Action Zones*

The area surrounding the plant is divided in two concentric zones:

1) a zone of 2-3 km radius around the plant in which the countermeasures to be taken are: the sheltering of the population during the cloud passage, iodine tablets administration and, if the case, evacuation.

2) a zone of 10 Km radius (including the zone mentioned in 1) around the plant. This zone is divided in 45° sectors, which allow to identify, according to the meteorological situation, where actions shall be implemented. Sheltering, administration of iodine tablets, and evacuation are the possible countermeasurements. The decision to apply protective measures is taken after a case by case evaluation. The reference criteria are set up in Circular n.70 of the Ministry of Interiors dated August 1973. The basic criterion for the protection of the public is to avoid a whole body exposure of 25 rem (0.25 Sv) for adult and 15 rem (0.15 Sv) for pregnant women and children. It has to be underlined that evaluations of risks and benefits connected with the adoption of countermeasures is always needed. Other provisions concerning the radiation protection of the population can also be taken such as banning of milk and other foodstuffs, fishing, swimming, etc. radio and television both national and local are used by the Prefect to disseminate information.

2.3 *Responsibilities and Duties of Various Bodies in Case of Emergency*

Director of the plant is in charge to: inform the Prefect about pre alarm and alarm conditions; alert the population in the immediate vicinity of the plant by acoustic means; implement the internal emergency plan; provide teams to carry out environmental radioactivity measurements.

Prefect, as outlined above, has the full responsibility of the emergency, in particular is responsible to implement the emergency plan, to convene the Expert Committee, to inform the population about any action to be taken.

Fire Brigade, other than its ordinary duties, is responsible to provide teams to carry out environmental radioactivity measurements, to collect meteorological and radiological data until the Committee of Experts has been set up.

Army and Police, are responsible for traffic control, forbid the transit where necessary, to provide the transport means in case of evacuation, to take all the measures to maintain order.

Air Force is responsible for provide meteorological data and weather forecast.

Health Service is in charge for radioactivity measurements, to set up and operate the decontamination centre, to supervise iodine prophylaxes, to collect contaminated materials, to supervise the consumption of food.

Veterinary Office is charged for livestock, to maintain them in stables and give uncontaminated pasture, to collect them in ad hoc stable in case of evacuation of the population.

National Institutions can supply mobile units for area monitoring and experts teams, other than to give expert advice.

Emergency exercises are carried out annually in each plant according to the requirements of the existing regulations. They allow to verify the provisions set up by the utility, their adequacy to the emergency situations.

2.4 Remarks

It has to be underlined that the approach described above to face emergency situations, relies on the assumptions that accidents are characterised by degradation of the plant and of the safety systems. However a complete malfunctioning of the safety and containment systems is not foreseen and the consequences are, therefore, limited in space and could affect the environment and human beings only on local scale.

3. Post-Chernobyl Planning

After the Chernobyl accident, the need was expressed to include in the safety analysis disrupting events with a low probability, but whose consequences were such as to demand nation-wide interventions.

3.1 Reference scenario for nationwide emergency interventions

The Italian National Emergency Plan considers "severe" accidents, characterised by the complete fusion of the fuel and degradation of the containment system. However it is assumed that the immediate loss of the containment system could be avoided, with large margin of success (95 per cent), by human interventions.

In case of 1000 MWe light-water reactors, releases for this category of accidents are equal to 10^{-3} of the inventory of fission products in the core, corresponding to 3000 TBq.

Table 1 shows the characteristics of the severe accidents taken into account.

Table 1. **Characteristics of the accident scenario outlined for national emergency planning**

- Fuel fusion and degradation of the containment system
- Remedial actions by the personnel
- Release outside the plant: 3 hours after the beginning of the accident
- Duration of release: 3 hours
- Caesium and iodine released: ~10^{-3} of the related inventory

It should be stressed that considering severe accidents implies a reduced time scale and a clear and timely recognition of the accident situation. The plant conditions, requiring the implementation of the National Emergency Plan, should be identified on the basis of the plant parameters.

3.2 Protective Measures

The dose reference levels adopted to implement protective measures are those recommended by several International Bodies in the early phase after the accident and reported in Table 2.

Table 2. **Doses for early phase protective measures**

Protective measures	Dose (mSv or mGy)	
	Whole body	Lung, thyroid and any single organ preferentially irradiated
Sheltering	5-50	50-500
Administration of stable iodine		50-500
Evacuation	50-500	500-5000

On the basis of the above-mentioned accident scenario and of the subsequent releases, the area surrounding a nuclear power plant is divided in different zones, to implement the Emergency Plan actions (Figure 3).

Figure 3. **Accident Response Zones (not to scale)**

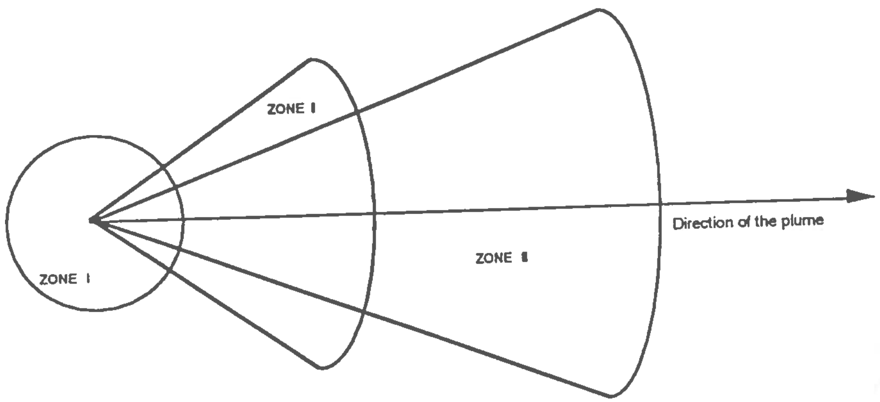

Table 3 shows the dimensions of the zones affected by the accident and the protective measures foreseen by the National Emergency Plan.

Table 3. **Zones and actions for severe accidents**

Zone	Distance (km)	Angular width	Actions
I	3	360°	sheltering iodine administration evacuation
II*	10	70°	sheltering iodine administration evacuation
III	20	45°	sheltering iodine administration

* Sheltering should also be implemented in the other sectors of Zone II. In Zones I, II and III the consumption of probably-contaminated foodstuffs should be banned as matter of caution.

The target of the plan is to carry out evacuation before the arrival of the radioactive cloud, that is within 3 hours from the declaration of national emergency state, without waiting for the results of the radiometric measurements. In case difficulties should arise for the actual implementation of the evacuation, population has to remain on sheltering. Evacuation will be then performed after the cloud transit. The protective measures, foreseen by the Emergency Plan, aim at keeping the dose equivalent values below the lower limits of the dose intervals, shown in Table 2.

This strategy allows to:

1) have a proper safety margin with respect to the uncertainties about the release and the dose estimations;
2) foresee the event of more severe accidents, without any remedial action by the personnel. In this case, the adopted countermeasures should be suitable to prevent deterministic effects.

3.3 Organization Structure

The units which, according to Emergency Plan, have to cope with severe accidents are outlined below:

Decision-making bodies: (Premier of the Ministers' Council, Operational Committee of the Civil Protection Ministry);

Technical unit: whose task is to evaluate both the post-accident situation and its evolution on the basis of radiometric data from selected laboratories existing on the territory. These laboratories carry out intercomparison exercises at regular intervals. The related health impact is also assessed, in order to allow the adoption of protective measures by the decision-making bodies. The unit is formed by radioprotection experts from the main Italian Research Institutes;

Operational unit: (Police, Fire Brigade, Italian Red Cross, etc), which has to implement the protective measures adopted by the decision-making bodies;

Support unit: (Services of the Civil Protection), which has to assure the proper functioning of the decision-making bodies and to get in touch with the press .

3.4 Implementation of the National Emergency Plan

In case of severe accident, the Director of the utility informs the Prefect and the local Fire Brigade. The Prefect informs the Support unit and starts immediately the implementation of the protective measures foreseen in the Plan, till Premier assumes the coordination task. The Support unit informs the decision-making bodies and the Technical unit.

4. Conclusions

In 1987, when the Italian National Emergency Plan was set up, the Italian Government decided the nuclear moratorium. The plan has therefore never implemented as far nuclear power plants are concerned (in this case local emergency plans as described are still in force). As the National Emergency plan takes into consideration other types of nuclear emergency such as nuclear fallout over the Italian territory, (due to accidents involving foreign nuclear plants, nuclear fuel-propelled ships, fall of nuclear powdered satellites etc), it should become effective if the need arises. The Technical unit (see par.3.3) was assembled and was put in operation in 1989 in occasion of the fall of Cosmos 1900 satellite. It took also part in the first international emergency exercise INEX 1, organised by OECD/NEA.

References

1. Decreto del Presidente della Repubblica 13 febbraio 1964, n. 185. Sicurezza degli impianti e protezione sanitaria dei lavoratori e della popolazione contro i pericoli delle radiazioni ionizzanti derivanti dall'impiego pacifico dell'energia nucleare. (*Presidential Decree no. 185 of 13 February 1964, "Safety of plants and health protection against the hazards of ionizing radiation resulting from the peaceful uses of nuclear energy"*).

2. Direzione Generale della Protezione Civile. Ministero dell'Interno. Agosto 1973 Circolare n. 70 sni criteri ol intervento. (*Ministry of Interior, General Directorate of Civil Protection, Circulat no. 70 on Criteria for Intervention*).

EMERGENCY PREPAREDNESS IN JAPAN

by

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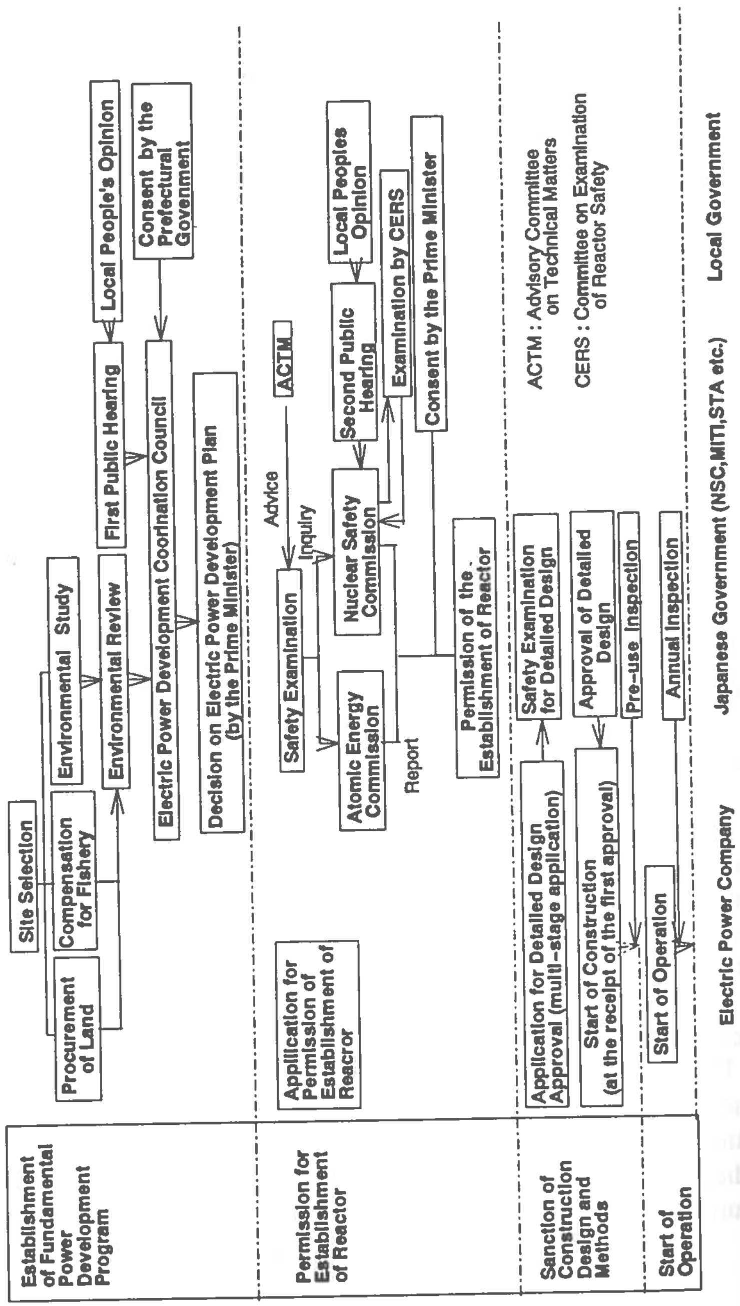
1. Regulatory System for the Nuclear Reactor

Nuclear and radiation related facilities in Japan are operated under the license of relevant regulatory systems to ensure a high degree of safety. Figure 1 shows an example of the licensing procedure of nuclear reactors in Japan. This consists of two stages of strict safety examination (check) processes of the basic design and concept (called "double check system"). The first stage is carried out by the competent administrative organization, either MITI (Ministry of International Trade and Industry) or STA (Science and Technology Agency), and the second stage by the Japan Nuclear Safety Commission (hereinafter called "NSC") and public hearings. Permission for installation of nuclear reactors is issued by the competent administrative organization.

Licensees permitted the installation of nuclear reactors shall get permission for the construction and must undergo the inspection of reactor and incidental facilities at every stage of construction by the competent organization. When the licensee begins to operate the reactor after the completion of the reactor facility, he must request inspection before use, by the competent organization, and also establish the safety prescriptions defining precisely the routine inspection of the system, radiation monitoring, waste management and disposal etc. The chief reactor engineers licensed by the government must also be assigned to operate the reactor. After the commencement of the reactor operation, the licensee bears a legal obligation to receive governmental periodical/temporal inspections and to submit periodical reports on the radiation exposure of workers and the status of storage of radioactive wastes etc.

Figure 1. Nuclear Power Station Licensing Procedure (from the textbook of JAICA)



2. Needs for Emergency Preparedness Arrangements

Nuclear reactors are designed, constructed and operated on the concepts of defense-in-depth with strict safety examinations and various kinds of inspections for quality assurance, it appears that no serious release of radioactive materials into the environment will occur. Nevertheless, in spite of all precautions that are taken, the remote possibility of failure or accident conditions leading to a nuclear emergency situation cannot be eliminated. These nuclear emergency situations (hereinafter called "accidents") differ from other emergencies in that they lead, or are likely to lead, to unacceptable releases of radioactivity or to unacceptable exposures. The operating organization (licensee) therefore needs to make preparations, in conjunction with national, regional and local government and other organization, to cope with these situations.

3. Emergency Preparedness Arrangements in Japan

3.1 The Disaster Countermeasures Basic Act and Nuclear Disaster

In Japan, nuclear disaster is defined as a "large quantity of radioactive release" in "The Disaster Countermeasures Basic Act" which was established in 1961 to consolidate an effective and coherent system for the protection of population from a disaster by making clear assignment of the responsibilities to the national and local governments and public organizations. The Act also aims to establish the comprehensive and systematic administration for the prevention of disasters by defining the basic rules for making disaster prevention plans, prevention of disasters, emergency countermeasures, remedial/recovery actions for the disasters and financial supports. The Act covers all kind of disasters such as typhoon, heavy rain and snow, flood, high tide, earthquake, seismic wave (tsunami), volcanic eruption, and large-scale fire and explosion.

3.2 Responsibilities of the National Government, Local Government and Public Organizations

1. Responsibilities of National Government

i. To adopt the prudent policy for the prevention of disaster by making "the basic plan" for the prevention of disasters, emergency countermeasures and recovery actions and to enforce the basic plan under regulation.

