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"Management of long-term exposure after a nuclear or radiological accident"

Proceedings of a scientific seminar held in Luxembourg on 14 November 2018

Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of Experts

Directorate-General for Energy
Directorate D — Nuclear Energy, Safety and ITER
Unit D3 — Radiation Protection and Nuclear Safety
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FOREWORD

Luxembourg, June 2020

The European Commission organises every year, in cooperation with the Group of Experts referred to in Article 31 of the Euratom Treaty, a Scientific Seminar on emerging issues in Radiation Protection – generally addressing new research findings with potential policy and/or regulatory implications. Leading scientists are invited to present the status of scientific knowledge in the selected topic. Based on the outcome of the Scientific Seminar, the Group of Experts referred to in Article 31 of the Euratom Treaty may recommend research, regulatory or legislative initiatives. The European Commission takes into account the conclusions of the Experts when setting up its radiation protection programme. The Experts' conclusions are valuable input to the process of reviewing and potentially revising European radiation protection legislation.

In November 2018, the EU Scientific Seminar covered the issue *Management of long-term exposure after a nuclear or radiological accident.* Internationally renowned scientists presented:

- The European context: Requirements on the management of long-term exposure in the BSS Directive
- Management of nuclear emergency and post-accident situations (population protection measures)
- Risk evaluations of long-term exposure after a nuclear or radiological accident
- Health surveillance strategies for long-term exposure after a nuclear or radiological accident
- Stakeholder involvement and research needs
- Experience with the management of long-term exposure after a nuclear accident

The presentations were followed by a round table discussion, in which the speakers and additional invited experts discussed potential *policy implications and research needs*.

The Group of Experts discussed this information and drew conclusions that are relevant for consideration by the European Commission and other international bodies.

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1 THE EUROPEAN CONTEXT: REQUIREMENTS ON THE MANAGEMENT OF LONG-TERM EXPOSURE IN THE BASIC SAFETY STANDARDS DIRECTIVE

Bharat Patel

DG ENER, European Commission, Luxembourg

1.1 Introduction

The EU Basic Safety Standards (BSS) Directive (Directive 2013/59/Euratom) [EU2013] provides strengthened requirements on emergency preparedness and response, taking into account some of the lessons learned from the Fukushima accident.

The Directive follows the situation-based approach to radiation protection recommended by the ICRP, distinguishing between existing, planned and emergency exposure situations. For the management of emergency exposure situations, the previous approach based on intervention levels has been replaced by a more comprehensive system comprising an assessment of potential emergency exposure situations, an overall emergency management system, emergency response plans, and pre-planned strategies for the management of each postulated event.

1.2 Emergency management system

The essential elements to be included in an emergency management system (prior assessment of potential emergency exposure situations, allocation of responsibilities, efficient coordination, cooperation and communication measures, management of doses, stakeholder involvement etc.), and in an emergency plan (reference levels for exposure, optimised protection strategies, pre-defined generic criteria, default triggers or operational criteria etc.) are specified in Articles 97, and 98 of the Directive.

The need for efficient management of an emergency with cross-border consequences is recognised through provisions for enhanced cooperation between Member States in emergency planning and response in Article 99. These provisions require Member States to cooperate with other Member States and with third countries which may be involved or are likely to be affected by an emergency, with a view to sharing the assessment of the exposure situation and coordinating protective measures and public information by using bilateral or international information exchange and coordination systems.

The emphasis on optimisation, using reference levels, in emergency and existing exposure situations expands the earlier use of optimisation from planned activities to all exposure situations. To achieve optimised protection strategies, accounting for the effects of ionising radiation as well as other societal criteria, is of particular importance in an accident and post-accident phase.

1.3 Existing exposure situation

The transition from an emergency exposure situation to an existing exposure situation, as well as recovery and remediation must be considered as one of the elements in the emergency management system. Articles 72-73 and Articles 100-102 address the need to identify and evaluate existing exposure situations, establish strategies for their management, by defining the objectives to be achieved, and specifying the reference levels as defined in Annex I. An appropriate environmental monitoring programme shall be put in place.

Due consideration is needed for assigning responsibilities for the implementation of the strategy, and for ensuring coordination between the relevant parties involved, for evaluating the effectiveness of the planned and implemented measures and for assessing doses received with a view to reducing exposures above the reference level. The involvement of stakeholders in decisions regarding the development and implementation of strategies for managing exposure situations is provided for, as well as the need to provide exposed populations with information on health risks. The reference levels set shall take account of the prevailing situation as well as societal criteria including, if appropriate, specific information on, and the means for managing the population's own exposures. Cooperation between countries is also required in the transition from an emergency exposure situation to an existing exposure situation (Article 99).

1.4 Conclusion

The Basic Safety Standards Directive sets out a comprehensive set of requirements for the post-emergency scenarios. The effective implementation of these will be challenging and calls for adequate preparation in the planning stage. Exchanging information on national approaches as well as experience from responding to earlier accidents is valuable in this context. It should also enable to identify areas of further work at the EU level.

References

[EU2013] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom, Official Journal of the European Union OJ L13, 17.1.2014, p. 1 – 73

2 MANAGEMENT OF NUCLEAR EMERGENCY AND POST-ACCIDENT SITUATIONS (POPULATION PROTECTION MEASURES)

Jean-Luc Godet, Pierrick Jaunet, Jeanne Loyen

ASN - French Nuclear Safety Authority

2.1 Introduction

The long-term management of the risk of population exposure to ionizing radiation following a nuclear or radiological event, relies upon the planning of protective actions (in the preparation phase), particularly the actions to be implemented during the emergency phase, and the anticipation during the early phase (when the releases take place) of decisions to be extended during the transition period (the first months of the post-accident phase). With regard to the actions to implement, stakeholder involvement in the preparation phase and from the beginning of the transition period is a necessary condition to lead the population on the road to resilience.

➢ **Issues and management aids**

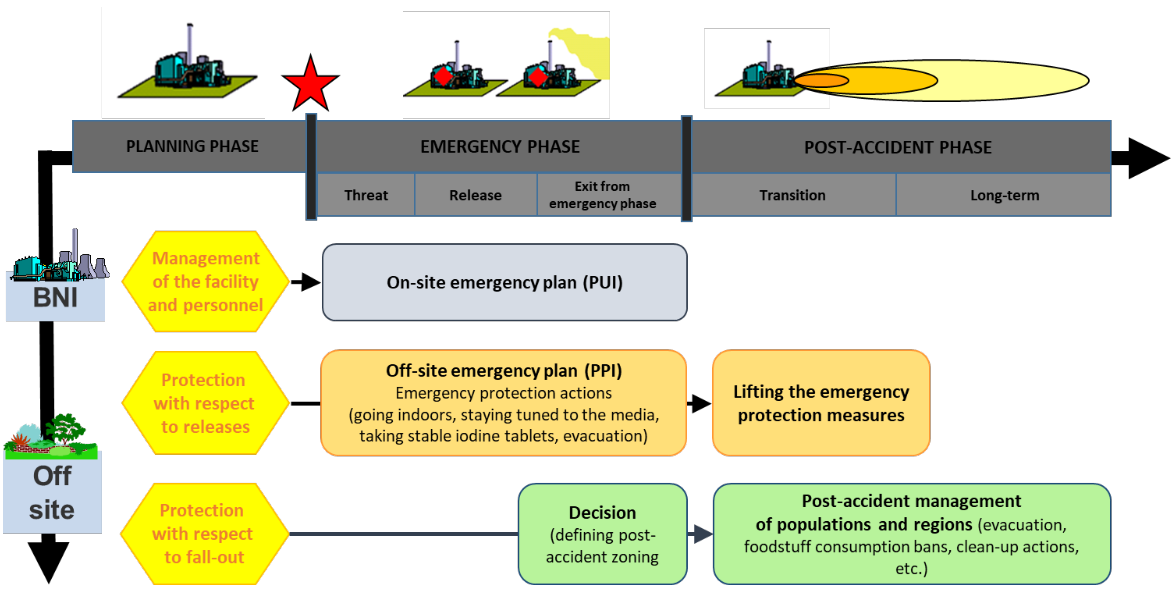

Figure 1: from emergency phase to post accident phase

2.2 Risk management preparedness regarding a nuclear or radiological event

The management of nuclear emergency and post-accident situations is intended:

- to provide support to the populations affected by the accident,
- to protect the populations against the dangers of ionizing radiation (particularly to reduce the probability of developing pathologies such as cancers a few years or even a few decades after the event),
- to treat the pathologies associated with the stress caused by the accident,
- to face the deterioration of economic and social conditions and to win back the economically and socially affected regions.

The management of emergency and post-accident situations must take into account of the variability of nuclear and radiological accident scenarios and their highly changing nature, particularly in the case of a large-scale accident. Different issues must be considered such as the duration and nature of the release (iodine and caesium isotopes, α-emitters, etc.), the weather conditions and the season, as well as the characteristics of the affected regions (population density, main types of agricultural production, etc.).

2.2.1 The National Response Plan for major nuclear or radiological accidents

After the Fukushima nuclear accident, the French government considered it essential to reinforce the prevention and the emergency preparedness.

The national response plan for major nuclear or radiological accidents has been updated accordingly and published in February 2014.

The response plan complements the long-standing organization to manage nuclear emergencies, provides elements to better understand these highly unlikely situations and their potential consequences, and introduces strategies for eight reference situations within or outside France. It also achieves transparent and clear public information and international information and exchanges.

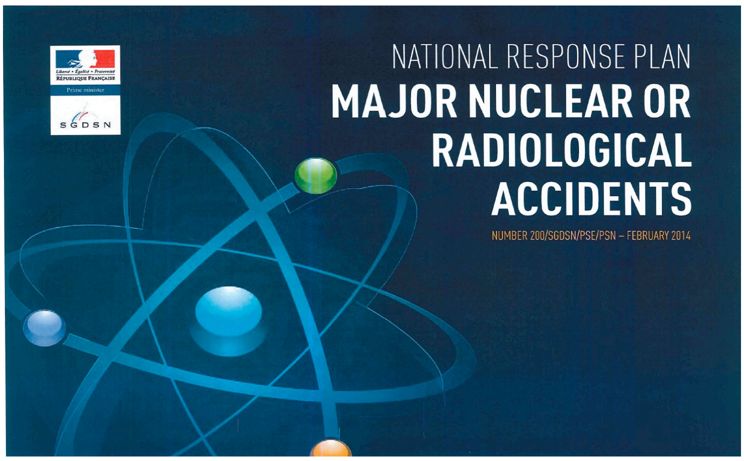

Figure 2: French national response plan

The eight situations described in the French national response plan are:

- Situation 0: uncertainty
- Situation 1: immediate and short-term release
- Situation 2: immediate and long-lasting release
- Situation 3: delayed and long-lasting release
- Situation 4: transport accident with potential release
- Situation 5: accident abroad with potential significant consequences in France (population protection could be necessary)
- Situation 6: accident occurring abroad with no significant impact in France
- Situation 7: accident at sea with potential release.

This plan also describes the emergency organization at local and national levels, the protection strategy and the main measures to be taken during the emergency phase and at the beginning of the transition phase.

2.2.2 The Off-Site Emergency Plans

Around each Basic Nuclear Installation (NBI), including Nuclear Power Plants (NPP), an Off-Site Emergency Plan has been established since several decades. This local plan is connected with the National Plan established and adapted for the local Public Authority (Prefect).

The objectives of the off site plan are:

- To protect the public and the environment;
- To define the local crisis organization;
- To set out the plan for monitoring the radiological environment;
- To indicate the site assistance for emergencies (injuries, fires);
- To prepare the local population, municipalities and media information.

Protective actions to be implemented during the early phase, included in the Off-Site Emergency Plan are regularly tested during national and local exercises (around 10 exercises each year).

Taking into account the lessons learned from the Fukushima accident, several evolutions were decided for Off-Site Emergency Plan for NPP, and especially the extension of the radius of this plan from 10 km to 20 km.

Considering the possibility of long-lasting releases from NPP, the population evacuation criteria were also revised in 2017 (table 1).

Situation	Phase	Protective actions
Immediate and short-term releases	Reflex Phase	Sheltering over a 2 km radius

Possible core melt, immediate and long-lasting releases	Immediate Phase (up to 12 h)	Evacuation over a 5 km radius
Other situation	Concerted Phase	Population protective actions based on projected doses and local context

Table 1: Protective actions during the early phase of a nuclear accident (2017)

Intervention levels (IL) associated with protective actions, regularly tested during the national exercises, are included in the national regulation since 2003. The dose values associated with those IL, considering the duration of the releases (or 24h in case of long lasting release) are the following:

- IL for sheltering: Effective Dose = 10 mSv
- IL for evacuation: Effective Dose = 50 mSv
- IL for taking iodine tablets: Thyroid Equivalent Dose = 50 mSv.

The instruction not to consume foodstuff produced after the start of the releases is issued to the population living within areas concerned by sheltering and/or taking iodine tablets, noting that the iodine-taking perimeter could extend beyond the Off-Site Emergency Plan (beyond 20 km), depending of the severity of the accident.