According to the basic plan, relevant organizations for disaster prevention are nominated as "designated administrative organization (STA, MITI)" and "designated public organizations (electric power company, Japan Atomic Energy Research Institute (JAERI), Power Reactor and Nuclear Fuel Development Corporation (PNC) etc.)" which must enact "Disaster Prevention Operational Plan", while local governments also enact "Local Disaster Prevention Plans". Local governments have a primary responsibility for off-site emergency countermeasures.

ii. To promote the operations of local governments and designated public organizations for the prevention of disaster and to make overall coordination between them.

iii. To share rationally the expenditure needed to cope with the disasters.

iv. Relevant national organizations for disaster, such as designated administrative organizations and designated local administrative organizations, should cooperate with each other in order to satisfactorily achieve the obligations assigned to them. They should also take proper measures with local governments (prefectures, cities, towns and villages) for making and implementing the local disaster prevention plan smoothly by appropriate recommendations, guidance and advice.

2. *Responsibilities of local government (prefecture)*

i. To protect the life, body and property of the people in the district, local governments have the responsibility to enact local disaster prevention plans in cooperation with other relevant organizations.

ii. Assist and coordinate prevention services sponsored by the municipalities and local offices of the national government.

3. *Responsibilities of local government/(municipality)*

i. To enact and implement disaster prevention operational plans with the cooperation of relevant organizations and local government.

ii. To strengthen the disaster related organizations in the district by education and training, and to systematize substantially public organization.

4. *Responsibilities of designated public organizations*

i. To enact and implement disaster prevention operational plans for each organization.

ii. To cooperate with national government and local governments (prefectures and municipalities) on disaster prevention plans.

5. *Responsibilities of the public organizations*

i. Public organizations and the managers belong to the responsible facilities from a view point of disaster prevention must play an active part according to the local disaster prevention plans.

ii. Every resident in the district should also cooperate with the disaster prevention activities according to the instruction of local government.

3.3 Nuclear Emergency Action Plans

After the nuclear accident at Three Miles Island Nuclear Power Plant (TMI) in 1979, the emergency preparedness arrangements in Japan were revised to strengthen and fill up considering the special aspects of the emergency countermeasures of nuclear power stations reflecting the lessons learned from the TMI accident.

3.3.1 Action plan for nuclear disaster prevention by national government

In July 1979, "The Central Disaster Prevention Council" issued "Urgent measures for disaster prevention at nuclear facilities by the governmental agencies" (hereinafter called "Urgent measures"). Figure 2 shows the off-site nuclear emergency response system in Japan. "Urgent measures" specifies the following:

i. An emergency communication network system connecting nuclear power plants, national and local governments is fully equipped and maintained. When an accident has the possibility of off site influence, headquarters for disaster control consisting of governmental agencies (hereinafter called "national headquarters") is set up.

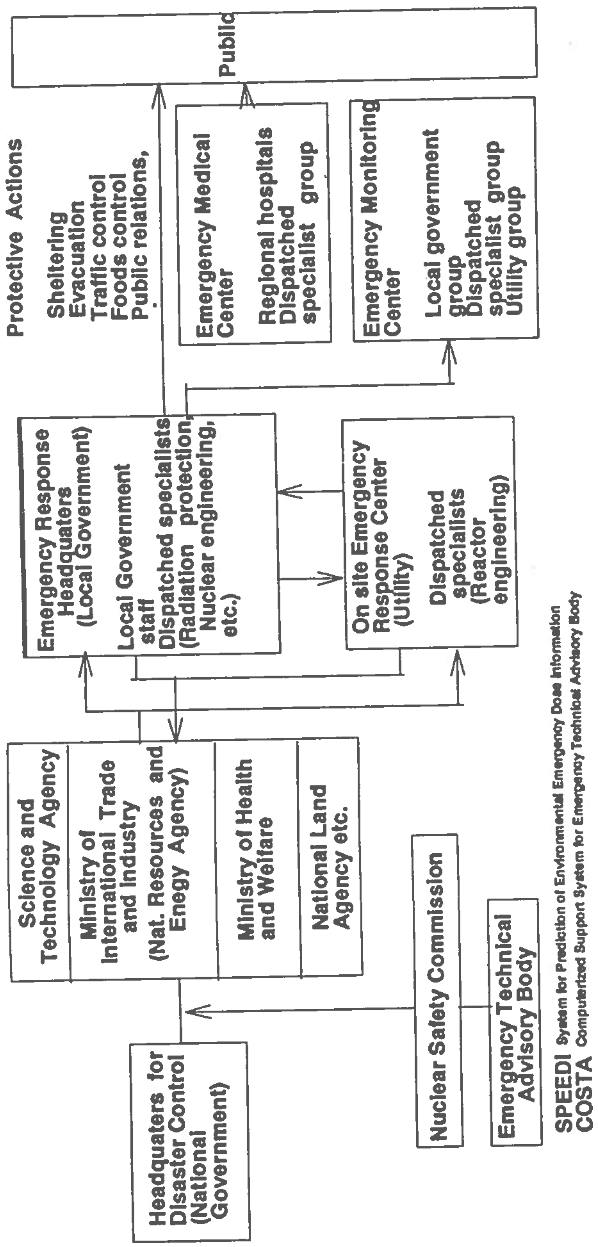


Figure 2. Off-site Nuclear Emergency Response System

ii. In the event of an accident occurring at nuclear facilities and should such an accident affect the off-site areas, the Emergency Technical Advisory Body is convened for giving directions, guidance and advice to the national headquarters who assist the local emergency response headquarters (hereinafter called "local headquarters") in deciding upon which actions to take.

iii. An organization consisting of technical specialists in the fields of nuclear reactors, radiation protection etc. is composed and maintained by the government to dispatch these experts to the local headquarters in case of emergency situations.

iv. The operational system for dispatching the emergency radiation monitoring staff and for supplying instruments to the local headquarters is called and maintained to provide for the emergency radiation monitoring.

v. The emergency dispatch system of medical staff is called and maintained to strengthen emergency medical countermeasures at local headquarters.

3.3.2. Action plan for nuclear disaster prevention by local government

In June 1980, the NSC established from a technical viewpoint the guideline entitled "Off-site Emergency Planning and Preparedness for Nuclear Power Plants" (hereinafter called "Guideline for off-site emergency"). The guideline intended to make possible the implementation of harmonious and effective emergency countermeasures by local governments, taking into account the special aspects of nuclear disaster. The outline of the Guideline is as follows:

1. General

It is mostly possible to cope with the nuclear disaster by conventional emergency plans for natural and industrial disasters by adding the appropriate technical advice on the radiation (radioactivity) and their impact on the human body and on the nuclear reactor by the specialist on radiation protection and nuclear engineering.

From the physical and chemical natures of radioactive materials in nuclear reactors and the safety systems of the nuclear power plants, and from a view point of disaster prevention of nuclear reactors, the most important radionuclides are noble gases (Kr, Xe etc.) and volatile nuclides (I etc.). Therefore it is important to constitute the emergency preparedness arrangements by focusing on these nuclides. It is also important to know the abnormal situations precisely by accurate information for the implementation of appropriate countermeasures. The following items are important for the implementation of harmonious and effective emergency countermeasures:

i. Popularization and enlightenment of the knowledge on nuclear disaster prevention among the inhabitants around the facilities

It is necessary to enlighten the general public on nuclear disaster prevention so that they behave orderly and without confusion and agitation in accordance with the instructions by the local headquarters.

a. characteristic of radiations and radioactive materials;
b. general descriptions of nuclear power station;
c. specialty of nuclear disaster;
d. matters to be taken into consideration in case of nuclear disaster.

ii. Education and exercise for the personnel assigned for the disaster prevention in local government:

Education:

a. basic knowledge on the atomic energy
b. knowledge of the system and organization of nuclear disaster prevention
c. knowledge of the facilities of nuclear power generation
d. knowledge of radiation protection
e. measuring methods for radiation and radioactive materials and knowledge of the equipment (including radiation measuring instrument) used for countermeasures

Table 1. **Training courses on nuclear disaster prevention by Nuclear Engineering School of JAERI**

Training Categories	Courses	Capability for application	Term (frequencies/year)	Quarum
Elementary Courses (i) Elementary knowledge on nuclear disaster prevention	Elementary course on nuclear disaster prevention	Staff of local government responsible for safety of residents	2 days (14)	50
(ii) General knowledge on nuclear disaster prevention	Course on nuclear disaster preventive measures	Staff of local government responsible for disaster prevention measures	5 days (2)	32
Specialized Course Emergency environmental monitoring (EEM)	Specified course	Staff for EEM (members of fields monitoring team)	2 days (4)	30
	General course	Staff for EEM (members of Information acquisition and dose estimation team)	5 days (2)	30
Training for the manager and supervisor	Course for the manager responsible for the disaster prevention	Manager and supervisor of local government responsible for the disaster preventive measures	2 days (4)	30
Occupational training	Fire defence	Staff responsible for fire defence	2 days (4)	30
	Police	Staff responsible for the public safety as a police	2 days (1)	30

Exercise

a. exercise of emergency communication
b. exercise of emergency environmental monitoring
c. combination of a), b) and information notification to residents
d. overall exercise including the national organizations

iii. Preparation of instrument, equipment and installation

a. emergency communication network for residents
b. communication system among related organizations to prevent congestion of telephone lines and to cover the lack of communication

lines in case of emergency; communication network to transmit the projected information calculated by the SPEEDI[1] network system

c. equipment needed for the emergency staff
d. instrument and installation for the emergency environmental monitoring
e. installation for the emergency medical treatment

iv. Preparation of data needed for disaster prevention

a. data on organization and system of nuclear facilities, local government and public agencies etc.
b. social data around the site
c. data needed for the projection of radiological impact to facilitate SPPEDI system.

2. *EPZ (Emergency Planning Zones)*

To effectively enforce the protective measures in order to reduce the exposure of the residents in the limited time of the emergency situation, it is important to that the EPZ be established beforehand, so that specific measures for the nuclear disaster can be fully provided for, i.e. emergency environmental radiation monitoring, places and routes of evacuation, evacuation and communication systems, etc. EPZ is defined by comprehensively taking into account the specific features and the effectiveness of disaster prevention measures such as technical aspects of the facilities, the distribution of population, administrative division and topography, etc. Considering these requirements, EPZ for the nuclear power plants in Japan is proposed to be about 8~10 km in radius from the plant.

As the concentrations of radioactive materials released sharply decrease with distance, due to atmospheric dispersion, the countermeasures beyond the EPZ are not necessarily effective. Exposures caused by the ingestion of contaminated foods and water might develop wider area via commercial distribution system, but there may be sufficient time to restrict (control) the ingestion of

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1 System for Prediction of Environmental Emergency Dose Information (SPEEDI). SPEEDI was developed as a system which provides emergency headquarters with information on predicted concentration of radioactive materials, radiation dose etc. in case an emergency situation is imminent or occur. In normal situations, SPEEDI acquires the meteorological and radiation monitoring data around NPP sites from the monitoring centers of local government together with nationwide meteorological data (AMeDAS) from the Japan Weather Association and forecasts wind direction and velocity. During an emergency, predicted weather data are combined together with the geographic data and the source term information.

contaminated food and water compared with the exposure from the radioactive plume.

3. *Emergency environmental monitoring*

When large quantities of radioactive materials are released (or possibly released) into the environment due to the serious situation of nuclear reactors, special environmental monitoring (hereinafter defined "Emergency environmental monitoring or EEM") is implemented to get the information on γ-radiation and radionuclides in the environment (Figure 3). The objectives of emergency environmental monitoring are as follows:

i. Evaluate the exposure to the residents and furnish the data needed for determining the protective measures for them using the information on the γ-ray air absorbed dose and the concentration of radionuclides in the air obtained by emergency environmental monitoring and other information such as release, meteorology and dose estimation. Rapid measurements of γ-radiation and radionuclides are required for this purpose.

ii. Evaluate and decide the radiological impacts on the public and environment.

4. *Guidelines for the implementation of disaster countermeasures*

i. Protective measures

a. sheltering in house
b. sheltering in concrete building
c. evacuation
d. restriction of the intake of food and water
e. dosage of stable iodine (tablets)
f. control of access and egress
g. protective measures for the staff engaged in disaster prevention

ii. Criteria for protective measures are shown in Tables 2 and 3.

Figure 3. **Organization of Environmental Monitoring Center**

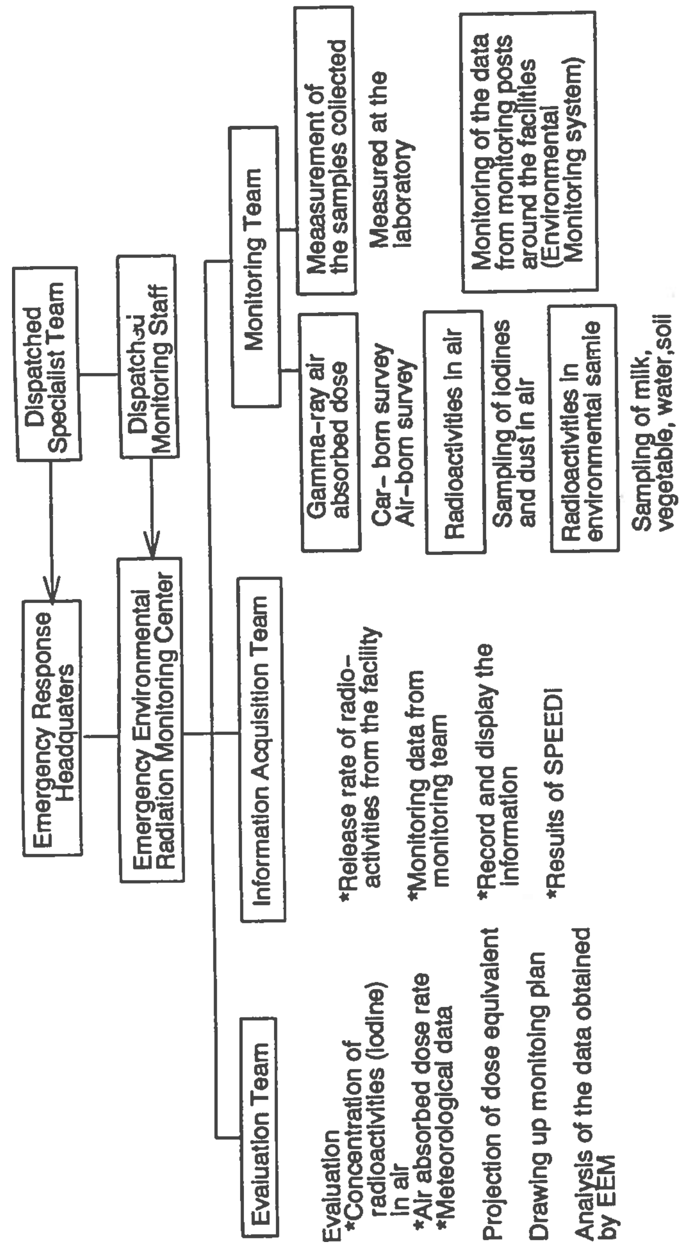

Table 2. **Guidance for indoor sheltering and evacuation**

Projected dose equivalent		Measures	Objects
Whole body (mSv)	Thyroid (mSv)		
10-50	100-500	Stay indoors	Infants, children and Pregnant women
50-100	500-1000	Stay in the concrete building or evacuation	Infants, children and Pregnant women
		Stay indoors	Adults
100-	1000-	Stay in the concrete building or evacuation	All

Note: The hazard prevention headquarters estimates the projected dose equivalent.
The public are informed of the projected dose equivalent together with the countermeasures instructions.

Table 3. **Guidance on the ingestion restriction of contaminated food and water**

Item	I-131 Concentration
Drinking water	1 x 10^2 Bq/L
Vegetables	6 x 10^3 Bq/kg
Milk	2 x 10^2 Bq/L

5. *Emergency medical treatment*

An Emergency medical centre is organized under the local emergency response headquarter. The role of the emergency medical centre is to practice medical treatment to the injured and exposed populations based on the synthetic judgement and coherent view obtained by the close cooperation with relevant medical agencies. Invalids considered in the nuclear disaster countermeasures are classified in the following three groups.

i) The first group
Persons with general physical abnormalities and aggravation of diseases caused by the confusion of emergency regardless of radiation exposures and contaminations.

ii) The second group
Persons with radiation exposure without any acute sickness and low level internal and surface contamination with radioactive materials. The first group might be included in this group.

iii) The third group
Persons with radiation exposure and contamination required special clinical observation or medical treatment.

CORRELATIONS BETWEEN MALIGNANT TUMOURS AND LOW DOSES OF IONIZING RADIATIONS FROM NATURAL BACKGROUND, GLOBAL FALLOUT AND CHERNOBYL ACCIDENT IN RUSSIA

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1. Introduction

The latest (up to 1994) results obtained by Saint Petersburg Institute of Radiation Hygiene on carcinogenic effects of low doses of ionizing radiations represent two regions of Russia:

- the Arctic coast of Russia, from Chucotka to Kolski peninsula; and
- the most contaminated part of Russia resulting from the Chernobyl accident (Bryansk oblast).

Effective radiation doses found in aborigines in Arctic (50 000 inhabitants) in the lichen-reindeer-man food chain during 30 years (1961-1990) from ^{137}Cs were an average of 30 mSv with a fivefold difference between regions. Effective dose from natural ^{210}Pb - ^{210}Po was 1 mSv annually. In Bryansk oblast[1] with a total population of 1.47 million, about 112 000 people were exposed to higher radiation dose from Chernobyl accident in May-June 1986; up to 10 Gy to thyroid from radioiodine and 50 mSv effective dose during 1986-1993. Mean absorbed dose to thyroid was 54 mGy and collective absorbed dose for the all oblast 79 120 person-Gy.

Arctic studies indicate that the mortality of aborigines from all malignant tumours correlates with ^{210}Pb-^{220}Po content in reindeer bones, corresponding with radiation dose in population (correlation coefficient +0.68±0.22), with ^{137}Cs in reindeer (-0.79±0.16) with ^{137}Cs in human body (-0.35±0.34), with annual

1 Bryansk Oblast is an Administrative district.

precipitation rate (-0.68±0.22), vegetation periods (-0.63±0.26) and with anthropogenic properties of population (-0.80±0.12).

In 1986-1993 in all Bryansk oblast 608 thyroid cancers have been registered, and 16 from this number in 316 000 children (0-14 years old at the time of the accident). Morbidity per 100 000 population increased from 1.5-2.4 to 5.0-10.5 cases. The correlation of this increase with radiation exposure is doubtful, since the morbidity difference between populations of "clean" (^{137}Cs less than 0.037 TBq or 1 Ci/km^2) and contaminated regions (^{137}Cs from 0.037 to 3.7 TBq or 1-100 Ci/km^2) during the last five years was not observed. Health statistics data showed the peculiar increase 2-5 times of morbidity rate in contaminated areas immediately after the accident in 1986-1987. It might be explained by a tremendous improvement of diagnosis in contaminated areas during the first two years. Children's morbidity rate (14 years and under at the time of the accident) in Bryansk oblast was the following for 100 000 children:

1986 - 0.0	1987 - 0.3	1988 - 0.0	1989 - 0.0
1990 - 0.9	1991 - 0.6	1992 - 1.2	1993 - 1.8

These data are similar to the statistics for Ukraine and Belarus, with the exception of the Gomel region, where they are five times higher. Increase of cancer in children after 1990 was observed also in "clean" areas of Bryansk oblast, however, in these areas the rate was 3.5 times lower than in the contaminated ones.

To prove the connection of childhood cancer dynamics with radiation we still need more detailed and time consuming studies.

A radical change in the recently dramatic re-evaluation of radiation risk (1), which plays role of foundation for radiation protection, has poured oil on the flame of scientific investigations of radiation cancer. Following the Chernobyl accident discovery by Belarus scientists on unusual early and frequent children thyroid cancers, that have been confirmed by the World Health Organization (2,3), well known orthodox radiologists (4) became anxious. The problem of radiation carcinogenesis has many blind alleys. And one of them is an absence of the radiation specificity of carcinogenic effect, which can be induced, promoted or weakened from influence of many factors in environment and of genetic nature. Now it is quite clear there is essential variability of radiation risk for the same dose and the same organism. A lot depends on the combination of others factors including even consumption of different ordinary

food-stuffs, climatic conditions, as well as smoking or drinking. But especially important appeared the standardization of skill in diagnostics of such cancers as in thyroid, which can be dormant (occult) during the whole life without deteriorating health in practically 10% of people. The complexity of such problems was met during investigation of radiation carcinogenesis from natural and global fallout radiation in the Arctic coast of Russia (5) and thyroid cancers among populations living in highly contaminated areas in Bryansk oblast after Chernobyl accident (6).

2. Materials and Methods

The schematic map of our researches in Arctic is shown in Figure 1, where we noted places of sampling different environmental materials and of measurements. In these places information about cancers from medical certificates of death were collected. Here we give the information only concerning those aborigines who were connected with the lichen-reindeer-man food chain. This food chain has been studied in all arctic countries since 1960 (7). An established fact is that links of the chain have some peculiarities leading to higher accumulation of the radionuclide ^{137}Cs from global fallout, and natural ^{210}Pb and ^{210}Po (10-100 times than in other food chains). For 30 years (1961-1990) thousands of samples of soil, lichen, venison, fish, urine, faeces, autopsy materials from reindeer-herding men have been collected, and measurements of them and ^{137}Cs body burden in aborigines were made. Levels of ^{90}Sr, ^{210}Pb and ^{210}Po in bones after autopsies were carried out on only 20 people. Therefore a more reliable quantity to reflect irradiation of people by these radionuclides appeared to be radionuclide levels in reindeer bones, which were measured in hundreds of samples. In accordance with calculations during 30 years of observation, 50 000 aborigines incurred additional (to ordinary background) radiation effective dose from ^{137}Cs at average 30 mSv and 1 mSv annually from ^{210}Pb and ^{210}Po.

Variances in irradiation and in cancer mortality between nations (regions) appeared almost 5 times (Table I), that gave the ground for correlation analysis. The observed regions have remarkable variances in climatic conditions; Taimir, Yakutia and Chukotka belong to very severe cold climatic zones, but Komi republic, Nenetz district and Kolski penninsula have more mild climates.

Our attention was drawn by ethnogenetic heterogenesity of the north populations. The better known quantities appeared two tests: 1) part (in per cent from the nation) of peoples, who do not excrete ABH-antigens in saliva depending on recessive gene"s", 2) mean quadrate of genetic distance of the nation from original presiberian population (8, 9). The two tests reflect an adaptation of nations to the environment.

Methods of research of radiation doses and population health in Bryansk oblast were reported during an international scientific workshop in January 1994 (Japan, Chiba, Institute of Radiological sciences, (6)). Here we show additional data for 1993. The number of thyroid cancer cases among children aged from 6 to 16 has increased by including persons aged from 15 to 22 years at the time of the study but who were children aged 14 years and under at the time of the accident. Earlier (6) they had not been included in the tables.

3. **Results and Discussion** (see Tables I-VI)

As one can see from Table I, doses from natural radionuclides (^{210}Pb and ^{210}Po) in reindeer bones had a positive correlation coefficient (+0.68±0.22) with total cancer mortality at aborigines. But the correlation of the mortality with ^{137}Cs in reindeer and aborigines themselves was a negative one (-0.79±0.16 and -0.35±0.34; in the last case not essential). High enough and statistically significant such were negative correlation relationships of cancer mortality and climatic conditions as annual levels of precipitations, air temperature and mean vegetation period. The more severe climate of Timir, Yakutia and Chucotka probably promotes the induction and development of cancer. But the highest correlations of cancer mortality were determined with the ethnogenetic features. The more the percentage of people who do not excrete ABH-antigens the less the cancer mortality in the studies populations. The same results were obtained in relationship with the mean quadrat of genetic distance.

These relationships between cancer mortality and climatic and genetic factors appear more reliable than those with radiation.

The difficulty in demonstrating the importance of radiation in cancer induction can see from the data on thyroid cancer among population in Bryansk oblast after Chernobyl accident.

The dynamics of thyroid cancer morbidity during 8 years after the accident in connection with the levels of radioactive contamination of the regions and absorbed doses in thyroid from ^{131}I do not give possibility with conviction to prove the sought for correlation (Tables II-III).

Sharp rise (2-5 times) of thyroid cancer morbidity for all ages in contaminated areas, as compared with the levels before accident and in clean zone (<0.037 Tbq $^{137}Cs/km^2$), happened in 1986 and 1987. In the following years these differences between regions became unstable and even in contrary position. The above mentioned sharp rise hardly could be explained by influence of radiation. As well known a minimum latent period for thyroid cancer is 5 years. Exactly during "the rise" the Ministry of Health had sent additional hundreds of physicians from Moscow, Leningrad and other centres for more careful examinations of people only in contaminated regions (6). A total between 1986-1993 of two times rise of thyroid cancer morbidity over all Bransk oblast (314 cases observed before the accident, 608 cases observed after) was not due to cancer in children (all in all 16 cases during 8 years), but was due to cancers in older people. Taking into account that children (0-≤14) consist of 22% of Bryansk populations, it is easy to demonstrate that absolute morbidity risk for adults for the 8 years was 5 times higher (24 per 100 000), than for children (5 per 100 000) and thus to conclude that there exists higher radiosensitivity of children to thyroid cancer is not correct. Child morbidity drew special attention because it was sporadic and had not been revealed before the 4 years after accident. The importance of rise of medical attention can not be crossed out in this case too. Belarus scientists could not have provided hystological diagnosis almost for 10% of operated children (3). This is clear evidence of exaggerated diagnostics.

Child thyroid cancer morbidity in Russia (Bryansk oblast) per 100 000 children is almost the same as in Ukraine and Belarus (11, 12), but in Gomel oblast (neighboring to Byransk oblast), the morbidity was 5 times higher. Half of 16 cases (8 cases) at Bryansk children fall on the "clean" zone with absorbed dose from ^{131}I for thyroid < 38 mGy (4 rad). The total number of children living in others "contaminated" zones is 3,5 times less than in "clean" one, the cancer morbidity here is accordingly higher. Of course it is early yet to conclude about radiation cause here: not enough cases and high attention of medical service could not be excluded. Considering mean data on morbidity in 1986-1993 (Table II bottom line) the increasing of "effect" with dose or contamination levels (2 times at contamination 1, 10-3, 70 TBq $^{137}Cs/km^2$ and thyroid mean dose 200 mGy) is changing even to the confidential decreasing at 0, 19-0, 52 TBq $^{137}Cs/km^2$ and dose 91 mGy.

According to reference (13), risk of morbidity from ^{131}I is equal to 25 per 10^4 person-Grey. It means that for all Bryansk oblast (dose - 79, 120 Person-Gy) 200 cases of additional thyroid cancers (morbidity) for the whole life (for 30 years) are expected. But in reality the rise of morbidity (Table III) during 8 years (of which 5 should be considered as minimum latent period) made up 294 cases, and for 30 years the effect will reach about 1100 cases, otherwise 5 times more than accordance to ICRP-60 (1). We have not observed any latent period at all.

During all 8 years there was very stable and quite confidential relation in morbidity of females to males 5, 7: 1. At the same time for other countries it accepted at 2: 1 (13). Relations of different hystological forms of cancers stayed without changes in 1986-1993 (Table V). No dependence of these forms on the levels of radiation (Table V1) has been determined. One can notice definitely a decrease in the portion for cancers under the diagnosis "others and without diagnosis" from 40% in 1986 to 13% in 1993. This is an evidence of improvement in diagnostic quality.

4. Conclusion

Studying the influence of low doses of ionizing radiations on carcinogenesis one should take into account, apart from well known factors (chemical carcinogens, smoking, food stuffs) such other ordinary factors as climatic and ethnogenetic. They can modify carcinogenic effects of radiation considerably.

Almost twofold increase of thyroid cancer morbidity among Bryansk population in Russia (from 341 to 608 cases) during 8 years after Chernobyl accident till now could not be connected directly with influence of radiation. Sharp rise of morbidity (3-5 times) on higher contaminated regions happened already in 1986-1987, when here medical diagnostic was improved and mimimum latent period (5 years) for thyroid cancers did not expire. It was not possible to prove surely the dose-effect relationship. At "middle" dose (91 mGy) and level of contamination 0, 19-0, 52 TBq ^{137}Cs/km^2, the morbidity appeared for certain less than in "clean" area (0, 037 TBq ^{137}Cs/km^2).

The highest and essential absolute augmentation of morbidity for 8 years happened among adults (24 per 100 000) and not for expenses of children (5 per 100 000). The observed rise of children morbidity by 10 cases (of 16) in latest years (1992-1993) was noticed for 7 cases at attained age 16-20 years. As the irradiated children will be growing older a future rise of morbidity 5 times even without influence of radiation can be predicted. Subsequent development of diagnostic and its approach to revealing so called dormant or occult cancers (8 per cent in accordance to (14)) can result in almost 1000 times rise of thyroid cancer morbidity without taking into consideration severity of the illness and influence of radiation.

5. Acknowledgements

Many sincerely thanks to Bryansk physicians and especially to the physicians of Oncological dispancery who prepared original data for this report. We thank very much the Organizing Committee of the workshop and most of all Director T. Sugahara for giving us the opportunity to present this report.

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Table 1. **Correlation between cancer mortality and low doses of ionizing radiation and other factors at aborigines on the far north of Russia**

Observed							Correlations between X and Y
region	Kolski	Komi	Nenets	Timir	Yakutia	Chukotka	
nation	Saami	Komi	Nenets	Dolgan	Yakut	Chukchi	
number of people	2 000	15 000	7 000	5 000	6 000	15 000	
X - cancer mortality cases per 10 000 aborigines per year, in 1961-1990	16	10	11	30	32	41	
Y_1 - ^{210}Pb, ^{210}Po in reindeer bone, Bq/kg	551	111	278	426	351	577	±0.68 ±0.22
Y_2 - ^{137}Cs in reindeer muscles (10^2Bq/kg) 1965-1967	36	30	21	14	6	9	-0.79 ±0.16
Y_3 - ^{137}Cs in reindeer herding men, 1965-1967 (10^3Bq)	122	56	59	37	17	63	-0.35 ±0.34
Y_4 - Precipitations, mm per year	675	500	350	230	175	400	-0.68 ±0.22
Y_5 - Air temperature (July), C	12	10	9	5	7	7	-0.58 ±0.30
Y_6 - Vegetation period (days) (10)	100	90	80	40	60	75	-0.63 ±0.26
Y_7 - ABH - nonsecrete, %% (8)	25	25	25	5	5	10	-0.76 ±0.19
Y_8 - Quadrat of genetic distance (.10^3) (9)	50	50	30	4	8	13	-0.80 ±0.12

Table 2. **Thyroid cancer morbidity of population in Bryansk obalst**
(cases per 100 000 inhabitants)

Contamination of regions, ^{137}Cs, TBq/km^2 (Ci/km^2)	<0.037 (<1)	0.037-0.019 (1-5)	0.19-0.52 (5-15)	0.52-1.10 (15-30)	1.10-3.70 (30-100)
Populaion, (thousand)	1.109	121	153	78	14-7
1986	2.9	4.1	3.9	7.7	6.0
1987	3.5	9.1	8.5	14.2	20.0
1988	5.1	4.1	5.3	5.2	6.6
1989	5.4	2.5	3.3	5.2	0.0
1990	4.0	2.5	2.0	14.2	16.0
1991	5.1	4.1	2.6	10.3	10.8
1992	6.6	6.6	3.3	5.7	0.0
1993	7.6	11.6	3.9	6.5	14.3
1986-1993 mean ±	5.0±0.7	5.6±1.2[8]	4.1±0.8*	8.6±1.4*	10.5±2.7*

Note:
* Confident statistical differences with data on area <0.037 TBq^{137}Cs/km^2; $p<0.05$.
1. Before accident thyroid cancer morbidity in region with contamination <0.037 TBq ^{137}Cs/km^2 was 2.4 per 100 000.
2. In accordance with general census of the population in 1989 in Bryansk oblast there were 1 470 000 peoples; 671 000 males and 799 000 females; 316 000 children (9≤14) or 22 %.