The updating of the national regulation (June 2018), as part of the transposition of the 2013/59/Euratom directive, led to the maintaining of the intervention levels (henceforth called "*benchmark value"* for decision) but also to the introduction of a "*reference level*" for ionizing radiation risk management in emergency situations. Considered as a dose optimisation tool, the value of 100 mSv/duration of the emergency phase has been stated for the reference level.

2.2.3 Iodine prophylaxis

To prevent the development of thyroid cancer among exposed populations in case of atmospheric releases containing radioactive iodine isotopes, regular iodine tablet pre-distribution campaigns have been organized since 1998.

In 2016, the campaign organized:

- Covered a 10 km-radius around the 19 French NPPs (the radius will be extended to 20 km in the near future);
- Concerned 430,000 households, 70,000 companies and public buildings, 500 towns;
- Planned to send a personal letter from the authorities inviting persons living near NPPs to collect their boxes of iodine tablets from their pharmacy within 6 months;
- Included the postal mailing of tablet boxes to those who had not collected them.

The launching of the campaign was associated to communication in order to redefine the position of iodine, taking among the other protective measures, to make the citizens aware of the nuclear risks and take an active part in their own protection. Local relays were mobilized (20 information meetings dedicated to mayors, 20 information meetings dedicated to health professionals), and a communication kit was delivered for the mayors, the pharmacists and the medical doctors involved.

In addition to the Off-Site Emergency Plan, the distribution of iodine tablets to the population in a real situation could be decided if necessary and organised using the stocks already located on the national territory.

2.3 The protective actions during the beginning of the post-accident phase

A steering committee for post-accident phase management, called CODIRPA, was set up in 2005. CODIRPA, chaired by NSA, is a pluralistic structure, including local and national authorities, institutional experts, licensees, elected officials and associations. The first doctrine elements to be considered for the management of long term exposures were issued in November 2012, and introduced in the National Response Plan (2014). The updating of these elements, currently in progress and probably to be published in 2019, takes into account:

- The Fukushima accident feedback, and the need to consider long-lasting release scenarios in the measures to ensure emergency preparedness;
- The development of new measurement techniques (airborne means) ;
- The feedback from national nuclear exercises ;
- The reference level for existing exposure situations (Effective dose = 20 mSv/first year, then 1 mSv/y at term), recently introduced in the national regulation (June 2018).

2.3.1 Implementation of the “post-accident” actions

The National Response Plan identified the main actions to be implemented at the end of the early phase and at the beginning of the transition phase. These "post-accident actions" are intended:

- **To reduce exposure of the public (ALARA)**, by issuing recommendations for good everyday living practices, engaging cleaning operations to reduce environmental contamination and organising the management of waste;
- **To develop exposure monitors** in order to characterise the environmental contamination, including drinking water monitoring, to create radiation measuring centres (for persons, foodstuffs), to provide systems for self-measurement of radiation in foodstuffs (home-grown, gathered) and to organise health and dosimetry monitoring of individuals;
- **To organise the control of foodstuffs**, on the basis of the European Maximum Permitted Levels (MPL);
- **To deliver information to t**he **consumers** (home-grown food, gathering, hunting, etc.) and to **the private companies** about the risks associated with the use of contaminated materials, and selling contaminated goods (other than foodstuffs);
- **To win back the economically and socially affected regions.**

The implementation of these actions was prepared in 2012 taking into account a short-term release from NPP. For this implementation, the post-accident zoning - set up immediately after the releases stop – was considered as a starting point of the post-accidental phase. This zoning is based on an Exclusion Perimeter (PE) or relocation zone, a Public Protection Zone (ZPP) and a Territorial Surveillance Zone (ZST).

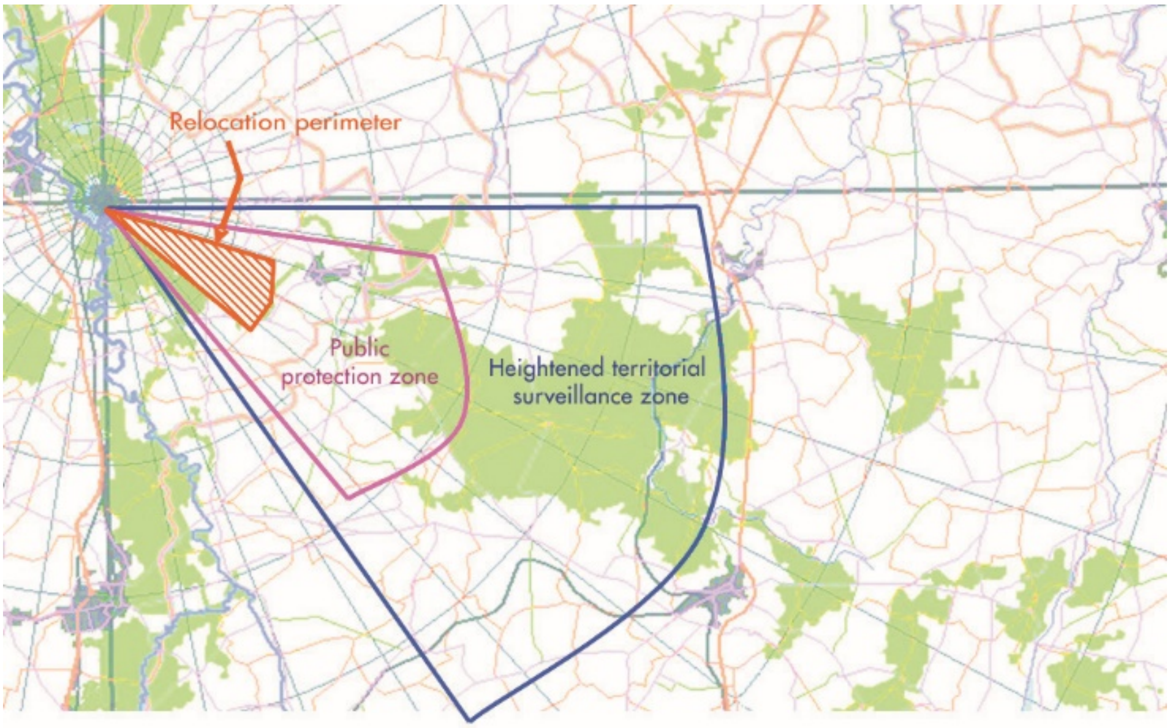

Figure 3: French post-accident zoning

An indicator with a guidance value is used to delimit the Exclusion Perimeter (PE): the estimated effective dose by external pathway (other than ingestion) over the 1st month (emergency phase excluded) would be higher than 10 mSv.

Two indicators with guidance values are used to delimit the Public Protection Zone (ZPP): the estimated effective dose (external pathway and internal contamination) over the 1st month (emergency phase excluded) higher than 10 mSv or the estimated equivalent dose to the thyroid (external pathway and internal contamination) higher than 50 mSv over the 1st month (emergency phase excluded).

An Indicator based on the maximum distance at which the European Maximum Permitted Levels (MPL) are found is used to delimit the Territorial Surveillance Zone (ZST).

2.3.2 Orientations to update the post-accident zoning

It emerges from the recent work of CODIRPA (2018), based on the examination of a long-lasting accidental release from a nuclear power plant, that the conditions for defining and implementing post-accident zoning would in some cases benefit from greater flexibility or even simplification.

For example, the principle whereby the first post-accident zoning must be operational as soon the emergency phase is over seems less relevant today. Indeed, it implied for the public authority's decision to be based on nothing but modelling results, pending significant measurement results. This evolution was decided given the lessons learned from the Fukushima accident and the improvements in modelling and radiological measurement tools.

It is nonetheless necessary to ensure continuity between the emergency measures and the post-accident measures during the transition phase which, pending more complete knowledge of the actual consequences of the accident (measures, modelling, sampling), can last from a few days to a few weeks.

Post-accident management should be thought of more as successive developments in the public protection measures guided by knowledge of the actual consequences of the contamination.

When justified by the external exposure levels, relocating the local populations and imposing restrictions on the consumption of some foodstuffs are the priority protection measures to implement when the atmospheric releases have stopped. However, it is not always possible to define the duration of relocation at the beginning of the post-accident phase.

It is also considered that the criterion for determining the exclusion perimeter (annual effective dose based only on external exposure due to deposits) would have the advantage of being transposable into directly measurable quantities in the field (dose rate for example), once the composition of the deposit is known, and to facilitate informing of the populations and their embracing of it. This operational indicator (recommended by the IAEA) should be able to evolve over time to take into account the decrease in environmental contamination levels during the first months of the post-accident phase.

Stopping the consumption, in the immediate future, of home-grown products, market-garden products and products taken from the natural environment (e.g. mushrooms, berries, wild game), in the regions situated beyond the relocation zone constitutes an additional measure (already taken into account in the CODIRPA doctrine of 2012) which comes under the optimisation principle. It is even more necessary given that the diet of some groups of people, particularly those living near the relocation zone, may be largely based on such products.

The question of the criterion for determining an extended perimeter for issuing instructions not to consume certain foodstuffs - which would replace the current Territorial Surveillance Zone (ZST), a perimeter within which precise and personalised information will be necessary - remains open. For this criterion, an all-inclusive approach defined in the preparation phase - as has been adopted by several European countries – might be preferred rather than the European Maximum Permitted Levels (MPL).

Lastly, the fact that the actual contamination levels of the foodstuffs produced in the ZST are liable to vary significantly according to the nature of the deposits, the season in which the accident occurred and the agricultural sectors concerned, must be taken into account. The environmental radiological measurements, which can serve to correct or confirm the modelling results, should be taken before establishing one or more surveillance zones as appropriate for the specific issues of each agricultural sector.

The question of defining the Public Protection Zone (ZPP), in relation with the lessons learned from the Fukushima accident on the implementation of contamination reduction actions and the large quantities of waste produced, would also merit being reconsidered. Thus, in order to supervise and anticipate the contamination reduction actions aiming to optimise exposure of the public, the identification of a contamination reduction zone, in the same way as the zone outside which contamination reduction measures would not be justified, could be defined by an annual dose that excludes the ingestion of contaminated foodstuffs, taking account of the reference level and how it evolves over time.

More generally, the CODIRPA is wondering about the benefit of maintaining the Public Protection Zone (ZPP), considering that the perimeter-determining criterion based on the effective dose, including external exposure and internal contamination, was not always appropriate given the large number of actions that must be initiated in the ZPP, and the fact that some of them should be implemented beyond this perimeter.

2.4 Conclusion

Preparedness is a clue of a wise response given by decision makers in front of a nuclear or radiological emergency situation. Since the Fukushima accident, the French government has been working on a strategy of protection described in a national plan. Decision makers relying on specific local plans and a post-accident doctrine can implement this strategy.

Today, those strategies keep evolving with the introduction of reference levels for both the emergency phase and the existing exposure situation and accepting the need of an implementation gradually of the protective actions in the post-accident phase.

3 RISK EVALUATION OF LONG-TERM EXPOSURE AFTER A NUCLEAR OR RADIOLOGICAL ACCIDENT

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Abstract

Legacy sites arising from nuclear or radiological accidents usually comprise of complex variety of prevailing circumstances and thus, require full consideration of a range of different aspects. In years after the accident, main question at existing exposure sites would remain what the actual health consequences caused by the accident were and how efficient conducted countermeasures were. Answering these is not an easy task and implies need on holistic consideration of situation by evaluation of the radiation doses and risks to humans and environment, but in addition social, psychological, ethical and economical domains in the given situation.

The main objective of this paper is to provide an overview of risk evaluation methodology and related issues on cases of the following:

- long-term exposure situation in Norway due to the Chernobyl fallout after the accident in 1986;
- long-term exposure situation in the area of Mayak PA Facility due to complex radiation situation, consequence of combination of several historical factors (as described in Section 3.2).

Lessons learned concerning risk evaluation, difficulties and good practice in management and radiation protection strategies are evaluated for both case studies in order to identify the issues where further international activities on development and harmonization are needed and to provide help for management and protection at similar existing legacy sites.

3.1 Introduction

Legacy sites are, in general, a global issue that requires full consideration of a range of different aspects. Sites with existing radiation exposure result from nuclear and/or radiological accidents, former peaceful nuclear explosions and weapons testing, former uranium or natural occurring radioactive material (NORM) mining and milling facilities, nuclear reprocessing and nuclear power plants (NPP) can be found all over the world (Figure 1). Some of these existing exposures may or may not be considered as potential legacies depending on where they are and how everything is regulated, as they are currently in operational phase in accordance with modern and advanced safety standards. However, general awareness that protection objectives, and consequently, regulatory requirements evolve in time is necessary and if lessons from the past are not properly learned it could happen that new legacies are created where not expected (Sneve *et al.,* 2018).

International organizations have highlighted the importance of understanding the complexity of issues in legacy management and related regulatory control processes as well as great value of international cooperation on this topic. Several initiatives in IAEA, ICRP and OECD

NEA have recently been taken to ensure expert discussions, sharing the different national and international experiences, both challenges and good practices, in order to provide international guidance and enable harmonization of national approaches in the management of legacy sites.