Table 3. **Estimation of the current thyroid cancer morbidity risk in Bryansk oblast in 1986-1993**

Contamination of region ^{137}Cs TBq (Ci) km^2	Population in thousands	Absorbed dose from ^{131}I in thyroid		Number of cancer			Actual risk of morbidity for 8 years	
		Individual mean, mGy (rad)	Collective Person-Gy (person -rad)	Observed	Expected	Excess	Per 10^4 person y-Gy (10^6 PYR)	Per 10^4 PGy (10^6 PR)
<0.19 (<5)	1.230	38 (4)	46 720 (4 672 000)	499	285	214	5.7	46
0.19-0.52 (5-15)	153	91 (9)	13 950 (1 395 000)	47	18	29	2.6	21
0.52-3.70 (15-100)	92	200 (20)	18 450 (1 845 000)	67	11	56	3.8	30
Bryansk oblast all	1.475	54(5)	79 120 (7 912 000)	608	314	294	4.6	37

Table 4. **Age, sex and severity of thyroid cancer in Bryansk oblast**

Registration of morbidity	All population (thousands)	Number of registered cases, (all children 0≤14)	Males		Females		Dead in the year of registration (%)
			%	Mean age of patients (years)	%	Mean age of patients (years)	
1986	1.471	50(0)	26	47	74	55	6.0
1987	1.473	77(1)	12	49	88	51	5.2
1988	1.474	72 (0)	15	51	85	52	4.2
1989	1.475	72(0)	11	53	89	50	5.5
1990	1.469	63 (3)	16	43	84	47	11.1
1991	1.464	74(2)	15	49	85	51	10.7
1992	1.463	90(4)	16	46	84	47	8.8
1993	1.463	110(6)	12	43	88	50	6.4
1986-1993	1.469	608(16)	15±2	48±1	85±2	50±1	7.2±0.9

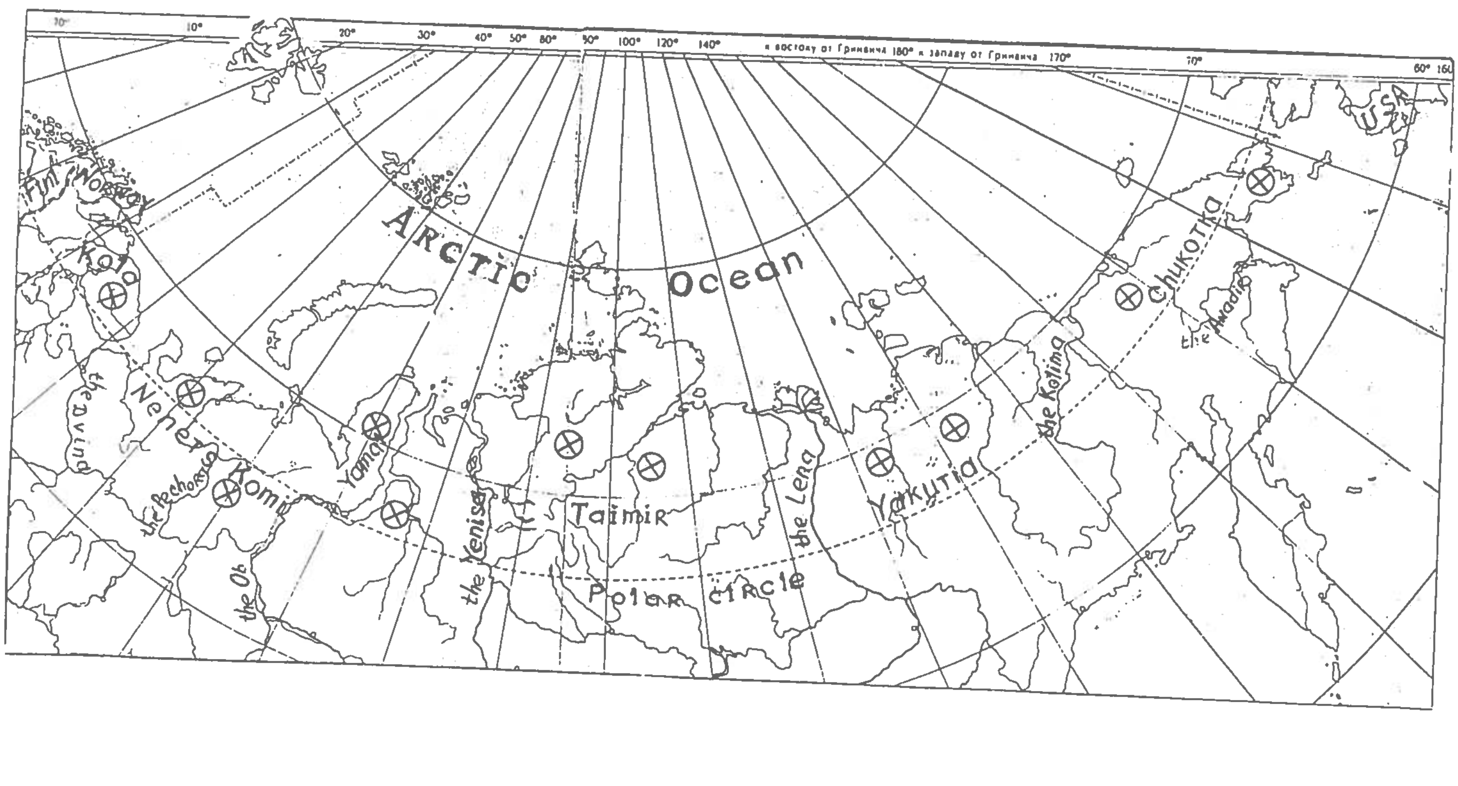
Table 5. **Histological characteristics of thyroid cancer in Bryansk oblast in 1986-1993 (in %).**

Diagnosis of type	1986	1987	1988	1989	1990	1991	1992	1993	Mean ±
Papillary	38	48	56	51	56	50	54	63	52±3
Folliculary	22	20	18	24	23	16	27	24	22±1
Others/without diagnosis	40	32	26	25	21	34	19	13	26±4

Table 6. **Histological characteristics of thyroid cancer in Bryansk oblast in 1986-1993 on areas with different levels of contamination**

Contaminated areas ^{137}Cs TBq (Ci) per km^2	Papillary No. of cases	%	Folliculary No. of cases	%	Others No. of cases	%
<0.037 (<1)	241	55	86	23	83	22
0.037-0.19 (1-5)	41	63	12	19	12	18
0.19-0.52 (5-15)	13	62	5	24	3	14
0.52-1.10 (15-30)	28	62	16	36	1	2
1.10-3.70 (30-100)	5	62	1	13	2	25

Figure 1. **Regions of investigations on the far north (Arctic) of Russia**



COUNTERMEASURES IN SWITZERLAND

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Introduction

The present concept of emergency planning and preparedness around Swiss nuclear power plants is a part of a comprehensive concept of emergency preparedness for all types of radiological hazards and has been described in the information submitted for INEX 1 and in the references (1) and (2). Parts of the concepts are tested every year in exercises. Developments, experiences and trends since 1991, influenced by the installation of containment venting and filter systems at all NPP and the distribution of iodine tablets, are described in the following presentation.

Swiss NPP are located in relatively densely populated areas with several hundred thousand inhabitants in the emergency planning zones (EPZ; zone 1 radius 3-5 km, zone 2 radius 20 km). The majority of the houses are built in brick, stone or concrete and almost all have massive stone or concrete basements, including civil defence shelters in those built after World War 2. Thus staying indoors provides protection factors of 10 to over 100, and therefore "vertical evacuation" (sheltering) within the buildings was chosen as the main prophylactic countermeasure if a release is expected. Public buildings, schools, hospitals, industrial and office buildings etc. have shelters for their normal number of occupants during working hours. The population has also been advised to have at any time food stores sufficient for several days in their homes.

The alarm concept (1) has several steps of action following the beginning of an emergency in a NPP. As soon as the NPP has to activate its on-site emergency organisation it has to alert the National Emergency Operations Centre (NAZ) and the Nuclear Safety Inspectorate (HSK). Criteria have been fixed in the NPP emergency procedures when they – in accordance with NAZ and HSK – have to alert the emergency staffs of the cantons and the communities in the EPZ (WARNING). If the radiological situation in the plant deteriorates, the decision to issue a GENERAL ALARM is taken by NAZ after consultation with HSK and the NPP. GENERAL ALARM is given by sirens followed by a radio message prepared by NAZ. All communities in the country have civil defence sirens, with a higher density in the EPZ. The population is instructed to listen to radio messages if "General Alarm" is sounded by sirens. If a release seems imminent, the population is advised by another GENERAL ALARM + radio message to stay indoors and to move into basements or shelters. The beginning of a release is announced by another siren signal "RADIATION ALARM". Cable television and broadcast are relatively widespread in larger villages and in the cities, and FM radio emitters can be boosted in order to allow reception even inside shelters.

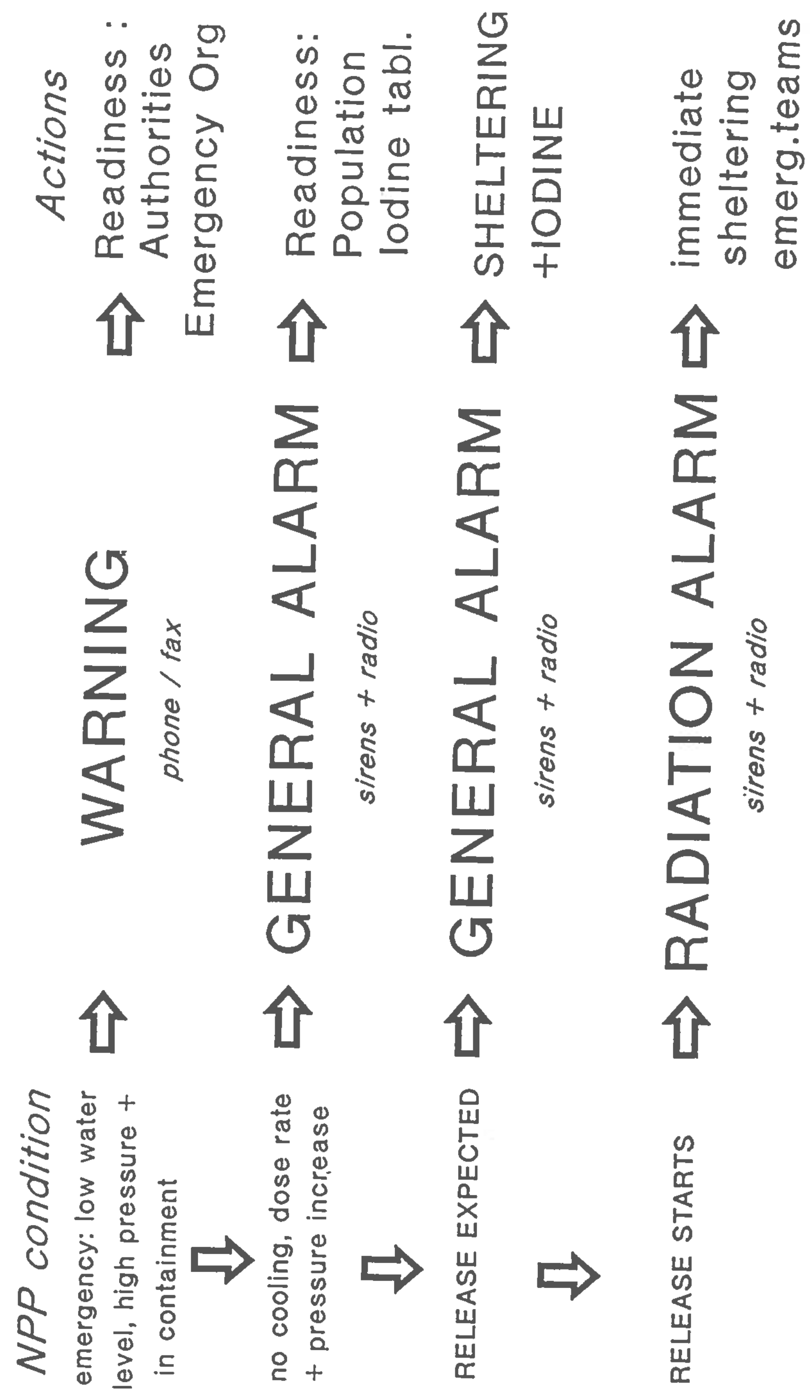
An operational emergency management in the EPZ is a condition for operating a NPP in Switzerland, and the NPP operators have to pay the costs for special installations and preparations within the EPZ such as sirens, dedicated communications, automatic monitoring network in the inner EPZ and iodine tablets for the EPZ population.

Recent Developments which Influence Emergency Planning

At the end of 1993 all five NPP were equipped with installations for containment venting through special filters. While this does not influence the rare gas cloud, it reduces the release of iodine and volatile fission products such as Caesium by a large factor and reduces the potentially contaminated area around a NPP.

In 1993 the Nuclear Safety Inspectorate (HSK) started the operation of four additional automatic monitoring networks, MADUK, with about 20 stations each in the central EPZ of the four NPP sites. The new system allows also on-line access to in-plant data. The MADUK monitoring data are compatible with the country wide NADAM network and are also updated every 10 minutes, with results available both to HSK and to NAZ. This network allows an earlier and more detailed monitoring of the movement of an activity release and the extent of the ground contamination.

Figure 1. Alert Steps



A station of the Swiss country-side monitoring network NADAM is now operating on the site of the Institute for Atmospheric Physics (IAP) in Freiburg/Breisgau, Germany, an trials of data exchange between NADAM and the German IMIS system have started. If they are successful we shall attempt to connect the Swiss and German monitoring networks.

The old aerosol monitoring network is being replaced by the new automatic RADAIR network, operated by SUeR Fribourg (with data transfer to NAZ) which uses the same kind of monitors as the German aerosol monitoring network (7 alpha/beta monitors, 3 gamma-spectrometry monitors, iodine monitors).

Swiss embassies in Eastern Europe have been equipped with portable dose-rate monitors of the same type as used for the AWP (police posts) network; they perform periodic dose-rate measurements at their sites in order to be able to judge their situation in case of an accident.

The aeroradiometry equipment of the Emergency Organisation (EOR) is now ready to be installed in the Army's new Super Puma helicopters and will allow to follow a radioactive cloud thanks to the much higher peak-altitude and to the all-weather capabilities of that helicopter. The same equipment will be used for a first quick survey of the ground contamination after passage of the cloud.

Early in 1994 Switzerland applied formally for participation in the EU notification system ECURIE.

Finally, during 1993, potassium iodide tablets have been procured for the entire population and have been distributed to all inhabitants in the inner EPZ (zones 1) and to local distribution centres in all communities of the outer EPZ (zones 2). For the rest of the country (zone 3) there is a central storage on an army helicopter base from where each canton could be supplied in less than 12 hours. Cantonal and local distribution is organised by cantons and communities, mainly with help of civil defence and health services.

Emergency Planning Zones

In the present concept, the EPZ 1 have a radius of 3-5 km and are always alarmed entirely. The zones 2 have a radius of 20 km. In the case of the Muehleberg NPP (KKM) this zone includes the cities of Bern, Bienne and Fribourg. Depending on wind direction and stability, one or more overlapping 120° sectors would be alarmed, but during the rather frequent situations with low wind speeds the entire zone 2 would have to be alarmed which in the case

of KKM even would paralyse our capital. Based on the safety improvements installed in the NPP the reference accident which serves as a basis for emergency planning was recalculated. The results show that the minimum period between warning and begin of a release is around 7 hr, not 4 hr as assumed earlier.