Understanding that wide range of issues needs to be addressed regarding different legacy sites worldwide, the Norwegian Radiation and Nuclear Safety Authority (DSA) organized recently two international workshops on “Regulatory Supervision of Legacy Sites: from Recognition to Resolution”, in 2015 and 2017, with support of international organizations (IAEA, ICRP, OECD NEA, IUR). General conclusions from these workshops highlighted a substantial gap between theory and good practice and suggested that further international guidance on practical application would be valuable. Many different questions were raised and discussed; specific recommendations were published (Sneve and Strand, 2016; Sneve *et al.,* 2018).

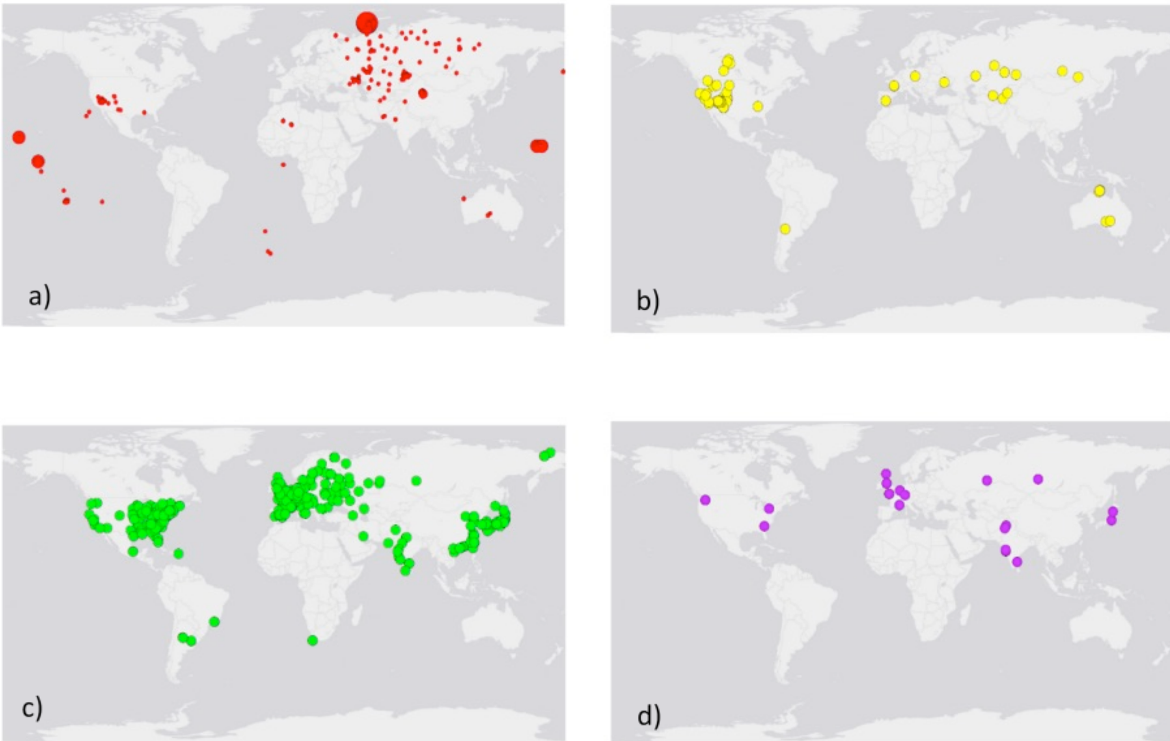


Figure 1: Legacy and potential legacy sites worldwide: a) nuclear explosions b) uranium mining sites c) nuclear power plants d) nuclear reprocessing plants (Sneve et al., 2020).

Radiation exposure following nuclear or radiological accidents is of great concern for the public, but also for the authorities with responsibility to ensure public safety, health and well-being as well as protection of the environment as a whole. In years after the accident, main question at existing exposure sites would remain what the actual health consequences caused by the accident were and how efficient conducted countermeasures were. Answering these is not an easy task and implies need on the holistic consideration of situation by evaluation of the radiation doses and risks to humans and environment, but in addition social, psychological, ethical and economical domains in the given situation.

Detailed guidance on application of ICRP 2007 Recommendations to the protection of people living in long-term contaminated areas after a nuclear or a radiological emergency was provided in the report ICRP 111, 2009. Consideration of how the justification and optimisation of protection strategies and application of reference levels as well as consideration of practical aspects for these are given. Currently, Task Group 93, under the ICRP Committee 4, is working on the report on Protection in the Event of a Nuclear Accident updating Publications 109 and 111 in the light of lessons learned and international developments concerning protection of people living in such long-term exposure conditions.

The main objective of this paper is to provide an overview of risk evaluation methodology and related issues on cases of the following:

- Long-term exposure situation in Norway due to the Chernobyl fallout after the accident in 1986;
- Long-term exposure situation in the area of Mayak PA Facility due to complex radiation situation, consequence of combination of several historical factors.

Lessons learned concerning risk evaluation, difficulties and good practice in management and radiation protection strategies are evaluated for both case studies in order to identify the issues where further international activities on development and harmonization are needed and to provide help for management and protection at similar existing legacy sites.

3.2 Impact and risk assessments

Environmental impact and risk assessment typically covers for the human health assessment and ecological assessment. Historically, scientific and regulatory activities have emphasized human health risk and mainly neglected ecological effects and risks to non-human organisms (Suter II, 2007). However, the prevailing anthropocentrism and belief that protection of human health automatically protects non-humans, have been more often replaced with ecological risk assessment (ERA) (ERICA, 2007; Suter II, 2007) or integrated risk or impact assessment for both humans and non-humans (Suter *et al.*, 2003; WHO, 2001). Although approaches are named differently, the practical assessment tiers remain the same, i.e. approaches differ more in their mandate than in the way of analysing and managing hazards to the environment. However, the concept of environmental protection and legislative requirements still differ from country to country, and no true consensus has been achieved with regard to environmental protection questions (Suter II, 2007).

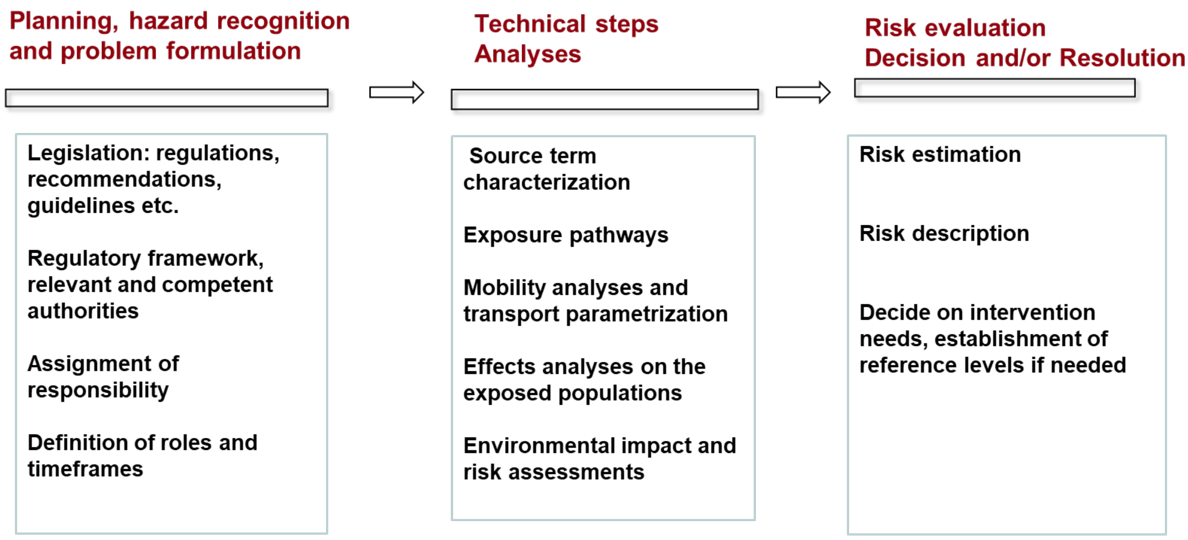
Risk evaluation is commonly used to characterize the nature and magnitude of health risk to humans and environment receptors from different radionuclides released in given nuclear and radiological accidents (case studies). Risk evaluation can be done shortly after the accident, but also at stage of long-term exposure. However, some of the aspects to be evaluated in risk assessments can then be quite different. Addressing all the different risks can, however, be challenging, and requiring both short and long-term risks to different populations to be addressed proportionately. Issues also arise concerning the practical application of protection principles. For example, the principle of optimization requires a common framework of protection objectives across different hazards for both people and the environment, but such a framework is not currently available. A holistic, multi-dimensional approach to human health and environmental protection from multiple hazards is needed (Sneve *et al.,* 2018).

In the process of regulatory decision, making at long-term exposure situations that encompasses risk estimation as a central point, main questions are:

- What are the hazards of concern?
- Which are the main exposure pathways?
- Who is at risk, for how long and which effects can be expected?
- Which efforts and mitigation methods can be done in order to reduce estimated risk if needed?

Answering these questions allows final risk evaluation and regulatory decision-making. Main steps in a 3-tiered impact and risk assessment procedure adopted in the DSA's regulatory practice is given in Figure 2.

The planning stage is undertaken prior to assessment, where certain issues such as the goals, scope and complexity of the assessment, as well as different management options, are discussed by regulators, assessors, managers and if possible other relevant stakeholders. Defining the problem includes collecting of all available information concerning radioactive sources, establishment of screening criteria, definition of assessment endpoints, describing the conceptual model and development of an analysis plan. During the analyses stage, exposure to radiation (contaminants) and possible effects are identified and analysed. Measurements of radionuclide concentrations, analysis of the environmental pathways and mobility and distribution, spatial and temporal variations, measurement of effects, dose-response analyses should be included. Impact identification consists of estimation and characterization of the possible impacts. Risk evaluation, comprising of risk description and risk estimation, is based on a combination of results, calculations and models, probability analyses, while the associated uncertainties are always described, evaluated and properly acknowledged (Suter II, 2007).



- Financial decisions within this horizontal process
- Social aspects and decisions: risk perception and communication
  stakeholders involvement

Figure 2: Steps in the environmental impact and risk assessment.

The ICRP (2007) acknowledged the complexity and difficulty related to environmental protection. However, ICRP subscribed to the global needs to and efforts required to maintain biological diversity and to protect the health of humans, but also status of ecosystems, natural habitats and communities. Accordingly, several frameworks and approaches have introduced the use of ˝reference organisms˝ as typical entities that can provide a basis for estimating the radiation dose (ERICA, 2007; ICRP, 2008; UNSCEAR 2008; ICRP, 2014). The appropriate regulatory decisions should be made based on the integrated risk and impact evaluation where it is possible.

Demands for re-evaluation of long term exposure situations after nuclear or radiological accidents comprise of need to re-estimate the consequences and risks within (large) endangered geographic areas, evaluate applied countermeasures and effects seen in many aspects of society, check how good coordination of information and continuous engagement of stakeholders was as well as how good international information exchange was. However, it has been recognized (Sneve *et al.,* 2018; Sneve and Strand, 2016) that no universal answer exists on how to assess and manage long-term radiation risks. The case specific approach, taking into the consideration prevailing circumstances (such as existence of other risk beside radiation, different targeted populations of humans and biota, their habits and lifestyles, presence of radioactive waste, regulatory framework, legislation, etc.) is recommended.

3.3 Lessons learnt from national and international experiences

3.3.1 Case study: Management of long-term exposure to Chernobyl fallout in Norway

Part of the Chernobyl fallout from the accident in 1986 reached Norway and most of the contamination was deposited in the high mountainous, pasture areas in the central and southern parts of the country (Figure 3) (NRPA, 2006). Common traditional agricultural practices in these rural areas as breeding of sheep, goats as well as reindeer herding was under the risk as high uptake in plants and transfer within the food chain was observed already in summer 1986. As a consequence, people living in these areas, reindeer herding Sami were mostly affected, actually to that level that their whole life-style was threatened (Skuterud and Thørring, 2012; Liland *et al.,* 2009). Elevated activity concentrations of radiocesium were measured in foodstuff, reindeer and fish. Activity concentrations up to 150.000 Bq/kg of radiocesium were measured in reindeer meat while sheep, freshwater fish and goats' meat levels of contamination were respectively 40.000 Bq/kg, 30.000 Bq/kg and 3000 Bq/kg at the same time (Strand *et al.,* 1992; NRPA, 2006). As a result, about 2800 tonnes of food were condemned during 1986.