A modified concept is being studied. It proposes to subdivide zone 2, to form an inner 10 km -low wind zone and to alarm this zone entirely in all cases. In the outer region between 10 and 20 km the emergency staffs of the communities would be warned together with those of the inner zone and would be ready to trigger the sirens if necessary. Prophylactic staying indoors or in basements and shelters would still be implemented in the 10 km-zone before the beginning of a release, but in the outer zone it would only be commanded for those communities expected to be under the path of the cloud which now can be determined and followed more precisely and quickly thanks to the improved monitoring capabilities. Farther away from the source staying indoors may give sufficient protection and may be soon relaxed once the cloud has passed. In the region closer to the source which may show a significant ground contamination the countermeasures would be relaxed selectively after detailed contamination monitoring.

Sheltering

The main short term countermeasure which is implemented preventively already before a release of activity is staying indoors and – where necessary – moving into basements or shelters of the same building or house. Collective civil defence shelters built for wartime are not used for such emergency purposes as they are normally used for other purposes (storage, garages etc.) and would need one or more day to be prepared for occupancy. During the stay in the basement or shelter people would be allowed to use hygienic and cooking facilities in the upper floors during specified short periods as the massive houses provide a reasonable protection. As part of the general civil defence concept all families are required to have food supplies for several days at any time. This alleviates the sheltering period, together with the psychological advantage of remaining in the familiar surroundings of the own home or workplace. Emergency services during the sheltering period must be provided by the communities. Their civil defence protective equipment and monitoring instruments allow adequate protection of emergency personnel such as fire brigades or medical emergency staff.

Hospitals

Special planning for hospitals and similar institutions has been initiated by the Nuclear Safety Inspectorate. A pilot project at a large cantonal hospital evaluated the protective factors of the various rooms and floors and analysed the composition of the patients and the organisation needed for the provision of adequate protection of the patients and the staff. Hospitals have civil defence underground facilities into which those patients can be moved which need only normal care. A relatively large percentage of the patients are those whose treatment is finished but who still stay at the hospital for observation before being released, these can be released and go home in the period between warning and alarm, provided the hospitals are included in the warning. The remaining problems are those patients which cannot be moved because they need special facilities for their treatment, mainly the intensive wards. These facilities are usually located in the inner parts of the floors and have relatively high protection factors. This allows to keep those patients and a minimal staff in these facilities during a sheltering period. Based on this pilot experiences such studies and planning have been made for the hospitals and similar institutions in the EPZ.

Farmers

Studies of the protection possibilities on farms with regard to the protection and care of animals have been done which resulted both in an evaluation method for farms, now being applied by local civil defence teams in co-operation with the farmers, and in a training program for farmers which is now being started in co-operation with agricultural schools. More information on this will be provided for the 1995 workshop on farming problems.

Experiences

We have no experience with sheltering during any radiological event. But shelters have been used during other types of emergencies, for example avalanches. Shelters of various types are routinely used during several days for civil defence and army exercises, and some public shelters have been used over long periods as housing for refugees or during shorter periods for housing families evacuated during disasters such as floods or gas / gasoline explosions. Swiss civil defence has also carried out special exercises with volunteer families staying several days in public shelters. The hygienic conditions and the problems arising under such conditions (high humidity, group behaviour problems, need to occupy children with games etc.) are more severe than when people have to shelter in their own residences, but the experiences showed that

living in shelters during several days is manageable and probably poses less problems than an evacuation. Taking care of domestic animals is also easier.

Iodine Tablets

The concept for administration of iodine tablets is based on the recommendations of ICRP publication 63. Preventive administration of a first dose is therefore always linked to the command of staying indoors or sheltering. The age-dependent dosage is given in the written instruction included in the tablet package. The tablet package for one person contains 10 tablets at 65 mg KI (= 50 mg I) with a shelf life of 8 years. Dosage for persons above age 12 is two tablets/day for 2 days, for children between age 3 and 12 one tablet/day, for children below age 3 half a tablet/day.

The tablets have been distributed to the inhabitants of the EPZ 1 and to the cantons having regions in EPZ 2. It is left to the cantons how they want to organise the distribution in the EPZ 2: they can distribute the tablets to the population in advance even in zone 2 or they can store them at local distribution facilities such as pharmacies. In the latter case they have to provide an organisation which makes it possible for the public to fetch their tablets at the distribution points within two hours after the first "General Alarm" and the relevant instruction by radio. The cantons are now elaborating and testing their distribution concepts and time will show which solutions will be chosen. NAZ had advocated to distribute the tablets to all inhabitants of the zones 1 and 2, but the legislators allowed more choice for the cantons.

Iodine tablets have not only been procured for the inhabitants in zones 1 and 2 and for the emergency personnel, but for the entire Swiss population, based on a political decision following requests by cantons, which is not based on any scenario for Swiss NPP events but rather on psychological reasons. The population of some border regions, mainly Basle and Geneva, is worried by the proximity of the French NPP of Fessenheim (30 km), Bugey and Creys-Malville (70 km), largely as a result of years of disinformation by regional anti-nuclear movements and media.

Evacuation

Evacuation as a normal preventive action is not considered in our plans for the residential and working population of an EPZ. But the local authorities are responsible for detailed planning for their specific situation and may have to plan for evacuation of temporary residents or transients without adequate protection, for example campers, participants of open air festivals or sports events. As such groups mostly have their own transportation means they can be made to leave the EPZ in the period between General Alarm and a beginning of a release or can be relocated to public buildings or shelters with better protection. Similarly the public transport authorities are included in the warning and immediately start to plan the reorganisation of traffic and the timely removal of their passengers from the EPZ.

For the period between General Alarm and begin of the release we expect a certain percentage of the population to leave the EPZ on their own initiative and despite the instructions given by the authorities. Local authorities and police are advised not to prevent such actions, and public transports shall operate as long as possible in order to allow people to rejoin their families or pupils to be sent home from schools.

But as a general countermeasure evacuation or rather relocation remains a **planned post-release** action which shall be implemented only when the contamination situation is well known and severe enough to require such a step. Then this action should be carried out well prepared and at the optimal time.

There is limited evacuation experience from non-radiological disasters, most recently severe floods in September 1993 in Brig and Locarno and from railway accidents followed by gasoline explosions in Stein/AG and Zurich-Affoltern. In all these events population groups had to be evacuated, very quickly in the explosion cases, with more time for planning in the flood cases. This was organised by police and fire brigades, later supported by army and civil defence teams, and did not pose special problems except those later discussed under information. Evacuated quarters were guarded by police or army against looting.

Information

Information will always be a major problem during any emergency. Experiences from radiological events in other countries, from a recent plane crash into a lake followed by rumours that it might have a radioactive cargo, from satellite re-entries, earthquakes and from the already mentioned flood and explosion disasters show that it is impossible to predict how the public and the media will react. Anything from no reaction at all to near panic and media overreaction without any proportion to the real event have been experienced. All experiences have shown that it is important to inform the public from the very beginning of an event, not to try to hide anything, to co-ordinate the official information in order to avoid contradictions, to facilitate the tasks of the media by frequent and well organised press conferences and written material. Official information is broadcast by the Swiss Radio and TV Corporation, but

it is necessary to include local and regional radio stations (42 in the entire country) in the emergency organisation because of their greater familiarity with the local situation and population. Telephonic mail boxes where both media and authorities can get access to the latest information bulletins have proven to be very useful and help to take some of the load from the information team of an emergency management centre. Text tv is a medium which we intend to make more use of in the future, as most Television sets in our country incorporate this free-of-charge feature. Information given by radio can also be shown on text tv where the public can have access to it at any time. NAZ routinely shows daily average dose rates from 16 radiation monitoring stations, including all NPP sites, on text tv.

The federal information centre and the information teams of the cantons will be tested in this year's NPP exercise. Previous exercises have shown that everybody involved, from the affected population over local authorities to media expects almost continuously updated information, an impossible task for any information service. All available technical and professional means of information production and distribution must be used, but care must be taken to give the same or compatible information to all these channels. There is on the other hand the risk to flood or even drown the information receivers with a lot of information they do not want. A good principle seem to be to give a reasonable amount of information of general interest to everybody concerned at reasonable intervals of one to a few hours, but to advise and allow those who need more detailed or more specific information to **fetch** or **request** this information when needed from specified sources or by use of special technical means such as electronic mail-boxes, text tv, tape messages accessible by phone or special inquiry phone lines (hotlines).

Experiences from recent evacuations after local disasters showed the importance of information management. The evacuated people need information on the situation in the evacuated area and on their future situation and prospects, their friends and relatives want to get information on their whereabouts and ad their health, so a high-capacity and well informed, constantly updated telephone service (hotline) for such inquiries must be quickly organised and the contact phone numbers must be announced by radio.

Exercises

The national Emergency Organisation Radioactivity (EOR) organises at least one, mostly several exercises of various types and sizes each year and participates in exercises organised by others. This may comprise the entire range from table top over command post to field exercises or combinations of these types. The NPP are requested (4) to carry out an emergency exercise each year, every eighth year involving elements of the off-site emergency organisations on the local cantonal and national level. For EOR and NAZ this means that they are involved in such an exercise every second year, but each time for another NPP site. The director of such a major exercise usually is the president of the consulting commission KOMAC. This year's exercise in November will involve the Beznau NPP and the emergency organisations both on the Swiss and the German sides, with information management as a primary exercise goal. The information teams will be tested by a rather large team of media professionals (who in a real emergency would be mobilised in the frame of their compulsory military service in order to reinforce the federal information centre). As in the previous exercise involving the Muehleberg NPP (DIANA), part of which some of you experienced as observers in February 93, we find it useful to split-up the exercise into several parts which are easier to manage and to evaluate than if you test the entire organisation at the same time and need a huge staff for the management and observation of the exercise. Thus we have separated the field exercise for the environmental monitoring organisation (April and August) from the command post exercise for the NPP and the local, regional and federal emergency and information management staffs (November) and from a table top exercise for the federal emergency management board (LAR) on the day following the NPP command post exercise. The same scenario, a fuel handling accident, is used for all three parts. Monitoring results from the monitoring field exercise will be overlaid with calculated accident data and be used for the command post exercise. While the monitoring and the NPP phases deal with the first day of the accident, the federal board will have to consider the management of the following days.

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UNITED KINGDOM APPROACH TO COUNTERMEASURES FOLLOWING A NUCLEAR ACCIDENT

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Abstract

In the UK, off-site nuclear emergency planning has been subject to continual review and development since the commissioning of the first commercial Magnox reactors in the early 1960's. Legislation requires each nuclear site to be licensed and conditions attached to the licence ensure that operators have adequate on and off-site emergency arrangements. Planning in detail is restricted to emergency planning zones of up to 3.5 km radius but plans are capable of extension in the unlikely event that a very severe accident was to occur. The short-term countermeasures of sheltering, stable iodine and evacuation all feature in plans for UK commercial nuclear sites. Exercises test on and off-site arrangements at regular intervals.

1. Introduction

This paper presents a brief summary of the UK approach to the use of short term countermeasures following a nuclear accident. The paper begins with a description of the legislative framework for off-site planning in the UK, which requires all sites to be licensed. It is via the site licence that the main regulatory control over emergency planning is exercised. Off-site planning is based on the concept of a detailed planning zone around each site which delineates the area in which the use of short-term countermeasures is planned for in detail. Plans developed by the local authorities, the operator and other government departments make provision for the use of the short-term countermeasures of sheltering, evacuation, the administration of stable iodine and restrictions on food and water supplies. Exercises are held frequently and indicate that the approach adopted is workable, although the plans are subject to continuing review.

2. The Legislative Basis

2.1 The Current Regulatory Framework

Under United Kingdom legislation governing the safety of nuclear installations, civil nuclear sites are required to be licensed. Licences are granted by the Health and Safety Executive (HSE). HM Nuclear Installations Inspectorate (NII) is that part of HSE responsible for administering this licensing function. A typical site licence has over thirty conditions attached to it. One of the conditions deals specifically with emergency arrangements. This condition places the following requirements on the licensee:

1. There must be adequate arrangements for dealing with any accident on the site.
2. The licensee has to submit the arrangements to the HSE for approval.
3. Outside emergency planning organisations must be consulted.
4. The arrangements have to be exercised.
5. Licensee's staff must be trained.

The licensee's arrangements for dealing with the effects of an incident or emergency within the detailed emergency planning zone (including the on-site response) are defined in the licensee's Emergency Plan. It is this document that the NII approves as a condition of the site licence. The Emergency Plan is usually supported by an Emergency Handbook which provides the licensee's staff with detailed instructions for implementing the Plan. In general, the licensee will liaise with local authorities and other public bodies to ensure compatibility between the plans of organisations having responsibilities for responding to an incident with offsite effects.

2.2 Future Regulations

Legal obligations for nuclear emergency planning extend only so far as the site operator. Participation of the other organisations involved (local councils, emergency services, etc.) is by voluntary agreement. This arrangement has worked well and no problems have been apparent. However, it is being considered whether it would be appropriate to introduce regulations similar to those that exist for other major hazardous sites, which require the local authority

to make off-site plans. No progress on this is likely until the final form of the revised EC 'COMAH' Directive (revised 'Seveso' Directive) has been agreed as any new regulations will be made consistent with that Directive.

3. The UK Approach to Emergency Planning

It is considered that the safety standards used in the design, construction, operation and maintenance of nuclear installations in the UK reduce the risk of accidents which could have consequences for the general public to very low levels. Nonetheless, prudence requires the preparation of emergency plans. The basic principles for emergency planning in the UK are as follows:

a) there should be a defined zone closely surrounding each installation within which arrangements to protect the public should be planned in detail (the Detailed Emergency Planning Zone - DEPZ). The boundary of this zone is defined in relation to the maximum size of any accident which can be reasonably foreseen. For the older type of reactors, this gives a detailed planning zone size of up to 3.5 km. For more modern stations, design basis accident studies do not give significant doses beyond the site boundary. For these sites, a minimum detailed planning zone radius of 1 km is cautiously assumed.

b) emergency planning needs, however, to be capable of responding to accidents which, although being extremely unlikely, could have consequences beyond the boundaries of the detailed planning zone. In other words, the detailed plans should be capable of extension to a larger area if necessary.

To assist planners in checking the extendibility of their detailed plans, the NII have issued a hypothetical severe accident scenario.

4. The Response to an Emergency

A wide range of bodies would be involved in responding to a nuclear emergency, from the site operator, local authorities and emergency services up to various government departments at the national level. Co-ordination of the arrangements is therefore assigned to a specified government department (the 'lead' department).

Off-site planning arrangements vary slightly around the UK but are generally based on the concept of an Off-Site Facility (OSF), together with various other national and local centres. The OSF provides a centre where the agencies involved can come together at the local level, where advice on actions necessary to protect the public can be formulated and given to the local emergency services, and where information can be supplied to a nearby media briefing centre. In some cases, the OSF also has a role in supporting the affected site, by taking over responsibility for the operator's off-site activities, such as environmental monitoring, and mobilising resources to assist the site. The advice to the local emergency services would be given initially by the affected site, then by a senior member of the operator's personnel brought in from elsewhere, and eventually by an independent Government Technical Adviser (GTA) appointed by the lead department.

5. Short-term Countermeasures

5.1 *Intervention Levels*

In the short-term, off-site plans consider the application of sheltering, evacuation and the issuing of stable iodine. In addition, food and water restrictions may also be applied very quickly depending on the nature and severity of the accident. The basic principles for application of such countermeasures are based on advice from the National Radiological Protection Board (NRPB) that their use should be justified and optimised. In other words, no countermeasure should be planned for unless it is expected to achieve greater good than harm and that effort should be made to implement it in such a way as to maximise the net benefit.

The NRPB has specified Emergency Reference Levels (ERLs) which are levels of radiation dose to the public which need to be averted to justify introducing a given countermeasure. ERLs are formulated in a two tier system of dose levels (Table 1). The lower levels have been recommended as being levels below which countermeasures should not, in general, be taken because the conventional risks and social disruption resulting from the countermeasure are likely to outweigh the benefits. The upper levels have been recommended as being those at which action should almost certainly be taken. At values between these upper and lower bounds of ERL, implementation of countermeasures is desirable but not essential and must be considered in the light of the situation at the time. Application of ERLs will ensure that risks to the health of individuals are minimised. If ERLs are not exceeded, health effects would be very small and could not subsequently be distinguished from the normal

incidence of such effects. ERLs are subject to continuing review to reflect international developments in the understanding of radiation risks.

Table 1. **Emergency Reference Levels for early Countermeasures**

		Dose equivalent level (mSv)	
Countermeasure	**Body organ**	**Lower**	**Upper**
Sheltering	Whole body Thyroid, lung, skin	3 30	30 300
Evacuation	Whole body Thyroid, lung, skin	30 300	300 3000
Stable iodine	Thyroid	30	300

In developing emergency plans the ERLs, together with predictions of the impact of potential accidents and the likely effectiveness of the countermeasures, are used to define site-specific intervention levels. These intervention levels, expressed in directly measurable quantities, are used to trigger advice on protective actions following an accident. This advice would be given to the police who would carry the final responsibility for instigating the necessary measures, taking into account all the local factors at the time.

5.2 *Sheltering*

Sheltering is a countermeasure that would be considered around any nuclear site. In the off-site plans for some sites evacuation forms the primary short-term countermeasure (possibly supplemented by stable iodine) but, even for these sites, sheltering is likely to be required for the period before evacuation is begun. The areas surrounding the majority of the nuclear sites in the UK are sparsely populated, with few buildings of high multiple occupancy (apartments or flats) and, in general, residential properties are substantially constructed. Reasonably high protection factors are therefore likely for the majority of the sheltering population. In general, there are no purpose built public shelters. There are potential problems where sites have trailer or caravan parks in the vicinity, but the numbers involved are relatively few. It is likely that tourists caught in the open or people who are camping, would be advised to evacuate the area or to seek shelter in suitable public buildings.

There is no national policy on the maximum duration of sheltering. However, a UK survey has found that people would, in general, be able to shelter for one or two days without too much difficulty. Most accident scenarios for UK installations would not require sheltering from the radioactive plume for more than a few hours. Farmers with animals to tend, may find it difficult to shelter for more than a short time and, if necessary, special advice to such groups would be provided by officials of the agriculture ministry.

5.3 Stable Iodine

The UK has adopted the latest WHO recommendations with regard to doses of stable iodine. This is available in tablet form as potassium iodate, 50 mg iodine equivalent per tablet. The tablets have a limited shelf life and are replaced at two yearly intervals. Distribution is dealt with on a local level, taking into account such factors as local demography, geography and resource availability. The responsibility for making arrangements for distribution has been devolved to local health authorities. In general, local health authorities have chosen not to pre-distribute tablets. For a few isolated households within 2 km of the site at Sellafield, the local emergency planning authorities have, however, decided that pre-justification is justified. This reflects a pragmatic solution to the problem of distributing tablets quickly to widely separated households. Stockpiles of tablets, for public distribution, are held at various public buildings and police stations, and by the operators. The tablets would be distributed to individual households that have been, or are likely to be affected by a radioactive plume. Exactly how this is done will vary from site to site but may, for instance, involve the use of police and local authority staff.

5.4 Evacuation

Policy on siting and controls over increase in population around nuclear sites, ensure that evacuation of any affected 300 sector of the detailed emergency planning zone should be possible within about 2 hours. Local authorities' off-site plans identify one or more evacuation reception centres which would be equipped to receive and care for the expected number of evacuees. Special arrangements would be made to advise farmers who need to re-enter evacuated areas to tend animals.

6. Information to the Public

On January 1st 1993 the Public Information for Radiation Emergencies Regulations (PIRER) were introduced by HSE. These regulations implement

a European Community Directive and require, for those sites where there is a reasonably foreseeable radiation emergency: (i) the prior distribution of information by the site operator about possible radiation emergencies and their effects to members of the public who might be affected and (ii) that local authorities have arrangements to ensure that members of the public actually affected by a radiation emergency receive prompt and appropriate information on the facts of the emergency and intended health protection measures. Prior information to individual households is issued by the operators in a variety of forms including booklets and calendars. In the case of calendars, these are reissued annually.

In the event of an emergency, the primary means of communicating information to the wider public would be by way of the media (local and national radio and television). As part of the UK Radioactive Incident Monitoring Network (RIMNET), arrangements have been made for information on radiation levels and advice to the public to be included in national television-text systems.

7. Emergency Exercises

The Nuclear Installations Inspectorate requires all employees at nuclear installations who could be involved in an emergency to be trained for their tasks and to be involved in regular exercises to ensure appropriate team performance. In addition to these training exercises, NII requires regular demonstration exercises at each site. Such exercises, known as Level 1 exercises, are witnessed by NII, and this is one of the means whereby NII assesses the effectiveness of the arrangements, training and resources of the operators for dealing with emergencies.

Level 1 exercises mainly concentrate on the operators' actions on and off site and may not always be based on a scenario involving an off-site release. Such exercises may involve the emergency services and other external organisations. The extent to which the off-site facility is activated varies according to the needs of the operators or as required by NII. The timing and scenario of the exercise have to be agreed with NII.

In addition to the Level 1 exercises which focus mainly on the operators' arrangements, there are programmes of exercises to rehearse the function of the off-site facilities and the wider central government involvement. These are known as Level 2 and Level 3 exercises respectively. The aim of the programme of Level 2 exercises is to test the function of each off-site facility once every three years. Each such exercise requires the operator to staff the off-site facility and provides an opportunity for agencies with responsibilities or duties to take part and exercise their function as appropriate. A wide range of government departments and agencies usually take part voluntarily in such exercises.

The Level 3 exercise is a national exercise and, in addition to testing the setting up and operation of the off-site facility, includes the exercising of the various government departments at their headquarters and at the central government briefing centre, and the interactions between the various centres. The exercise may last more than one day and is chosen from the programme of Level 2 exercises once each year.

8. Closing Remarks

High standards of safety in the design and construction of nuclear plants in the United Kingdom and strict control of operations provide a very high degree of confidence that accidents which might affect the public will not occur. Emergency planning provides an additional safeguard so that even if there was an accidental release of radioactive material, protection could be provided to the public who might be affected. Nuclear emergency arrangements are evolving continually in response to changing circumstances, improved techniques and lessons learnt from emergency exercises. In recognition of this the plans are robust, flexible and under continuous review. This ensures that any changes necessary can be incorporated readily into the relevant contingency plans and emergency arrangements.

EMERGENCY PLANNING REQUIREMENTS AND SHORT-TERM COUNTERMEASURES FOR COMMERCIAL NUCLEAR POWER PLANTS IN THE UNITED STATES

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Introduction

Following the accident at Three Mile Island Unit 2, significant changes were required in emergency planning and preparedness for commercial nuclear power plants in the United States. The U.S. Nuclear Regulatory Commission's (NRC's) emergency planning regulations are now considered an important part of the regulatory framework for protecting public health and safety. Prior to the issuance of a full power operating license, the regulations require a finding that there is reasonable assurance that adequate measures can and will be taken in the event of a radiological emergency. The intent of the Commission's emergency planning regulations is to reduce the impact of an accident and to achieve "dose savings" through protective actions that take into consideration plant conditions, evacuation times, shelter factors, and other conditions that may exist at the time of an accident. As stated in NUREG-0654/FEMA-REP-1, Rev. 1, the overall objective of emergency response plans is to provide dose savings (and, in some cases, immediate life saving) for a spectrum of accidents that could produce offsite doses in excess of Protective Action Guides (PAGs).

Emergency planning regulations have been adopted as an added conservatism to the NRC's defense-in-depth philosophy of multiple-barrier containment and redundant safety systems. They differ in character from most of the NRC's siting and engineering design requirements which are directed at achieving or maintaining a minimum level of public safety protection. The emergency planning regulations do not require that an adequate plan achieve a preset minimum radiation dose saving or a minimum evacuation time for the plume exposure pathway emergency planning zone. Rather, the emergency planning regulations attempt to reduce the impact (consequence avoidance) and achieve dose savings for a spectrum of accidents with widely differing offsite consequences. Emergency planning in the United States is based on postulated accidents beyond the design basis accidents which the nuclear plant is designed to handle. For such design basis accidents, the small releases that might occur would not likely require responses such as evacuation or sheltering for the general public. These actions only become important when more improbable accidents than the design basis accidents are considered.

Emergency Planning Zones

Commercial nuclear power plants in the U.S. have two concentric emergency planning zones (EPZs). EPZs are defined as the areas for which planning is needed to assure that prompt and effective actions can be taken to protect the public in the event of an accident. The choice of the size of the EPZs represents a judgment on the extent of detailed planning which must be performed to assure an adequate response. In a particular emergency, protective actions might well be restricted to a small part of the planning zones. On the other hand, for the worst possible accidents, protective actions might need to be taken outside the planning zones.

The first zone, called the plume exposure pathway EPZ, is an area of about 16 km (10 miles) in radius from the centre of the plant. The major protective actions planned for this EPZ, evacuation and sheltering, would be employed to reduce fatalities and injuries from exposure to the radioactive plume from the most severe of the core-melt accidents, and to limit unnecessary radiation exposures to the public from less severe accidents.

The second zone, called the ingestion pathway EPZ, is an area of about 80 km (50 miles) in radius from the centre of the plant. The major protective actions planned for this zone, putting livestock on stored feed and controlling food and water, would be employed to reduce exposure to the public from ingestion of contaminated food and water. The ingestion exposure pathway EPZ of 80 km was selected because Federal protective action guidelines would generally not be exceeded beyond 80 km for a wide spectrum of hypothetical accidents.

The response measures established within the 16 km and 80 km EPZs can and will be expanded if the conditions of a particular accident warrant it. Also, although the plume exposure pathway EPZ is generally circular, the actual shape is determined based on local factors such as demography, topography, access

routes, and governmental jurisdictional boundaries at a particular site. Smaller EPZs have been established in the U.S. for gas-cooled power reactors and smaller water-cooled power reactors.

The principal technical documents that describe the process of defining the size of the EPZs and the planning and protective measures to be taken within them are NUREG-0396/EPA 520/1-78-016, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light-Water Nuclear Power Plants," December 1978, and NUREG-0654/FEMA-REP-1, Revision 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," November 1980. The principal technical study upon which the sizes of the emergency planning zones are based is WASH-1400 (NUREG-75/014), "Reactor Safety Study: Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," October 1975.

Offsite Emergency Planning and Preparedness

The Three Mile Island accident revealed that much better coordination and more comprehensive emergency plans and procedures were needed if the NRC and the public were to have confidence in the readiness of onsite and offsite emergency response organizations to respond to a nuclear emergency. Indeed, the acceptance of responsibility was a major problem. State and local government participation in the field had been -- and as of now still remains -- largely voluntary. There had been no clear obligation on the States or local governments to develop emergency plans for radiological accidents, and the Federal role was one of assistance and guidance. In December 1979, the Federal Emergency Management Agency (FEMA) was directed by the President to take the lead in assuring the development of acceptable State and local offsite emergency plans and activities for nuclear power facilities. FEMA regulations establish the relationships of the various Federal agencies in rendering assistance to State and local governments in radiological emergency planning activities. These FEMA regulations also set policy and establish the procedures for FEMA review and approval of State and local emergency plans.

In practice, and by regulation, FEMA's recommendations as to the acceptability of the offsite emergency plans are considered by the NRC, which has the ultimate responsibility to determine the acceptability of the overall radiological emergency plans for any nuclear power plant. A license to operate a nuclear power plant will not be issued unless a finding is made by the NRC that the state of onsite and offsite emergency preparedness provides reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. The NRC bases its finding on a review of the FEMA findings and determinations as to whether State and local emergency plans are adequate and capable of being implemented, and on the NRC assessment as to whether the onsite emergency plans are adequate and capable of being implemented.

The NRC and FEMA also work together in evaluating periodic emergency response exercises which are required by regulation to be conducted every two years at all operating nuclear power plants. These full participation exercises are integrated efforts involving the utility and local and State radiological emergency response personnel. The NRC evaluates the licensee's performance and FEMA evaluates the response by State and local agencies. In some cases, various Federal agencies also participate in these exercises.

Responsibilities of Nuclear Power Plant Operator

In the event of an emergency, the nuclear power plant operator (NPP) has two primary functions: (1) control the event and (2) notify offsite officials and, where appropriate, recommend protective actions for the public offsite. The NPP operator's first priority is to protect the core by ensuring that crucial safety functions are maintained by (1) making the core subcritical and keeping it there, (2) keeping the water flowing through the core, (3) keeping the core covered with water, (4) providing makeup for water boiled off, and (5) removing decay heat for the core to an outside heat sink. The licensee must also take action to prevent or reduce offsite consequences by (1) maintaining reactor containment and the engineered safety feature systems, (2) controlling radionuclide releases, and (3) recommending appropriate protective actions to offsite officials.

In parallel with attempts to correct the problem, the NPP operator must notify offsite officials of an emergency declaration within 15 minutes and the NRC within 1 hour. The NPP operator recommends initial protective actions to offsite officials because the licensee is the only one who would have a true and an early understanding of core and containment conditions. Furthermore, if an actual offsite radionuclide release occurs, the NPP operator is responsible for monitoring that release in conjunction with offsite organizations to ensure that actions recommended to offsite authorities are appropriate, i.e., that initial protective action recommendations and decisions continue to be valid based on current, actual monitoring data.

Emergency Classification System

Four classes of emergencies in order of increasing seriousness – Unusual Event, Alert, Site Area Emergency, and General Emergency – have been established by NRC regulations. The specific class of emergency that is declared is based on conditions that trigger the Emergency Action Levels discussed below. Typically, NPPs have established specific emergency plan implementation procedures for each emergency class that are to be implemented by the control room staff. The importance of correct classification cannot be overly emphasized. The event classification initiates all appropriate actions for that class, including notification to offsite authorities, activation of the onsite and offsite emergency response organizations, and, where appropriate, protective action recommendations for the public. These same emergency classes are also found in the State and local plans supporting each NPP site.

Emergency Action Levels

Appendix 1 of NUREG-0654/FEMA-REP-1, Revision 1, provides example initiating conditions for each of the four emergency classes. These initiating conditions form the basis for the establishment by each NPP operator of specific plant instrument readings which, if exceeded, would indicate that a given initiating condition had been met and that the appropriate class of emergency must be declared. The plant-specific instrument readings are called Emergency Action Levels (EALs). Their purpose is to provide a clear basis for the rapid identification of a possible problem and to initiate the notification of offsite authorities that an emergency exists.

An EAL, then, is a pre-determined, site-specific, observable threshold for a plant-initiating condition that placed the plant in a given emergency class. An EAL can be an instrument reading; an equipment status indicator; a measurable parameter (onsite or offsite); a discrete, observable event; results of analyses; entry into specific emergency operating procedures; or another phenomenon which, if it occurs, indicated entry into a particular emergency class. By NRC regulation, the EALs must be discussed and agreed on by the licensee and State and local governmental authorities, and approved by the NRC.

Responsibilities of State and Local Governments

State and local agencies are charged with protecting the public from the offsite consequences that might result from a nuclear power plant accident. These organizations have the ultimate responsibility for notifying the public to take protective actions in the event of a severe accident. State and local officials base their decisions on the recommendations of the NPP operator. The NPP operator cannot declare a state of emergency or order an evacuation surrounding the plant; the NPP operator can only *recommend* protective actions to the appropriate offsite officials. Those officials must make the decision to notify the public to implement any protective actions.