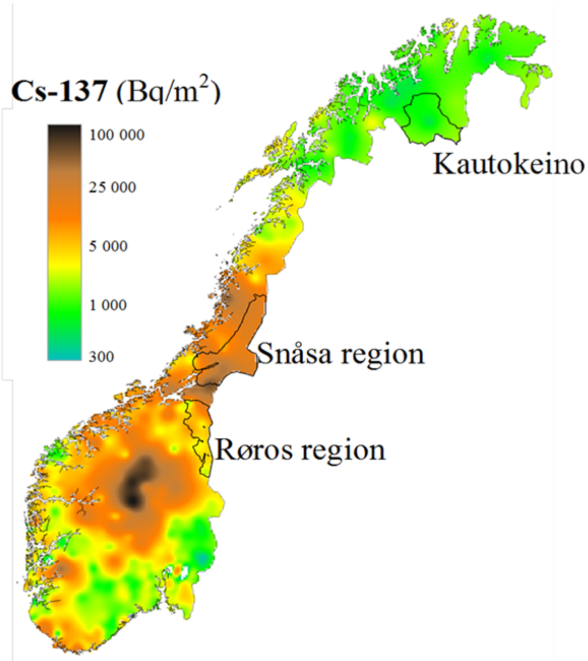


Figure 3: Activity concentration of ^{137}Cs in soil in 1986 (municipality average).

In order to protect both the Norwegian population (with relatively small reindeer meat intake) and the Sami population (with relatively high reindeer meat intake), but also to help Sami population to preserve their way of life (that depends on reindeer herding) and to reduce economic consequences as much as possible, the Norwegian strategy for Chernobyl fallout management focused on domestic food production. As the temporary limits of 600 Bq/kg for basic foodstuffs and 370 Bq/kg for milk and infants food (set in May 1986) were quickly exceeded, the authorities decided to raise the food intervention level (FIL) for reindeer meat (and also for game and freshwater fish) to 6000 Bq/kg for the general population, with a specific limit of 600 Bq/kg for the Sami population. This was justified by the fact that the average consumption of reindeer meat of the general Norwegian population is about 0.5 kg/year, whereas the average consumption of reindeer meat in the Sami community is around 50 kg per year. Norwegian Directorate of Health provided dietary advices (1987).

According to ICRP recommendations, main goal in a year just after the accident was to maintain the ingestion dose to the population under 5 mSv/y what corresponds to intake below 400.000 Bq of radiocesium, while the ingestion doses were planned to be reduced to below 1 mSv/y in subsequent years (below 80.000 Bq from ingested radiocesium). In addition, a range of other countermeasures was also implemented (Table 1). The above-mentioned levels and conducted measures were regularly re-estimated in a transition period from the emergency to long-term exposure, and consequently, the FIL for reindeer meat was in 1994 reduced from 6000 to 3000 Bq/kg.

Table 1: Overview of the countermeasures applied in Norwegian management of the Chernobyl fallout and established reference levels (1986 -2018)

Countermeasure	1986	1994 -2018
Food Intervention Level (FIL) – for Norwegian population in general		
- foodstuff	600 Bq/kg	600 Bq/kg
- milk and infant food	370 Bq/kg	370 Bq/kg
- reindeer, game and freshwater fish	6000 Bq/kg	3000 Bq/kg*
Food Intervention Level (FIL) – for Sami population		
- reindeer, game and freshwater fish (for Sami population)	600 Bq/kg	600 Bq/kg
Other countermeasures		
Use of Prussian blue, Animal dose monitoring, Clean feeding prior to slaughter, Alteration of slaughter period, Live monitoring of animals, Grazing in less contaminated areas	Intensive	To smaller extent, actual in the most contaminated area
Whole body monitoring of Sami reindeer herders	Actual	Actual
Ingested annual effective dose due to intake of radiocesium	< 5 mSv	< 1 mSv

**Subject to re-evaluation in order to further reduce FILs, on 1500 Bq/kg or 600 Bq/kg*

Currently, more than 30 years after the Chernobyl accident, there are demands for new re-estimation of the exposure situation and applied countermeasures. Results of long-term monitoring programmes, established in years after the accident, showed decreasing trends in lichen, vascular plants, fungi, fish, wild and domestic animals and foodstuff, but still with significant geographical and yearly variation (Gjelsvik *et al.,* 2014, Liland *et al.,* 2009). Furthermore, longer ecological half-lives of radiocesium than originally predicted (Gjelsvik,

2005) and still important transport of radiocesium in the food chain, giving elevated activity concentrations in animals on the food chain top, were observed (Gjelsvik *et al.,* 2014). Thus, countermeasures (in smaller scale than previously) are still considered as needed in large areas of sheep and reindeer production to comply with valid FILs (*e.g*., Skuterud *et al.,* 2005).

As shown in Strand *et al.,* 1992, applied countermeasures in Norway have contributed to the reduction of the contamination levels in the Sami population by 90% in years just after the accident. In the recent study of Skuterud and Thørring, 2012, an estimation of the countermeasures effectiveness and resulting averted doses to the Sami reindeer herders during the years after the accident was done. It was shown that the various countermeasures applied in the most contaminated areas reduced radiocesium ingestion doses by about 73% in certain areas, to an integrated dose of about 17 mSv. Further, to comply with the recommended ingestion dose limit of 1 mSv/y countermeasures are estimated to be needed for another 10 years. Projected committed effective doses received by southern Sami reindeer herders received in 50 years after the Chernobyl is given in Table 2 (from Skuterud and Thøring, 2012).

Table 2: Estimated committed effective dose (mSv) in 50 years after the Chernobyl

Region	With Countermeasures	Without countermeasures
N (Nordland and Nord-Trøndelag counties)	27	76 - 140
S (Sør-Trøndelag and Hemdark counties)	23	21 - 38

The Norwegian authorities recognized the significance of collaboration with local Sami population in relatively short time period after the accident. Thus, local population in the contaminated areas has been for years now actively engaged in the application of countermeasures and it has contributed to transparency of the decision-making. Effective communication has mutually helped to both affected people and regulators to understand the specific details of the situation and consequently to manage it. Further, a greater trust of local people in the state authorities has been observed.

Monitoring and countermeasures are still in place in Norway in order to reduce radiation risks from effective doses to population. Adjusting the applied countermeasures with time is common in the management of long-term exposure situations after nuclear accidents. The persistent Chernobyl contamination in Norway, with slow decreasing, but variable trends in the particular biota, has led to adjustments of countermeasures such as change of FILs, more intensively application of clean feeding than early slaughtering and others. It is important to keep in mind that many of these countermeasures are inter-related and changing one could lead to effects in other applied countermeasures.

The food intervention levels in Norway have not changed in 24 years. Recently, the Norwegian Food Safety Authority has requested a risk assessment study from the Norwegian Scientific Committee for Food Safety in order to re-assess the risks to human health from radioactivity in food and feed and to estimate if it is possible to further lower the limit to 1500 or even to 600 Bq/kg (VKM report, 2017).

More specifically, following terms of reference (ToR) were addressed to provide a detailed picture on radiation risks in Norway nowadays:

- What is the current health risk from radioactivity in food – food gathering and hunting included – to the whole population and specific groups in Norway?
- What health risk would the current levels of ^{137}Cs measured in live reindeer and sheep pose to the whole population and specific groups, if no efforts were made to reduce them?
- What would be the implication to the health risk if the FIL for reindeer meat was reduced from 3000 to 1500 or 600 Bq/kg, respectively – for the whole population and for specific groups?

The total effective dose from the diet of the Norwegian population is estimated to be 0.42 mSv/y, of which anthropogenic radionuclides contribute on average 0.01 mSv/y due to ^{137}Cs contamination. However, as previously explained, reindeer meat and wild mushrooms still have the high activity concentrations of ^{137}Cs and, thus, certain part of the population, Sami reindeer herders, with high intake of the reindeer meat could receive up to 3.1 mSv/y (Kamperud and Skuterud, 2018). In general population, contribution of the intake of ^{137}Cs in food to the excess cancer risk was considered to be very low, while excess cancer risk was estimated as low to moderate for specific groups with high intake of highly contaminated reindeer meat (VKM report, 2017). Further, according to VKM report, 2017, the current countermeasures have little effect on the national mean ^{137}Cs level in reindeer and sheep meat and consequently on existing effective doses and on overall health risks for general population. More detailed, if no countermeasures were performed, levels of ^{137}Cs in these meats would increase by approximately 14 Bq/kg for reindeer meat and 10 Bq/kg for sheep meat what would further lead to doses increment of about 0.0005 mSv/y. However, if no countermeasures were applied in the most contaminated reindeer herder's areas, the level of ^{137}Cs in reindeer meat would increase by significant 3900 Bq/kg what would lead to higher effective doses up to 2.6 mSv/y for these specific groups of population. Estimated health risks would then increase by approximately 20%, but it would, still, remain low to moderate. Further, it is showed that potential reducing the FILs from existing 3000 Bq/kg to 1500 or 600 Bq/kg would reduce the national mean level of ^{137}Cs in reindeer meat by about 6 or 46 Bq/kg, respectively. In the most contaminated districts, ^{137}Cs reduction would range from 41 to 1505 Bq/kg in the reindeer meat. The reduction in effective doses associated with this potential reduction of FILs to 1500 Bq/kg or 600 Bq/kg would be 0.00003 and 0.00022 mSv/y for an average adult in general population, respectively. No effects on health risk, consequences of these potential changes, have been observed for general population. For specific groups, the effective dose reduction resulting from FILs set to 1500 Bq/kg was up to to 1.0 mSv/y, while the corresponding dose reduction from decreasing the FILs to 600 Bq/kg ranged would be up to 2.4 mSv/y what would reduce the excess risk from moderate to low category (VKM report, 2017). Proposed adjusting the existing FILs in reindeer meat, game and freshwater fish on lower values (1500 Bq/kg or 600 Bq/kg), after years with accepted level of 3000 Bq/kg that was said to pose health risk neither to general population nor to specific groups of Sami population, could re-open discussions and media attention. However, reducing the levels when possible is in accordance of radiation protection objective to reduce exposure as low as reasonable achievable (ALARA principle) (ICRP, 2007). All economic and societal aspects must, however, be carefully considered to avoid additional stress and problems.

Lessons learnt from long-term management of Chernobyl fallout in Norway suggest that case-specific approach with careful consideration of prevailing conditions, transparency in decisions and engagement of relevant stakeholders is needed in emergency and transition periods after a nuclear accident. Strategies for the long-term management should preferably be planned with consideration of broad range of relevant aspects like current contamination levels, estimated effective doses to people and biota, applicable countermeasures and their feasibility, health and environmental effects, but also societal impacts.

3.3.2 Case study: Management of long-term exposure in the area affected by historical releases from Mayak Nuclear Facility, Russian Federation

Mayak Production Association (PA) nuclear facility plant was originally built for making, refining and machining plutonium (Pu) for weapon during the cold war. Later, the plant came to specialize in reprocessing the spent nuclear fuel from nuclear research reactors. During the decades of its operation, little to no attention was paid to workers safety or to proper disposal of radioactive waste. Several accidents with over-exposure of workers as well exposure of local population due to gas and aerosol emissions happened until 1960s. Chemical explosion of poorly maintained radioactive waste tank in 1957 and intensive wind spreading of dust containing radioactive substance from the dried bottom of the Karachay Lake in 1967 contributed also significantly to effective doses of the Mayak facility workers and population living in the surrounding settlements in the Southern Urals. In addition, the primitive, open-cycle cooling systems in nuclear facility directly contaminated thousands of gallons of cooling water of the reactor. Heavily contaminated water was discharged to Techa River. Based on all these facts, contamination of the wider Mayak area and exposure of the population and workers are actually a combination of historical issues in the radiation protection - lack of both willingness for protection and protection and safety standards, but also radiological accidents that came as results of the latter.

As a part of a continuing radiation monitoring program in the area around Mayak PA nuclear facility, a collaboration project was established between the NRPA and the Southern Urals Biophysics Institute (SUBI) to estimate committed effective doses to population from 1949 to 2013 (Table 3).

Table 3: Committed affected doses (mSv) accumulated in period 1949-2013 (Romanov S., 2015, in Sneve and Strand, 2016)

Town	Committed Effective dose E(50)				
	Sr-90	Cs-137	Pu-239	Am-241	Total
Ozyorsk (8 km, NW)	2.0 (15%)* 5.2 (32%)**	7.3 (57%) (45%)	3.0 (24%) (20%)	0.5 (4%) (3%)	12.8 16.3
Novogorny (8 km, SE)	3.0 (20%)	11.3 (72%)	1.0 (6.5%)	0.2 (1.5%)	15.5
Chelyabinsk (80 km, S)	1.4 (20%)	5.2 (73%)	0.4 (5.6%)	0.10 (1.4%)	7.1

** compound type is M, ** compound type is F*

Estimated committed effective doses were in range 7.1 to 16.3 mSv for general population in three settlements, with distance 8 – 80 km from the Mayak PA nuclear facility. The contribution of ^{90}Sr, ^{137}Cs, ^{239}Pu and ^{241}Am was assessed. The highest dose contribution was found to be from ^{137}Cs, up to about 70 % of the total dose. Analyses of the activity concentrations of ^{239}Pu in soil and air and ^{90}Sr in water have shown levels that implied environmental contamination. However, assessments of radionuclides body burdens have shown that there is no significant issue with ^{137}Cs and ^{90}Sr as there has been large reductions in body burdens over time. The same trend is evident for ^{239}Pu.

Consequently, annual effective doses have reduced for adults in the Ozyorsk population to below 0.1 mSv/y, and based on that fact, it can be questioned if this area should be further considered as contaminated and if additional measures beside common health care services should be provided in this area nowadays (Figure 4, Romanov, 2016 in Sneve and Strand, 2016).

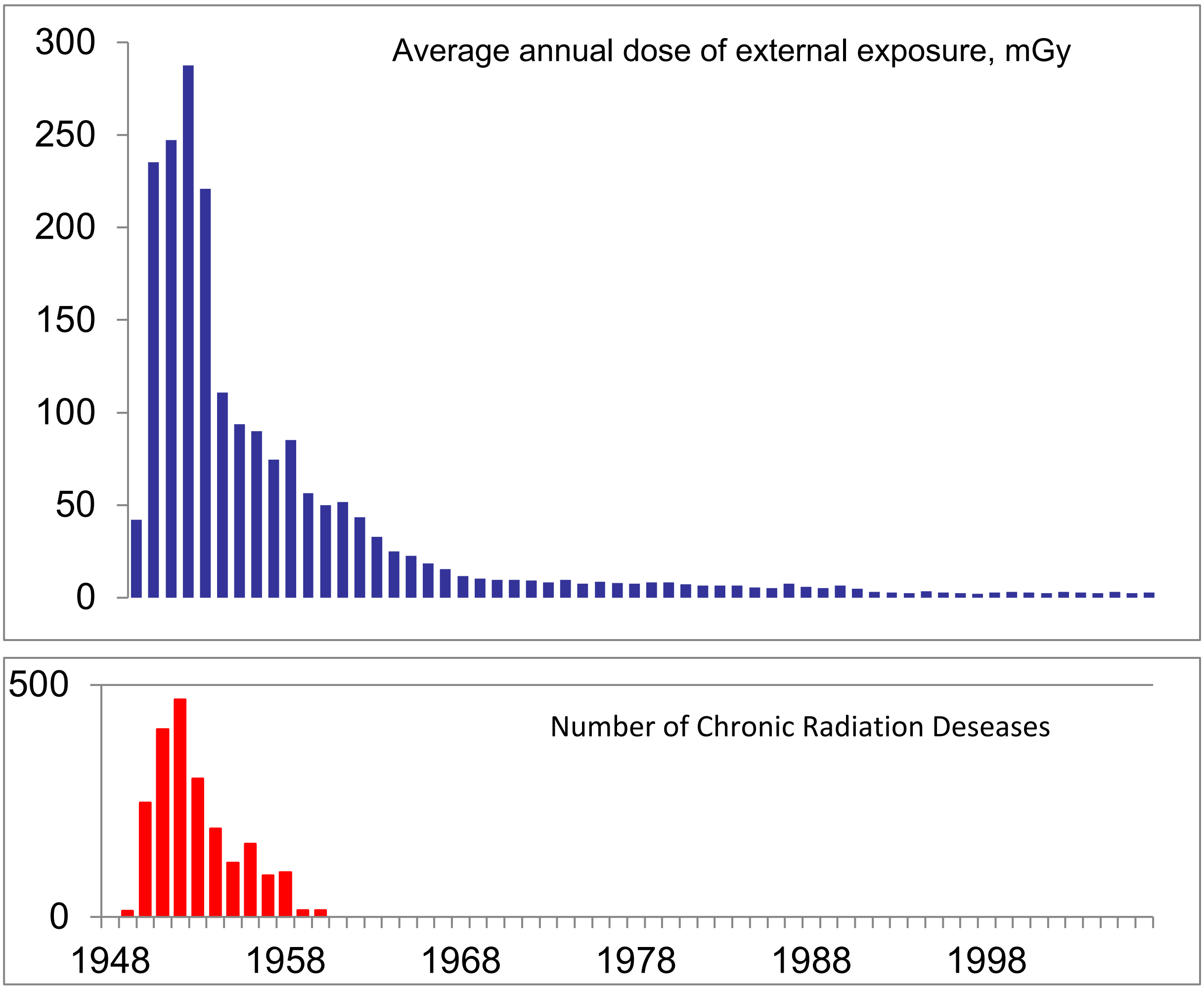


Figure 4: Declining trend of average annual effective doses and number of chronic radiation diseases over years in the Mayak area

As stated above, it has been in the recent decades often highlighted that risk assessment should cover not only for human health, but also for the non-human biota and general state of the environment. With respect to that, estimation of the effects of the Techa river chronic contamination on non-human biota (fish) was also done in a collaborative project of the Urals Research Centre for Radiation medicine (URCRM), the NRPA and the Norwegian University of Life Science (NMBU) (Pryakhin, 2018 in Sneve *et al.,* 2018). Analysis of accumulation of radioactivity in fish was of importance as they are a part of the human food chain. The total dose rate to fish in different reservoirs, calculated using the ERICA tool was shown to be variable and in a broad range 3-150 µGy/d with the highest doses (150 µGy/d) in the sampling station closest to the Mayak (Figure 5). Doses then decreased with distance down the river. A range of bio indicator tests have been performed on fish and it has been concluded that chronic dose rates of more than 100 µGy/d leads to genotoxic effects in fish and changes in physiological and pathophysiological reactions, as well as changes in the response to other factors. The radionuclide intake for the local population from the consumption of fish from the Techa River has also been investigated. Fishing is not permitted in the river, but does occur. If fish were to be consumed from the mid reaches of the river, the intake of ^{90}Sr would be higher than the allowable dose. Fish consumption could give rise to an effective dose of up to 0.5 mSv (Pryakhin, 2018 in Sneve *et al.,* 2018).

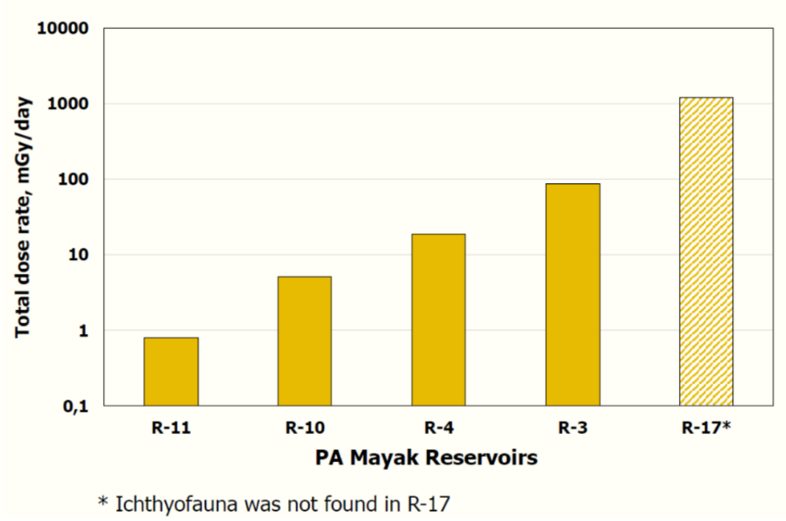


*Figure 5: Total radiation dose rate for roach in Mayak reservoirs (*no fish was present in the reservoir)*

One of the additional issues to be considered and carefully evaluated in the long-term exposure situation is social and psychological aspects of the usage of long-lasting contaminated territories. This has also been investigated at example of settlements near Mayak PA facility (Burtovaia, 2018 in Sneve *at al.* 2018). As mentioned above, in 1957 there was an airborne release of radioactivity because of an accident at the Mayak PA site. Over a period of around 11 hours, the East Urals Radioactive Trace (EURT) was formed, with 90 % of the radioactive fallout occurring on the territory of Mayak PA and 3 settlements were heavily contaminated. Short-lived radionuclides contributed greatly to the total activity and decay was evident over the first 5 years following the accident such that ^{90}Sr is now the main radionuclide contributing to dose. However, in difference to previous accidental situations in the Mayak area, in the case of the EURT certain emergency countermeasures were taken on time (e.g., evacuation of people, monitoring of foods and fodder, sanitary protection zone formation, etc.), but still not much care was directed to social or psychological aspects of life in the given situation.

Recently, in the long-term post-accident period, social-psychological consequences become one of the important issues for affected populations and are one of the most serious issues in the return of territories to economic use (Burtovaia, 2018 in Sneve *at al.,* 2018). One of the main issues faced in the return of the territory to normal use is the risk perception among the population. The population receives and assesses the degree of risk in a different way to experts; about 80% of the population thought that a radiation accident would happen again. Analysis has suggested that an early dialogue between authorities and the affected population, with properly phrased information from experts and opportunity for people to express their worries and thoughts, may have alleviated some of the issues.

Research and monitoring studies on risk re-assessment in the long-term exposure to artificial radionuclides in the area of Mayak PA facility show declining trends of radionuclides, but still existing contamination in the environmental media. However, doses to population are found to be low. Still, as legacy management has for years been complex and with difficulties, range of issues in radiation protection remain. Real risk and risk perception of affected people and consequently social and psychological aspects of their life is one of the current concern. Earlier involvement of relevant stakeholders and transparency in the decision-making processes would be beneficial for both population and authorities.

3.4 Concluding remarks

Management of long-term exposure situations after a nuclear or radiological accident is not a linear process, rather a long, often multi staged process with uncertainty that uncovers further problems with its progress. Although the focus is mainly on radiation protection considerations, the complexity of post-accident situations, which cannot be managed without addressing all the affected domains of daily life, *i.e.,* environmental, health, economic, social, psychological, cultural, ethical, political, should be understood and properly considered. It is necessary to acknowledge that we are living in a changing world and it is important, therefore, not to overpromise, but do the best in a holistic, the most transparent and consistent approach possible.

Risk evaluation with time is important in order to provide the current state information for both affected population and regulators, to evaluate conducted countermeasures and eventually do further optimization of radiation exposure where possible. One of the commonly discussed issues is adjustment of permissible levels in food and release of materials from emergency to transitional and further to existing exposure. Although it can produce further anxiety in the society and re-elevated media attention with questions why something that was explained to pose no risk for human health should be further reduced, this adjustment of reference levels (such as reduce of FILs in case of Norwegian reindeer meat) is in accordance with the ALARA principle (ICRP, 2007). Still, such changes should be carefully planned, with special attention paid to public communication of the changes and transparency with all related issues. Rationalization of the different values applied would be beneficial, providing background on their derivation and the context in which they are meant to be applied.

Steps in risk assessment are fully developed at the international level. However, scientific support for risk calculations for both humans and biota in terms of further work to minimize knowledge gaps, to improve existing models and to reduce the uncertainties is of great importance.

During the international meetings on legacy management, a question if the development of generic international criteria is needed, has been posed. There is consensus that a range of reference levels for existing exposures of 1-20 mSv can variably be used, but each existing exposure must be considered within site-specific conditions, with evaluation of all existing risk and variability in targeted groups of human population and non-human biota.

Risk communication is internationally recognized as issue of great significance in the long-term existing exposure situations. Public risk perceptions and the level of anxiety over long-term radiation exposure change depending on the complexity of situation. Confidence and trust in the authorities and their decision-making should be based on transparency, efficient communication and involvement of variety of stakeholders, especially local community in the management process. Stakeholder involvement and confidence related to nuclear legacy management is an important issue, deserving additional focus in separate publication and is not included in the scope of this paper.

3.5 Suggestions for further work

In line with the EU Scientific Seminar 2018 on ‘Management of long-term exposure after a nuclear or radiological accident’ several workshops on legacy issues ‘Regulatory supervision of legacy sites: from recognition to resolution’ have previously been organized by the DSA (formerly NRPA) together with international organizations IAEA, ICRP, OECD NEA and IUR

(Sneve and Strand, 2016; Sneve *et al.,* 2018). General conclusion from all these events was that complexity of legacy sites, including those resulting from nuclear or radiological accidents) needs to be properly addressed at international level in order to help development of management strategies at national levels. Exchange of experiences, including both challenges, difficulties and good practices is relevant and something to further work on.

As mentioned in the previous section Concluding remarks, risk evaluation and consequently decision-making at long-term exposure situations should be supported by science and address all environmental and human health issues, irrespective of the hazard. Issues to be further evaluated and addressed include following:

- How to address short and long term risks to different populations, proportionately?
- How to address all the environmental and human health issues, not just radiation in practice?
- How to reduce uncertainties in prognostic assessment of future conditions and impacts?
- How to make appropriate decisions in transition from emergency to existing exposure situation and later stages?

Principle of optimisation requires a common framework of protection objectives across different hazards, for people and the environment. Need for holistic, 'multi-dimensional' approaches to human health and environmental protection from multiple hazards is highlighted.

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4 HEALTH SURVEILLANCE STRATEGIES FOR LONG-TERM EXPOSURE AFTER A NUCLEAR OR RADIOLOGICAL ACCIDENT

Elisabeth Cardis

ISGlobal, Barcelona, Spain

The presentation can be found under:

https://ec.europa.eu/energy/sites/ener/files/documents/elisabeth_cardis_-_health_surveillance_strategies.pdf

5 STAKEHOLDERS INVOLVEMENT AND RESEARCH NEEDS

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5.1 Introduction

Chernobyl and more recently Fukushima accidents have demonstrated the challenges involved when managing long-term consequences of large-scale nuclear accidents. During these events, as time progressed, radiological, social and economic consequences became increasingly evident. In parallel, decisional responsibilities shifted from central government to local authorities and finally to affected communities and individuals. As a consequence, inclusive framework, including stakeholder involvement, needs to be considered to address the complexity generated by such long-lasting events.