Once a decision is made to take protective actions, NRC regulations require that there must be both the administrative and physical means to alert and promptly provide information to the public in the plume exposure EPZ. The alert and notification systems in the U.S. typically consist of a siren warning system, the activation of which is controlled by offsite authorities to alert the public to listen for emergency information, and pre-scripted emergency broadcast system (EBS) messages to inform the public as to what actions should be taken. The offsite alert and notification systems must have the capability to essentially complete the initial notification of the public in the plume exposure EPZ within about 15 minutes.

Emergency Response Centres

The authority to take action in the event of an emergency resides in the plant control room until the Technical Support Centre (TSC) or the Emergency Operations Facility (EOF) is activated. This includes the authority to declare emergencies, to notify offsite officials within 15 minutes of event declaration, and to provide any appropriate protective action recommendations. The NRC must be notified after the appropriate State and local officials are notified and no later than 1 hour after declaring the emergency. Upon declaration of an emergency, an onsite Emergency Director is designated who is in charge of the plant's response. This initially is the Shift Supervisor, the senior person in the control room. Once the appropriate augmentation staff arrive following declaration of an emergency, this responsibility (and title) normally transfers to the TSC and then to the EOF.

The TSC is the onsite technical support centre for emergency response. The TSC staff have access to plant technical information and are responsible for engineering support of reactor operations during an accident. The TSC also relieves the reactor operators of peripheral duties and communications not directly related to plant operation. Until the EOF is activated, the TSC also performs the functions of the EOF. The TSC is usually located close to the control room inside a protected and shielded area to allow fast access for face-to-face discussions with control room personnel.

The EOF is an offsite facility which is controlled and staffed by the NPP operator. The EOF provides for management of overall licensee emergency response, coordination of radiological and environmental assessment, development of recommendations for public protective actions, and coordination of emergency response activities with Federal, State, and local agencies. NRC guidance recommends the EOF should be 10 to 20 miles from the site, but some may be closer (with hardening/shielding or a backup), while others may be farther from the site. Provisions are made in the EOF to accommodate State and local as well as Federal responders to an emergency.

State and local response organizations establish emergency operation centre (EOCs) upon activation. At some sites there are several local governments within the plume exposure EPZ and each might have a centre. State governments typically operate from EOCs which are located in the State capital or in a regional office. In some cases, the State may establish a forward EOC near the plant site. The specific location of the offsite officials with the authority and responsibility to take action varies and is very site-specific.

Protective Action Recommendations

The technical basis and guidance for emergency response decision-making in the U.S. on determining protective actions for the public for severe (core damage) reactor accidents is found in NUREG-1210, "Pilot Program: NRC Severe Reactor Accident Incident Response Training Manual," Volumes 1-5, February 1987. The guidance in NUREG-1210 reflects the conclusions derived from severe accident studies such as NUREG-1150, "Severe Accident Risks: An Assessment for Five Nuclear Power Plants", December 1990.

Only a *very* severe reactor accident involving core damage and containment failure could result in doses sufficient to cause early significant health effects (injuries or deaths). This type of accident would involve core damage followed by a containment failure. For a severe accident, the control room staff should know (1) that the core is damaged and (2) that a large amount of fission products in the containment atmosphere could be released if the containment fails. However, they will not be able to predict when the containment will fail (or even if it will fail).

Studies of severe reactor accidents and the effectiveness of protective actions show that:

1. Evacuation must begin before or shortly after a release to reduce risk substantially.

2. Movement of even short distances results in substantial reduction in risk.

3. Shelter close to the plant for long periods may not be an effective protective action.

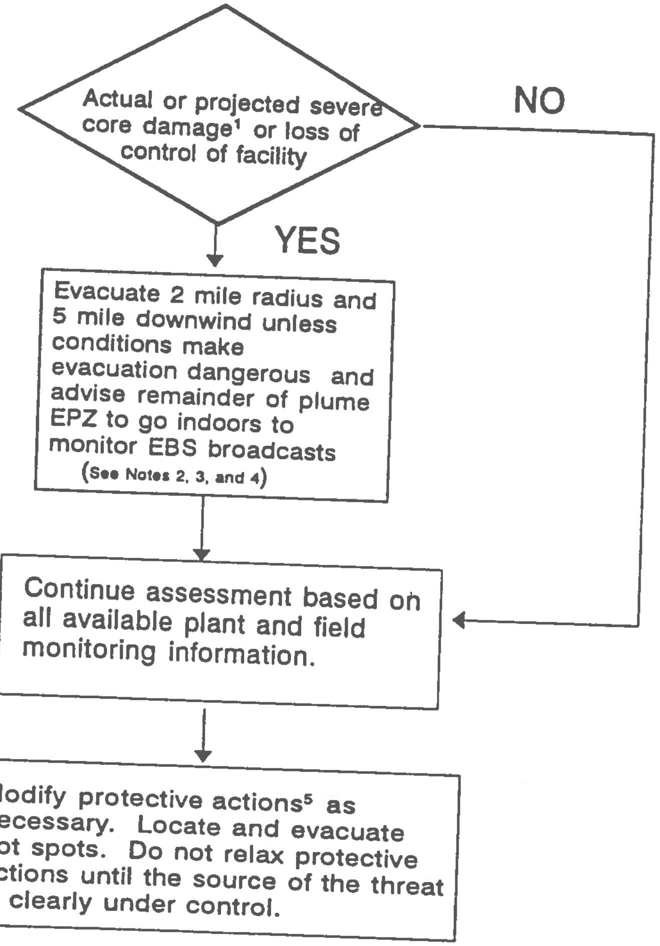
The initial, early protective actions to be recommended to the public under a given set of emergency conditions should be determined in advance (predetermined) if at all possible. However, adjustments to preplanned actions may be required at times if specific local conditions warrant. Early evacuation of nearby areas is the most beneficial protective action, and for the most severe accidents, early evacuation is the only protective action available to achieve basic radiation protection objectives near the plant (*i.e.*, 3.2 to 4.8 km). Severe reactor accident studies indicate that beyond about 4.8 km, sheltering followed by post-release monitoring and relocation from "hot spots" would be as effective as evacuation in meeting the basic protective action objectives. This may not be true under certain meteorological conditions, such as if the radioactive plume passes through rainfall or if severe inversion conditions trap and confine the plume near the ground. Such conditions cannot be predicted with any useful degree of accuracy, and monitoring results (after a release) must be relied upon to determine when later evacuation at distances greater than about 4.8 km from the plant would be warranted.

The NRC has incorporated the above guidance into response procedures and training manuals for the NRC staff, the latest edition of which is "Response Technical Manual (RTM)-94," NUREG/BR-0150, Vol. 1, Rev. 3. The protective action guidance is shown in a flow chart (Figure 1). The NRC, with the assistance of FEMA, is in the process of issuing this guidance as a supplement to NUREG-0654/FEMA-REP-1.

Use of Potassium Iodide (KI)

The use of the thyroid-blocking agent potassium iodide (KI) is not considered an adequate substitute for prompt evacuation or sheltering by the general population near a plant in response to a severe reactor accident. Ingestion of KI will serve only to help reduce the dose to the thyroid caused by intake of radioiodine. The primary risk to the population from a severe accident is whole body dose, not the radioiodine dose to the thyroid. In addition, KI is not considered to be an effective countermeasure for protection against the ingestion pathway in the U.S.

Figure 1. **Severe core damage or loss of control of facility public protective actions**



1. Severe core damange is indicated by:
   i loss of critical functions required for core protection (e.g. loss of injection combined with a LOCA;
   ii high core temperatures (PWR) or partially covered core (BWR);
   iii very high radiation levels in area or process monitors.
2. Distances are approximate - actual distances will be determined by the size of the preplanned sub-areas that are based onlocal geo-political boundaries.
3. Transit-dependent persons should be advised to remain indoors until transportation resources arrive if possible.
4. If there are very dangerous travel conditions or if there is a mobility impaired population (*i.e.* acute care patients) then shelter those affected.
5. Consider further implementation of EPA PAGs for evacuation/sheltering.

The Federal policy on distribution of KI around nuclear power plants was issued in 1985 (50 FR 30258) by the Federal Radiological Preparedness Coordinating Committee (FRPCC), an organization of about 15 Federal agencies. The policy recommends the stockpiling of KI and its distribution for emergency workers and institutionalized persons. It does not recommend that predistribution or stockpiling of KI be required for the general public. The policy is advisory for State and local governmental authorities -- it neither bars nor encourages State and local authorities from choosing to make KI available on a site-specific basis. Three States have decided to stockpile or predistribute KI for use by the public.

The Federal policy concerning the use of KI in the U.S. has been undergoing re-evaluation since shortly after it was issued. Cost-benefit studies continue to show that there is insufficient benefit to justify requiring the stockpiling or distribution of KI around nuclear power plants for the public. However, consideration of qualitative factors such as public expectation that KI would be available if needed may lead the FRPCC to recommend the creation of a Federal stockpile of KI in the future.

Federal Response to an Emergency

Significant improvements in radiological emergency preparedness have occurred in the U.S. since the accident at Three Mile Island (TMI) in March 1979. These include the development of a Federal response plan, establishment of direct communication links between power reactor sites and the NRC, establishment of a designated staff of operations officers at the NRC, the development of a means to receive digitized information on key plant parameters directly from the site, and an upgrade in facilities and training at all levels.

In fulfilling its legislated mandate for protecting the public health and safety, NRC has developed a plan and procedures that detail the agency's response to incidents involving licensed material and activities. In its emergency response plan, NRC recognizes that there are two primary decision makers in a radiological emergency at a licensed power reactor: the NPP operator (licensee) and the State or local government. The NPP operator has primary responsibility for mitigating the consequences of the event by taking the necessary and appropriate in-plant actions and by recommending the appropriate offsite protective actions. The State or local government has primary responsibility for determining whether and how to implement the protective actions recommended by the NPP operator.

The Federal Radiological Emergency Response Plan (FRERP) defines the Federal response role in support of State and local agencies. Under this plan, four agencies have major roles defined for nuclear power plant accidents. The NRC would be the Lead Federal Agency for an event at any licensed nuclear reactor in the U.S. The NRC as Lead Federal Agency is responsible for the technical assessment of the accident and for coordinating technical information and protective actions with other responding Federal and State agencies.

Under the FRERP, the Department of Energy (DOE) is responsible for coordinating all offsite Federal radiological monitoring assistance. DOE will establish a Federal Radiological Monitoring and Assessment Centre (FRMAC) to coordinate the collection and assessment of field monitoring efforts. DOE will also provide field and airborne monitoring assistance. Consolidated field monitoring information and assessments will be made available by DOE to the State, the Lead Federal Agency, and other responders at the FRMAC. After the situation has been stabilized and the accident moves out of the emergency phase, the Environmental Protection Agency (EPA) assumes the role of coordination of the Federal offsite radiological monitoring assistance. DOE and EPA are an important source of radiological monitoring capabilities and technical assistance for the State(s) and the NRC.

The fourth major agency is the Federal Emergency Management Agency (FEMA), which coordinates all Federal non-radiological assistance in support of the State(s) such as communications, transportation, and other logistical support including support from the U.S. Department of Defense. The FRERP, which was published in the Federal Register on November 8, 1985, has recently been revised and will be re-issued in the near future.

DEVELOPMENT IN THE EUROPEAN UNION OF RADIATION PROTECTION CRITERIA FOR URGENT INTERVENTION IN CASE OF ACCIDENTAL RELEASE OF RADIOACTIVE SUBSTANCES

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1. Intervention Planning and Intervention Levels

The current Euratom Basic Safety Standards Directive lays down that each Member State establishes intervention levels appropriate to different types of action required in case of an accident. This requirement will be reinforced in the revised B.S.S. taking into account different kinds of action and applying the general radiation protection principles for intervention. Intervention levels shall be part of intervention plans drawn up for the relevant installations within the Member States' jurisdiction and tested at regular intervals, as well as for possible emergencies outside its own territory.

2. Urgent Intervention

The need for urgent intervention pertains essentially to measures aiming at reducing the accidental exposure of individuals living in the neighbourhood of the damaged or endangered installations. The action is taken before or shortly after the accidental release of radioactive substances and is normally of short duration. This differentiates urgent intervention from medium and long term action that may be required such as the control of foodstuffs and relocation of people for extended periods of time. Urgent intervention encompasses actions such as:

- sheltering,
- distribution of stable iodine,
- evacuation.

3. Guidance on Intervention Levels

a) *CEC-Guidance*

In the aftermath of the Chernobyl accident intervention levels were adopted for foodstuffs and feedingstuffs placed on the market within the E.U. (Council Regulation 87/3954/EURATOM). Guidance on radiation protection criteria for temporary or permanent relocation has been given by the Art. 31 Group of Experts in 1993 (radiation protection-64), to form a basic framework for decision making in the event of a severe accident. Guidance on urgent countermeasures was issued already in 1982 (Radiological Protection Criteria for controlling doses to the public in the event of accidental releases of radioactive material, a guide on emergency reference levels of dose, V/5290/82).

b) *International Guidance*

Subsequent to the formulation of the general principles of Intervention in ICRP publication 60, guidance on the principles for intervention for protection of the public in a radiological emergency was brought forward by a task group of committee 4 of ICRP (Publication 63, 1993).

This publication recommends values of averted effective doses above which intervention is almost always justified, optimised levels for specific accident conditions expected to be lower by no more than a factor of 10. For sheltering the upper bound is 50 mSv, for evacuation 500 mSv, iodine prophylaxis will be justified in conjunction with sheltering or evacuation if an average individual thyroid dose of 0.5 Sv can be averted.

IAEA has issued guidance on intervention levels in a number of documents (Safety Series and Tecdoc's) along the principles laid down in SS no 72 (1985). The latest publications and drafts prepared by advisory groups and technical committees will be published soon as SS no 109: Intervention Criteria in a Nuclear or Radiation Emergency. Generic intervention levels have been selected on the basis of an analysis in cost-benefit terms. The proposed values for urgent protective measures are 10 mSv for sheltering, 50 mSv for evacuation, and 100 mGy for iodine prophylaxis. These values will probably be incorporated in Annex V of the IAEA Basic Safety Standards.

4. Scope of a Revision of Article 31 Guidance on Urgent Intervention

The establishment of appropriate intervention levels remains a responsibility of Member States. However, guidance at Community level on the radiation protection criteria applied in this context would be very useful in view of:

- harmonisation of the approaches for intervention planning,
- bring forward generic intervention levels appropriate to the European context,
- ensure consistency of the information provided to the population in application of Council Directive 89/618/Euratom, in particular in case of a transboundary impact.

It is intended to update the guidance published in 1982 in order to:

- relating it to the principles of intervention, in particular the concept of avertable dose,
- incorporate present views on the issue, which may have evolved e.g. as a result of the Chernobyl accident,
- put the guidance in perspective to international recommendations.

It may also be worthwhile to extend the guidance in terms of operational intervention levels, and to incorporate scientific guidance on the relationship between avertable dose and measurable dose-rates and contamination levels. Such guidance may incorporate reference to computer codes that were developed in the meantime such as COSYMA and RODOS.

Table 1. **Guidance of the Article 31 Group of Experts, 1982**
Range of reference levels for intervention

	Equivalent Dose (mSv)		
	Whole Body	Thyroid, or any other organ	Skin
Evacuation	100 - 500 (500)	300 - 1500	1000 - 3000
Stable iodine	-	50 - 250 (500)	-
Sheltering	5 - 25 (50)	50 - 250	25 - 250
(values in brackets are the upper bounds in ICRP-63)			

Session 5

CONCLUSIONS AND RECOMMENDATIONS

Chairman: Jan-Olof Snihs, Sweden

CONCLUSIONS AND RECOMMENDATIONS

1. Introduction

The last Session of the Workshop, Session 5, was dedicated to the development of conclusions and recommendations based on the presentations and discussions of the first four Sessions. Immediately prior to this Session, the Programme Committee met with the Authors and Rapporteurs to draft a set of proposed conclusions and recommendations. This draft document was distributed to the Workshop participants, and each point was discussed and, as appropriate, amended to better reflect the opinion of the Workshop.