The aim of the present paper is to address specific issues that are part of this inclusive framework namely stakeholder involvement and research needs in relation with recovery situation. In a first part, based on an experience of stakeholder involvement following Fukushima accident, some lessons will be drawn. Secondly, an overview of past and current research programmes dedicated to recovery situations together with research needs as identified at the European level will be presented. Finally, an IRSN[1] experience on stakeholder involvement in research activities in the field of post-accidental situation will be described.

5.2 Stakeholder involvement during the recovery phase: what have we learnt from nuclear accident? The Fukushima example

From 2012 to 2018, ICRP organized meetings - the so-called Dialogue meetings - in the Fukushima affected territories (Ban, 2016, Hanzawa, 2016, Lazo, 2016; Lochard, 2016). These meetings gathered various stakeholders such as experts, citizens, NGO representatives, authorities, professionals… The objectives of these meetings were to identify and exchange, with the affected people, on the problems and challenges of the rehabilitation of living conditions. They addressed a large variety of topics such as foodstuff control, role of measurements, radiological risks, compensation issues, economic issues, education, value of culture, concerns in relation with social structure…

IRSN together with CEPN[2] (Gariel et al., 2018) took the opportunity of these Dialogue meetings to perform an analysis to identify the main lessons, which can be learned from these meetings and benefit to radioprotection experts. This analysis was performed in cooperation with Japanese stakeholders and experts involved in these Dialogues in Japan through several workshops. The major findings of this study can be summarized in four topics: the human dimensions, the stakeholder's engagement (public, authorities, and experts), the co-expertise process and the development of the practical radiological protection culture.

The human dimensions

[1] Institut de Radioprotection et de Sûreté Nucléaire
[2] Centre d'Evaluation sur la Protection dans le domaine Nucléaire

The human consequences observed following the Fukushima accident are very similar to those observed after the Chernobyl accident and can be summarized as follows:

- A strong worry about health and especially about children health;
- A total loss of control on daily life. The irruption of radioactivity is a rupture, which deeply upsets the relationship of man with himself, others and his environment.
- In addition to the loss of confidence in authorities and experts, a feeling of abandonment and helplessness together with a general feeling of discrimination and exclusion.
- Finally, the main key issues that have to be addressed by each affected person are the followings: “Should I continue to live in effected territories or should I leave them”? and “Should I return or not at home” for evacuees.

The stakeholder engagement

In Belarus, after the Chernobyl accident, the stakeholder involvement was mainly driven by the experts from abroad. That was not the case following the Fukushima accident as local authorities and local communities mobilized themselves in order to initiate actions with the help of experts that were personally committed. From this experience, the feedback of the involved experts was the following:

- each individual situation is different.
- the major difficulty is to talk about the effects and risks associated with exposure to ionizing radiation. The experts should not conclude easily that the situation is safe and there advices should be consistent with the scientific knowledge and modest with respect to the uncertainties and limits of knowledge.
- Radiation protection is unavoidable but it cannot handle people’s lives. It is essential to focus on individual dosimetric data and on their distribution within the community.
- Finally, the values and choices of each person have to be respected.

The co-expertise process

The co-expertise process is the mechanism that allows both experts and affected people to assess jointly the situation. The success of this process relies on different factors:

- the establishment of places of dialogues allowing experts to listen and discuss together with affected people their concerns, questions and expectations.
- the joint assessment by local actors and experts (voluntary experts and local professionals) on the situation of the people and their community.
- the importance of means to measure and characterize the radiological situation.
- the implementation of projects to address the problems identified at the individual and community levels with the support of local professionals, experts and authorities.
- the evaluation and dissemination of the results. The importance of the social media in Japan in 2011 was pointed out.

The development of the practical radiological protection culture

The Fukushima experience has confirmed what was observed in Belarus. The co-expertise process described in the previous section is very effective to develop a practical radiological protection culture among the affected people. It allows everyone to interpret the results of measurements (ambient levels, external and internal doses, food products contamination,…). Therefore, it gives the opportunity to affected people to build their own benchmarks against radioactivity in daily life and to make their own decisions regarding their radiological protection (self-help protection).

It is obvious that, in this approach, access to individual measurements by the people with suitable and easy reading devices is critical.

Conclusion

Based on the analysis that was performed during the Dialogue meetings, it is obvious that the Fukushima accident has reinforced the role of stakeholder on recovery situation. To improve the efficiency and sustainability of protective actions, engaging stakeholders in the decision-making processes and empowering them to contribute to the assessment of the situation is crucial. Consequently, it's demanding for the experts who have to learn how to communicate and exchange with local stakeholders. In addition, there is a clear need, for the experts and the authorities to consider societal, ethical and economic aspects of a recovery situation.

5.3 On-going research projects and research needs at the European level

Since 2011, many European research projects, within the EURATOM framework, have been devoted to the main issues related to the management of recovery situation.

- the PREPARE project (2013-2016) addressed the review of operational procedures for dealing with long-lasting releases;
- the CathyMARA project (2015-2017) focused on the monitoring strategies and the assessment of thyroid doses;
- the SHAMISEN project (2015-2017) dealt on recommendations for medical and health surveillance of affected populations;
- the CONFIDENCE project (2017-2019) aims at reducing the uncertainties of radiological data in the area of long-term rehabilitation;
- the TERRITORIES project (2017-2019) has the objective of integrating management of contaminated territories characterized by long-lasting environmental radioactivity;
- the SHAMISEN-SINGS (2018-2020) focuses on the improvement of dosimetric, medical and health surveillance and stakeholder involvement;
- finally, the ENGAGE project (2018-2020) addresses the issue of the enhancement of stakeholder participation in the governance of radiological risks.

It should be noticed that, in all the above listed projects, stakeholder involvement is addressed through the participation of panels (experts, decision makers, public through the participation of NGO,…) that, in most cases, review and debate around recommendations proposed by the consortium. As far as the stakeholder involvement is concerned, several questions remain open:

- What is the representativeness of the elaborated panels? It's obvious that each member of a panel has an opinion to defend and, therefore, specific attention has to be paid when selecting the members of the panels in order to guarantee the diversity of positions among them.

- In all cases, stakeholders are included after the project has been elaborated and defined. One may ask the question of the inclusion of the stakeholders in the initial phase of a project (when elaborating it) in order to address scientific questions that are of interest for them (and not only for the experts/scientists).

Finally, it should be acknowledged that, at the European level and since the Fukushima accident, a large effort has been achieved to implement research projects dedicated to provide valuable inputs for the management of long-lasting nuclear accidents. In order to take profit of this research effort, the integration of all this new knowledge should be promoted and, hopefully, this should be done through a specific topic addressed in the work program 2018 of the EURATOM call.

5.4 Research needs defined at the European level

In 2017, the European platform NERIS, dedicated to emergency preparedness for nuclear and radiological emergency response and recovery, adopted its first roadmap for further research development taking into account the latest developments and the preliminary lessons learned following the management of the Fukushima accident. This roadmap identified three main issues (Schneider, 2018):

- Challenges in radiological impact assessment during all phases of a nuclear accident: it aims at the improvement of modelling, monitoring and development of data assimilation;
- Challenges in countermeasures and countermeasures strategies: the objective is a better knowledge on countermeasures and countermeasure strategies, an improvement of formal decision support and new development in disaster informatics;
- Challenges in setting up a transdisciplinary and inclusive framework for preparedness: this challenge aims at elaborating strategies for stakeholder engagement, involvement and public participation on different aspects such as health surveillance, socio-economic aspects,…It also propose the development of an integrated emergency management including non-radiological aspects and to address the issue of uncertainties and on the management of incomplete information.

These challenges will necessitate consolidating the connections between NERIS members with others organizations involved in the management of Chernobyl and Fukushima accidents, notably with ICRP and Japanese organizations.

5.5 Involvement of stakeholders in research activities: the IRSN experience

About ten years ago, the French "Institut de Radioprotection et de Sureté Nucléaire (IRSN)" established a "Research Policy Committee (COR)" which advises the IRSN board of directors. The COR evaluates the relevance of IRSN's research activities and how well they meet the expectations of the authorities and society. This Committee comprises a large variety of stakeholders: experts, ministry representatives, union representatives, NGO, etc. In 2017 – 2018, the research activities dedicated to recovery situations have been examined by the COR. At the end of the process, the COR provided several recommendations that are summarized in the present section.

- In the domain of the characterization of the contamination, an increase in the efforts in the domain of individual measurements (citizen science) is recommended whereas long-term collaboration with stakeholders, in the field of the transfer of radioactivity in the environment, should be initiated to ensure the ad equation of research programmes with their needs. When IRSN analyses the issues related to remediation in Fukushima, it is recommended that the consultation is not restricted to authorities but also includes both local residents and NGOs.
- In the field of health surveillance, there is a wish of more interactions with stakeholders to collect their needs and expectations together with more attention to be paid to ethical issues. It is also suggested to develop a national cancer registry in order to gather data that will be used as a reference in case a nuclear accident occurs.
- In the field of social sciences and humanities and economy, there is a necessity to address the issue of people that do not want to stay or return whereas more efforts should be made to develop research programmes on cost-benefits analysis in relation with remediation strategy or compensations.

From a more global point of view, the COR recommended a scientific and societal assessment at the end of each individual research projects to be performed. Moreover, all reports and publications from IRSN, in the field of recovery situations, should be in free-access and should be better publicized among the public. Finally, a portal that would gather all the IRSN works together with productions from both CODIRPA [3]and ANCCLI[4] should be established.

5.6 Conclusion

One should recognize that all parties involved in the management of a long lasting radiological event such as a nuclear accident would never be fully ready to cope with this situation. But, at least, the stakeholders, involving authorities, experts, NGOs, etc., should prepare themselves on different aspects based on past events feed event (Chernobyl, Fukushima,…) and on research activities in order to gain in agility in the accident happens.

During the planning and preparation phases, as well as when the real event occurs, stakeholder involvement is an absolute necessity. Several experiences, such as the one implemented by ICRP through the Dialogue meetings initiative, have shown the great interest of this involvement for both the experts and the affected people.

As far as the research activities in relation with recovery situation are concerned, the great majority, not to say the totality of the past and current European projects involved stakeholders through the constitution of panels that exchange on the results of the projects and provide recommendations. Although, some aspects, such as representativeness or the extent of their involvement remain open, this implication is a key factor for the credibility and the success of these projects.

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Ban, N. 2016. Japanese experience in stakeholder involvement: ICRP Dialogue meetings, Radioprotection, Volume 51, Issue HS1, 2016, Pages S51-S53.

[3] Comité Directeur pour la gestion de la phase post-accidentelle (Steering Committee for the management of the recovery phase)

[4] Association Nationale des Comités et Commissions Loacles (National Committee of Local Information Commission)

Gariel, JC, F. Rollinger and T. Schneider, 2018. The role of experts in post-accident recovery: lessons learnt from Chernobyl and Fukushima, Annals of the ICRP, 47(3-4), pp 254-259.

Hanzawa, T, 2016. Considerations and challenges in the ICRP dialogues, Annals of the ICRP, Volume 45, Issue 2_suppl, 1 December 2016, Pages 119-122.

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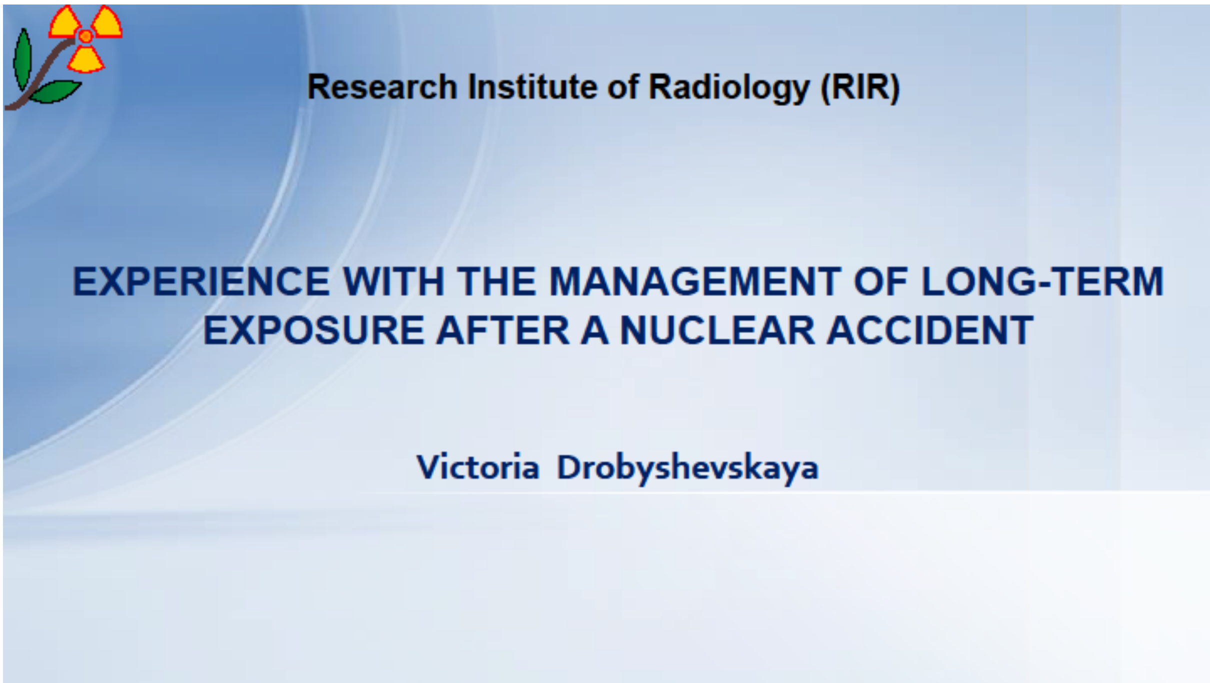
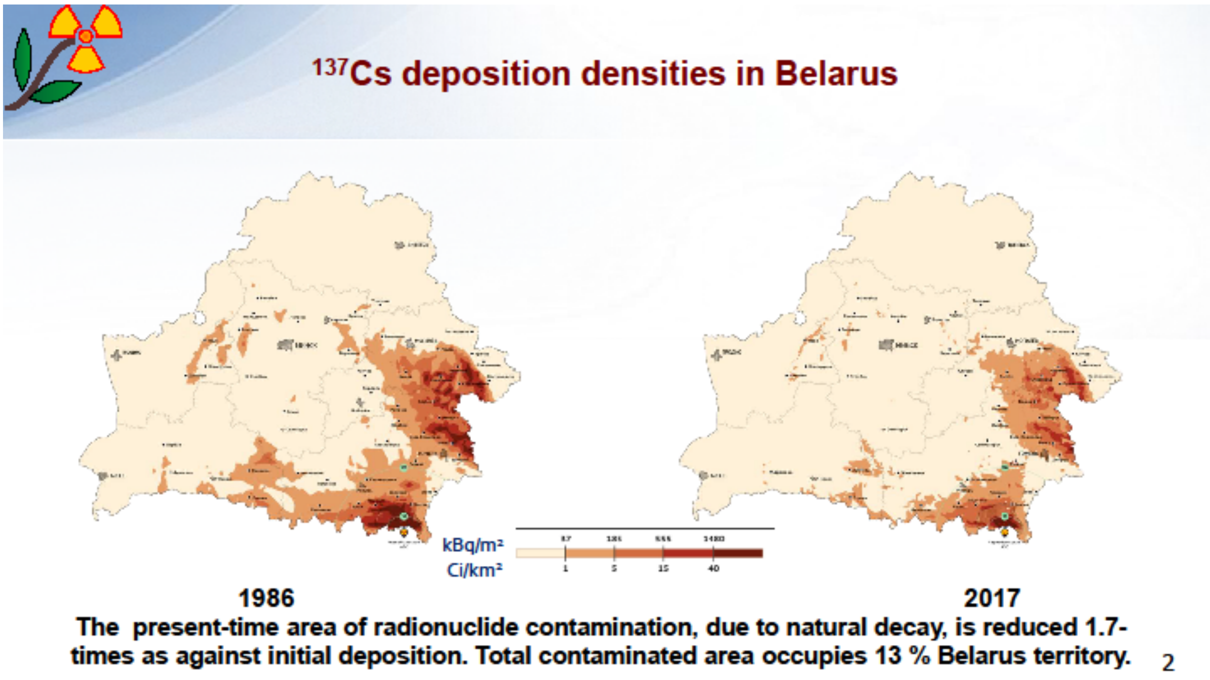
Schneider T., S. Andronopoulos, J. Camps, T. Duranova, E. Gallego, F. Gering, O. Isnard, M. Maître, C. Murith, D. Oughton, W. Raskob, 2018. The work program of NERIS in post-accident recovery, Annals of the ICRP, Volume 47, Issue 3-4, pp 221-228.

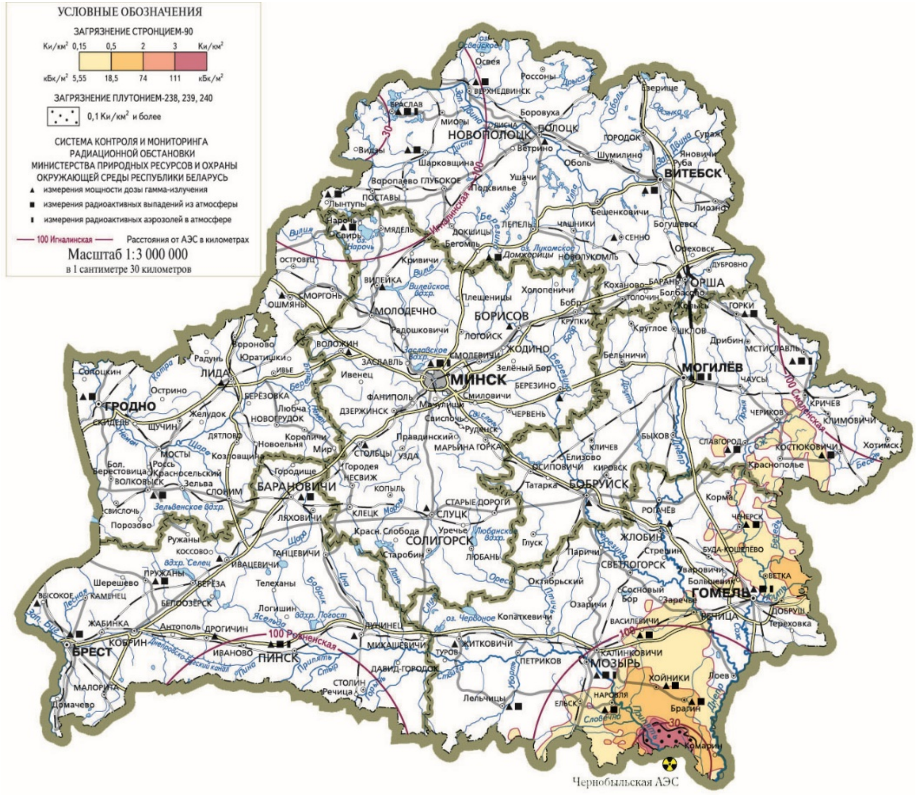
6 EXPERIENCE WITH THE MANAGEMENT OF LONG-TERM EXPOSURE AFTER A NUCLEAR ACCIDENT

Victoria Drobyshevskaya

Research Institute of Radiology (RIR), Minsk, Belarus





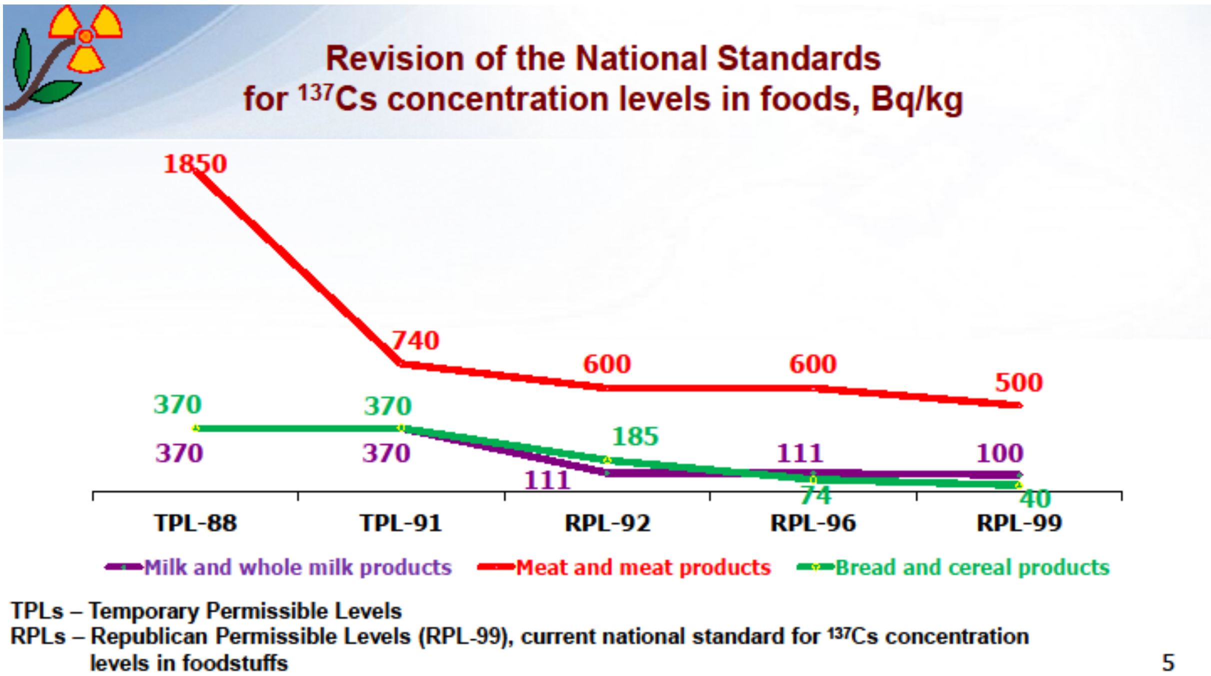


Slide 3: Belarus Contamination by ^{90}Sr and ^{238,239,240}Pu. The share of the areas contaminated by ^{90}Sr up to or above 5.55 kBq/m^2 is 5%, and these are the areas that are simultaneously contaminated by ^{137}Cs. The Gomel region territories that are contaminated with ^{238,239,240}Pu up to or above 0.37 kBq/m^2 constitute 1.3 % of the total area of the Republic.

Reference Levels for ^{137}Cs concentrations in foods (Bq/kg, Bq/l)

Product	EC	Belarus	Russian Federation	Ukraine	CUSTOMS UNION TP TC 021/2011
Year of adoption	**1986**	**1999**	**2001**	**1997, 2006**	**2011**
Bread, flour and cereal products	600	40	40–60	20-50	40
Milk	370	100	100	100	100
Baby food	370	37	40-60	40	40
Dairy products	600	50–200	100–500	100-500	100
Meat and meat products	600	180–500	160-180	200-400	200
Fish	600	150	130	150	130
Eggs	600	-	80	100	-
Vegetables, fruits, potatoes, roots	600	40–100	40–120	40–70	80