2. Conclusions and Recommendations

The resulting conclusions and recommendations are listed here. An effort was made to draw conclusions, based on the presentations and discussions, and from these conclusions to formulate appropriate recommendations. As such, conclusions and recommendations are grouped. Each is discussed in the context of the presentation(s) and discussion(s) from which it resulted.

Emergency Planning and Preparedness

Many of the conclusions and recommendations which were made were somewhat general in nature, and applied to a broad spectrum of emergency planning and preparedness areas. These are gathered here, and are generally recommendations which are suggested to be implemented at the level of National emergency plans.

The first paper presented covered the general subject of international criteria for short-term countermeasures. In this context, the author, Mr. Malcolm Crick of the IAEA, discussed the intervention levels recommended in IAEA Safety Series 109, the International Basic Safety Standards (BSS), and in ICRP Publication 63. It was pointed out that the most important use of intervention levels is perspective, that is, in the preparation of emergency plans. The Workshop agreed with this, noting that intervention levels serve as action guidelines, and should be adopted directly from the recommendations of ICRP Publication 63, IAEA Safety Series 109, or the BSS, or should be developed using specific criteria for particular populations. In either case, intervention levels should be adopted at the planning stage, and not in the "heat of the moment", at the time of an emergency. Therefore:

1. Conclusion:
The prime role of intervention levels is for the development of emergency plans.

Another important aspect of emergency planning and preparedness which was touched on during the Workshop was that of public trust. In paper number 9, Mr. Heriard-Dubreuil, MUTADIS Consultants, Paris, discussed the psychological consequences of short-term countermeasures. In order to minimize the stress which is caused in the public by emergency situations, social scientists would recommend a "pro-active" approach by decision makers and emergency planners. Translated concretely, this means that the public should be involved, in some fashion, in emergency planning and preparedness. The dialogue between the public and decision makers should be open, and should involve discussion of risks. It was based on this presentation that the Workshop Participants reached the following conclusions, and formulated several recommendations.

2. Conclusion:
The mutual trust between the local (and more distant) population and decision makers/emergency planners is essential. This relies upon the credibility of decision makers, the active encouragement of public participation in emergency planning and preparedness, upon a policy of two-way communications, and upon the dissemination of clear information on planning and risks prior to any accident.

2a. Recommendation:
Decision makers and emergency planners should not avoid talking about risk, they should have an established policy of communication with the public, regarding risks and risk management.

2b. Recommendation:
In order to reduce stress on the population during an emergency situation, emergency plans should be designed to give individuals greater

flexibility of action and to allow more individual initiative, as opposed to being extremely prescriptive.

2c. Recommendation:
A study should be performed into how to foster trust between decision makers/emergency planners and the public. This study should include the definition of effective communication strategies and practical implementational guidance.

Much of the presentation by Mr. Heriard-Dubreuil was based on experience after the Chernobyl accident. In this regard, it was noted that the complex political situation of that time (the fall of the Soviet Union specifically) contributed significantly to public confusion of "the accident phase" - controlled by the Soviets - and "the post-accident phase" - controlled by the newly independent National governments. As explained in the Paper, for various reasons the effected public feels that the deterministic and stochastic effects due to doses received during the accident phase (by high concentrations of radionuclides, many of which were relatively short-lived) are in fact caused by the residual contamination remaining today. This results in stress with regard to the current situation, and mistrust of governments claiming that the situation continues to progress back towards "normalcy". Based on these ideas, the Workshop Participants felt that the following conclusion and recommendation were important:

3. Conclusion:
After the Chernobyl accident, the confusion between the direct, immediate effects caused by the accident (deterministic and stochastic), and the longer term potential effects caused by residual contamination led to very harmful social and psychological consequences.

3a. Recommendation:
A distinction should be introduced, when communicating with the public before, during and after a nuclear accident, between risks associated with the accident phase, and risks associated with potential long term contamination during the post accident phase.

The papers from Session 2, the Effectiveness and Risks of Countermeasures, discussed the various positive and negative effects of countermeasures to be taken into account during the decision-making process. From these discussions, it was noted that the way in which information is managed can have a very important influence on the decision-making process. The immense volume of data which flows during an emergency situation must be effectively managed such that useful syntheses of these data can be performed. It was also noted that nuclear and radiological emergencies are, in many regards, no different than non-nuclear emergencies (natural or man-made). From these discussions, the following conclusions and recommendation were made.

4. *Conclusion:*
   Public and technical information management is important to the success of emergency management.

5. *Conclusion:*
   There is valuable experience to be gained from the emergency management of non-nuclear emergencies.

   5a. Recommendation:
   The experience gained during non-nuclear emergencies should be applied to nuclear emergency management.

Countermeasures

In view of the title of this Workshop, it is not surprising that it resulted in several conclusions and recommendations dealing specifically with countermeasures. Again, these follow from various papers.

Paper 3 was a survey of the short-term countermeasure practices in NEA-Member countries. The survey was seen as having been useful, although based on the questions asked and the types of responses received some ambiguities remain. Based on the results of this survey, it was noted that significant differences still exist among countries, both in terms of policy and implementation practices. As was shown by the experience of INEX 1 (which was discussed during the Workshop, and is presented in NEA Report, "INEX 1: An International Nuclear Emergency Exercise, Analysis of Results") differences in the implementation of countermeasures in geographically close areas separated by national borders can lead to confusion and stress in the public, and a loss of confidence in public officials. Based on these observations, the following conclusions and recommendations were made by the Workshop Participants:

6. *Conclusion:*
   The survey which was performed shows that there are still significant differences among countries in the application of countermeasures.

   6a. Recommendation:
   A short follow-up survey is recommended for the near future in order to clarify several of the points raised by the survey, and this type of survey should be performed every few years to follow developments.

7. *Conclusion:*
   The development of a national countermeasure philosophy depends on a number of factors, both technical and non-technical. All countries share common objectives in emergency planning, but they may treat these factors differently, leading to different detailed plans. Harmonisation is desirable and should be encouraged. However, in the short term differences will occur, and there is value in understanding differences among countries.

   7a. Recommendation:
   The planning and implementation of countermeasures having cross-border implications should be coordinated to ensure the consistency of countermeasures in border regions, and to ensure that any differences are fully understood.

8. *Conclusion:*
   Based on the results of the emergency planning and preparedness survey, most countries indicated that the return of the Nuclear Power Plant to stable/safe conditions and the return to normal environmental radiation levels in the affected areas would allow the cessation of short-term interventions. However, it was not clear that specific criteria were established for this cessation.

   8a. Recommendation:
   Criteria to end interventions should be considered for inclusion in emergency plans.

   8b. Recommendation:
   One of the goals of exercises should be to test the assumptions on which intervention policy is based.

The papers of Session 3 dealt with the factors influencing the selection of countermeasures, both at the emergency planning and accident management stages. Based on these presentations, the following conclusions were drawn by the Workshop Participants:

9. Conclusion:
Broadly adequate information exists, on the financial costs and risks associated with countermeasures, as an input to policy decisions.

10. Conclusion:
The financial costs and risks associated with short-term countermeasures (stable iodine, sheltering, local evacuation) for **major** accidents are not dominant factors in implementational decisions.

Use of Stable Iodine

Several papers, particularly in Sessions 1 and 2, dealt with the use of iodine prophylaxis. These presentations and their subsequent discussions resulted in several conclusions and recommendations.

In paper 6, Mr. Peter Waight discussed the effectiveness and risks of the use of stable iodine. From his presentation, it was agreed that, although the use of stable iodine should always be considered as one of many possible countermeasures, medically there is very little risk involved with its use. It was noted, however, that in the case of a population with a normally very low intake of dietary iodine a higher risk of some adverse thyroid reactions exists, and irrespective of the level of normal dietary intake, the risk of adverse thyroid reactions increases with age. It was also noted that, due to the latency period of thyroid cancer, the effectiveness of iodine prophylaxis decreases with age.

Based on this presentation and the subsequent discussions, the following conclusion was drawn:

11. Conclusion:
The detriment incurred by the use of stable iodine as a countermeasure corresponds to that associated with doses on the order of a few mSv. However, the choice of intervention levels involves the consideration of other factors as well.

In addition, while agreeing with the logic of decreasing the recommended dosage of stable iodine for older individuals (for whom the risk of thyroid cancer is decreasing and the risk of adverse reactions is increasing), the logic of having an easily applicable countermeasure (a single dosage of stable iodine for all ages) was seen by the Workshop Participants as being important. As such, the following conclusion was adopted:

12. Conclusion:
It is recognized that the risk associated with exposure to radioiodine decreases with age, and that the risk of side effects from the use of stable iodine increases with age. However, there are practical advantages to the uniform treatment of all adults.

During discussions, particularly of the thyroid cancers in the Gomel area of Belarusia (where it is suspected that large fractions of the dose from radioiodine may have been from ingestion rather than inhalation), it was noted that countermeasures other than the use of stable iodine prophylaxis, such as control of foodstuffs, would be more effective. This lead to the adoption of the following conclusions:

13. Conclusion:
The medical basis for the use of stable iodine is firm. However, stable iodine use should be limited to the protection against inhalation doses during the early phase of an accident. Doses by ingestion, which are most likely to be received during the late phase, are better controlled by other methods.

In addition to the above discussions, paper number 2 discussed the WHO recommendations for the use of stable iodine prophylaxis. The Workshop Participants, taking this and the previously mentioned discussions into account, agreed upon the following conclusion and recommendation.

14. Conclusion:
Stable iodine is most effective at reducing thyroid exposure from the inhalation of radioiodine when taken before the arrival of any airborne radioiodine.

14a. Recommendation:
The stable iodine dosage, which has been proposed by the WHO for use during radiological emergency situations involving the release of radioiodines, is recommended.

Paper number 3, the survey of countermeasure practices, the country presentations of national implementation and practice strategies, and their subsequent discussions revealed that there is significant variation in the use of stable iodine prophylaxis in the NEA-Member Countries. This includes differences in predistribution policies and practices, storage practices, distribution mechanisms, etc. After considering these elements, the Workshop Participants agreed upon the following conclusions and recommendations:

15. Conclusion:
Most countries include the use of stable iodine in their emergency plans, however few countries pre-distribute stable iodine tablets to households. Some countries are presently considering this option. Stable iodine policy and intervention levels are quite varied from country to country.

15a. Recommendation:
Further international discussion is necessary in the area of stable iodine pre-distribution policy.

16. Conclusion:
Questions remain as to the methods for the distribution of stable iodine to the population at risk in a timely manner, and as to the integration of these methods into emergency planning.

16a. Recommendation:
The practical aspects of the use of stable iodine require further guidance.

Decision Making

Session 2, Effectiveness and Risks of Countermeasures, and Session 3, Selection of Strategies, dealt with the practical implementation of various countermeasures. One ongoing theme of these sessions was that of decision making.

A topic in this area which resulted in some discussion was that of decision-making based on plant conditions. During the early stages of an accident, before any release of radioactive material has occurred, the only hard data available concerns the plant condition. Because some accident scenarios can result in fairly quick release of materials, there may be a need to analyze plant conditions and to make decisions regarding the implementation of countermeasures based only on the uncertain future release of an uncertain amount of radioactive material. This area, in general, was seen as being important and being in need of further study. As such, the Workshop Participants agreed upon the following recommendations and conclusions:

17. Conclusion:
The concept of considering the status of the plant, before any releases, as an initiator of countermeasures was not discussed until the final Session of the Workshop, but was viewed as a very important issue.

17a. Recommendation:
Greater consideration should be given, during the early phase of an accident, to the plant state as an initiator of countermeasures.

17b. Recommendation:
When making decisions, the ensemble of available countermeasures should be viewed collectively, not as isolated, independent actions.

18. Conclusion:
Effective emergency response decisions often need to be made under conditions of uncertainty and with incomplete and ambiguous information.

18a. Recommendation:
The decision-making process should itself be optimized to enable prompt and robust decisions to be made in situations of uncertainty. To facilitate this, the decision-making process should be as simple as possible.

The papers in Session 3 discussed various approaches used in the selection of countermeasures. It was noted during these presentations that a wealth of practical knowledge and "rules of thumb" exist in the collective experience of emergency planning, preparedness, and management experts. From these discussions, the following conclusions and recommendations were formulated by the Workshop Participants:

19. *Conclusion:*
"Rules of Thumb" can be useful decision aids during an emergency response.

19a. Recommendation:
Emergency planning and preparedness "Rules of Thumb", should be collected from all countries and put together in "Handbook" format.

19b. Recommendation:
Further study of the process for decision making with uncertain or incomplete information should be performed.

19c. Recommendation:
Decisions concerning long-term countermeasures should be considered as early as possible.

Issues to Discuss Further

In addition to those areas discussed above, on which consensus was reached by the Workshop Participants, several issues were identified during the course of presentations and discussions as requiring further thought.

The presentation and discussion of paper number 1, concerning international criteria for short-term countermeasures, as well as discussions during Session 3, Selection of Strategies, indicated that there is not a total consensus on the use of averted dose. While it is clear that international guidance now recommends the use of averted dose, in practical application this is far more difficult and uncertain to calculate than projected dose. This results in problems of

application. As such, the Workshop recommended that this issue should be further discussed such that a consensus could be reached:

1. The choice of averted dose or projected dose as the unit of measure for intervention levels should be discussed.

In parallel with the above mentioned discussions, the question of the use of operational (derived) intervention levels was addressed. Some Workshop Participants felt that such levels are unnecessary and confusing, while others felt them to be of great practical value. It was also noted that the models used to calculate operational intervention levels could vary significantly, resulting operational intervention levels which vary from country to country even though the intervention level used as the basis of calculation is the same. With these issues in mind, the Workshop Participants recommended further work in this area:

2. The value of using of operational intervention levels, and the harmonization/coordination of the models used to calculate them, should be further discussed.

Also raised in Sessions 2 and 3 were the psychological aspects of emergency situations. As previously cited in the conclusions and recommendations discussion, the question of public trust was seen by the Workshop Participants as being very important, and very practically difficult to obtain. The previously raised issue of allowing the public some flexibility and personal discretion in the application of countermeasures, so as to gain public acceptance of and confidence in countermeasures, was also seen as an important, yet open, issue. Finally, it was felt that the use of "reassurance" countermeasures, i.e., in situations below established intervention levels, required further discussion.

Taking all this into account, the Workshop Participants formulated the following list of issues which require further discussion:

3. The issue of how to get and keep trust should be further elaborated.

4. The amount of flexibility in countermeasures (required vs. recommended) should be discussed.

5. The question of whether, for psychological and/or social reasons, countermeasures should be implemented in situations which are below intervention levels should be discussed.

Lastly, and related to many of the issues discussed during the Workshop, the Participants felt that the type of accident scenario which is used in training exercises will have a large influence on emergency preparedness. If and/or how certain issues are included in the scenario (social factors; use of real-time; the size of the simulated release; the emphasis on pre-release, release, post-release, or long-term phases; etc.) will influence the way in which decisions are made, the portions of an emergency plan which are exercised, etc. The emphasis placed on decision-making based on real-time model forecasts, as opposed to on plant status, will also have a similar effect. As such, the Workshop Participants proposed these last issues as possible topics for further discussion.

6. The type of accident scenario which should routinely be used for planning and training should be discussed.

7. The feasibility/practicability of timely decision making on short-term countermeasures based on real-time model forecasts, versus based on plant status.

3. Epilogue

The unanimous feeling of the Workshop Participants was that practical and useful advances in mutual understanding had been made. While some of the conclusions drawn were seen as "obvious", their value as the stated consensus opinion of an international Workshop was seen as considerable. Other conclusions and recommendations were seen as being interesting from the standpoint that they have been slowly emerging from the international post-Chernobyl emergency preparedness and management community, and are now seen as "ripe". Finally, the list of recommended areas for further study was viewed as a useful contribution to the continuing debate on short-term countermeasures. As a whole, then, the Workshop and its conclusions and recommendations were appreciated by the Participants.

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