4

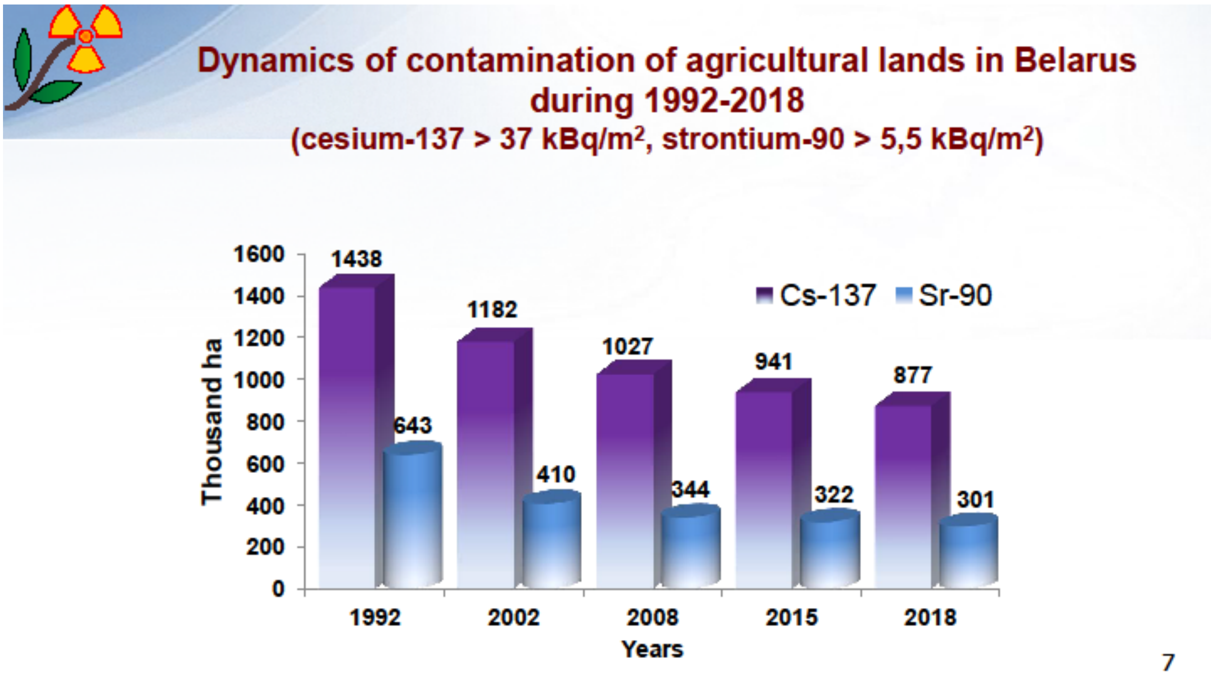


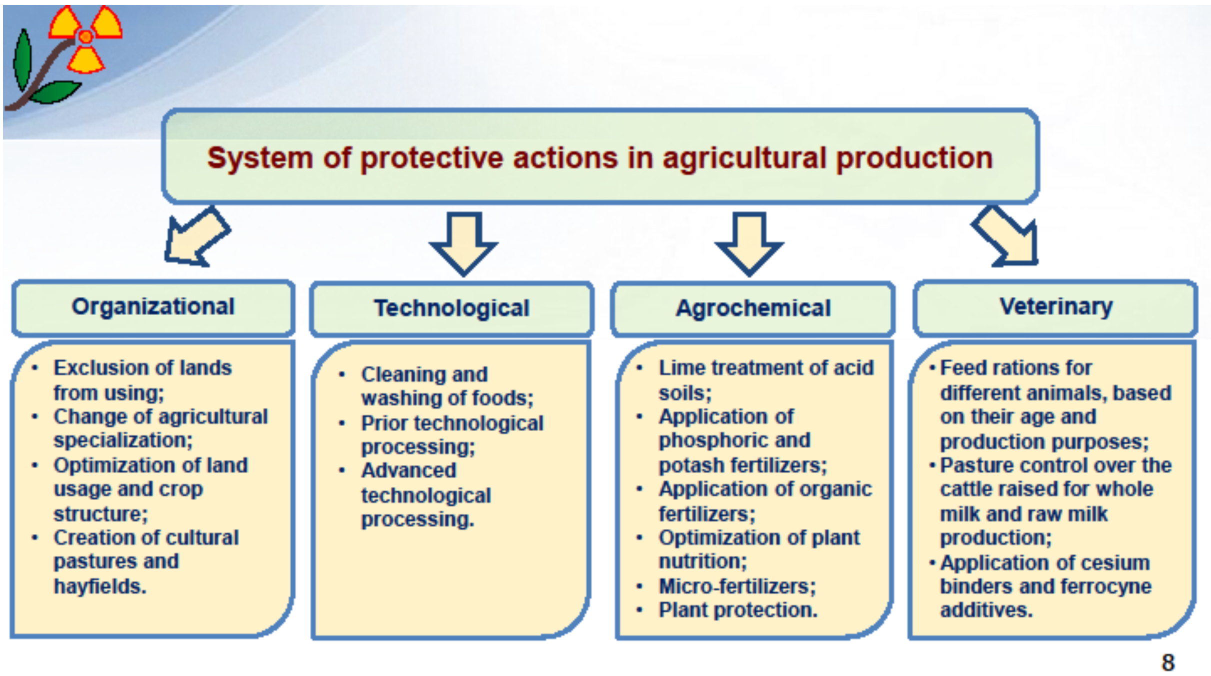
Slide 5: Starting from 1986, the national reference levels of radioactive contamination in foods and feeds have been revised 5 times, and they always stayed the most rigid when compared to the standards set by other affected countries.

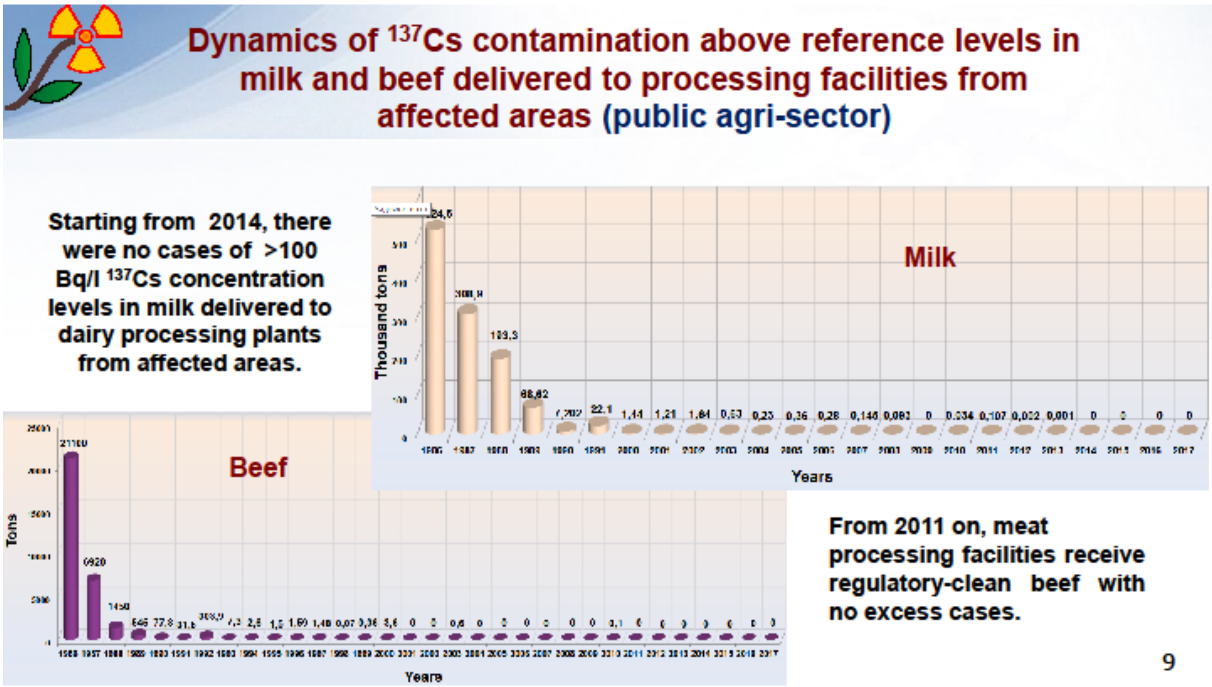
Permissible Levels for ^{90}Sr Concentrations in Food, Bq/kg, Bq/l

FOOD PRODUCT	BELARUS RPLs-99	CUSTOMS UNION TP TC 021/2011
Drinking water	0,37	not defined
Milk and whole milk products	3,7	25
Condensed and concentrated milk	not defined	100
Rennet cheese and cream cheese spread	not defined	100
Butter	not defined	60
Fish and fish products	not defined	100
Bread and cereal products	3,7	20
Potatoes	3,7	40
Vegetables	not defined	40
Baby food of any type (ready-to-eat)	1,75	25

6

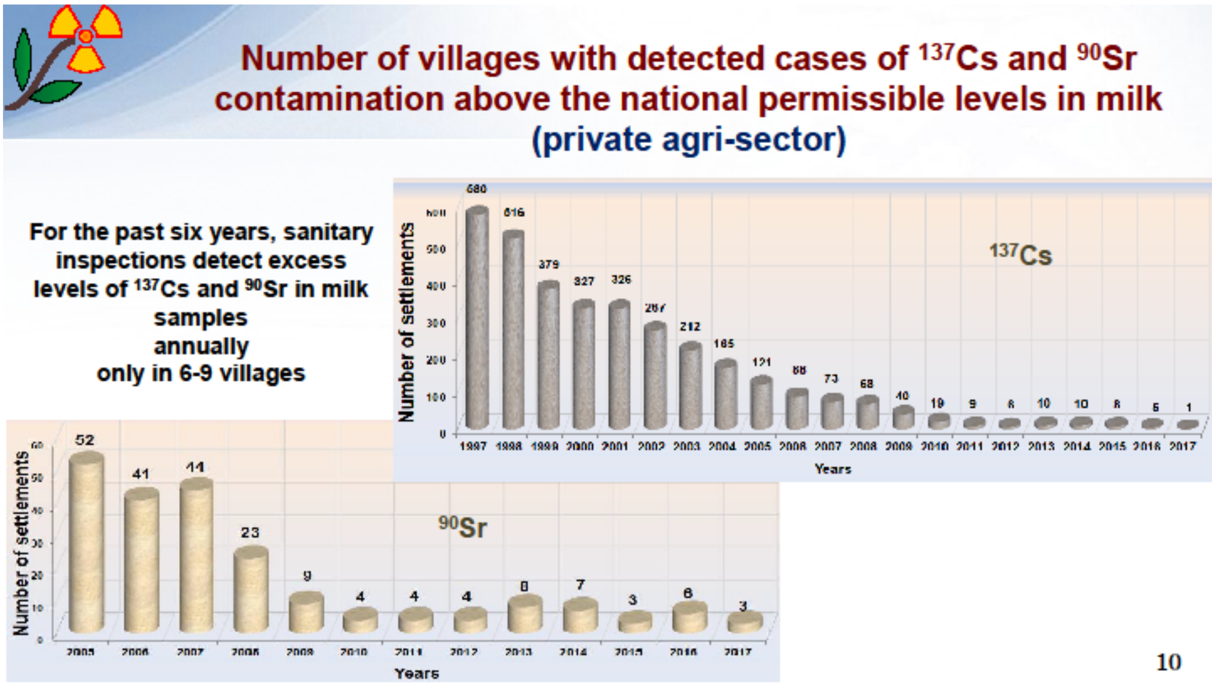

Dynamics of contamination of agricultural lands in Belarus during 1992-2018
(cesium-137 > 37 kBq/m², strontium-90 > 5,5 kBq/m²)
Cs-137
Sr-90
Thousand ha
1600
1400
1200
1000
800
600
400
200
0
1438
643
1182
410
1027
344
941
322
877
301
1992
2002
2008
2015
2018
Years
7

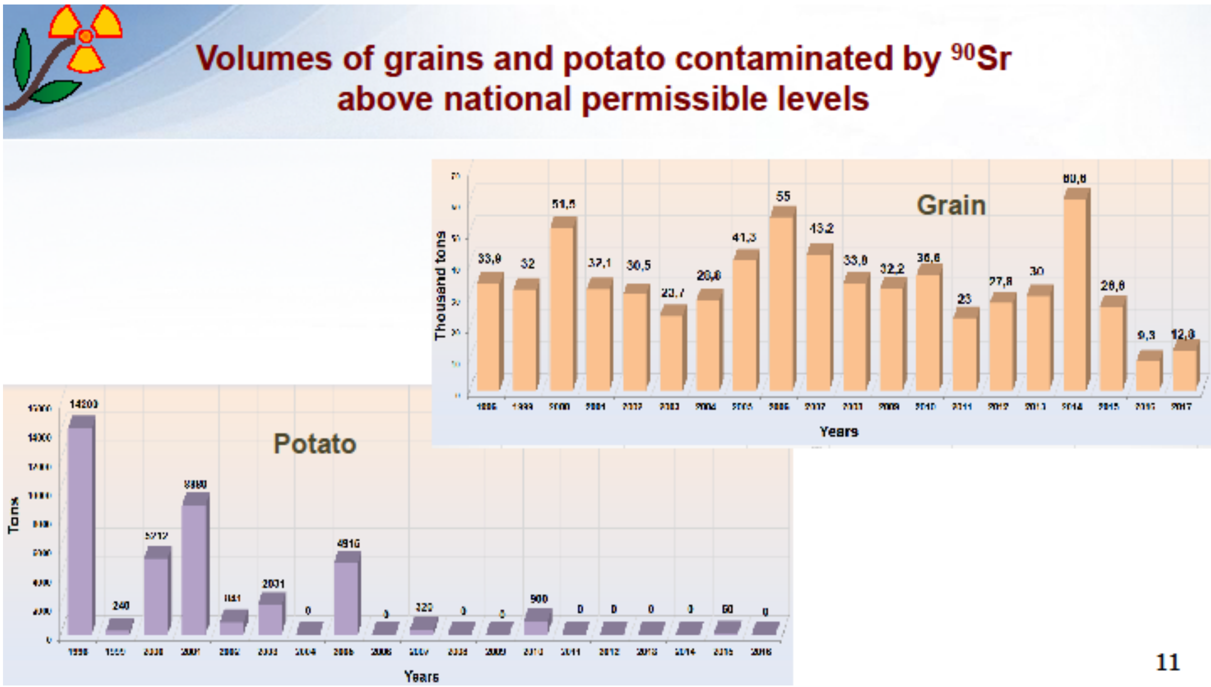

System of protective actions in agricultural production
Organizational
Technological
Agrochemical
Veterinary
• Exclusion of lands from using;
• Change of agricultural specialization;
• Optimization of land usage and crop structure;
• Creation of cultural pastures and hayfields.
• Cleaning and washing of foods;
• Prior technological processing;
• Advanced technological processing.
• Lime treatment of acid soils;
• Application of phosphoric and potash fertilizers;
• Application of organic fertilizers;
• Optimization of plant nutrition;
• Micro-fertilizers;
• Plant protection.
• Feed rations for different animals, based on their age and production purposes;
• Pasture control over the cattle raised for whole milk and raw milk production;
• Application of cesium binders and ferrocyne additives.
8



Slide 9: For the post-accident period in Belarus, the transfer of ^{137}Cs from soil into farm produce has decreased 15 – 20 times. Around half of this reduction is due to the implementation of agricultural countermeasures, the other half is due to natural decay factors and fixation of caesium radionuclides in soil. For a number of consecutive years, the grain, potato and vegetables produced in contaminated areas have been 2 – 10 times less their respective ^{137}Cs permissible levels.

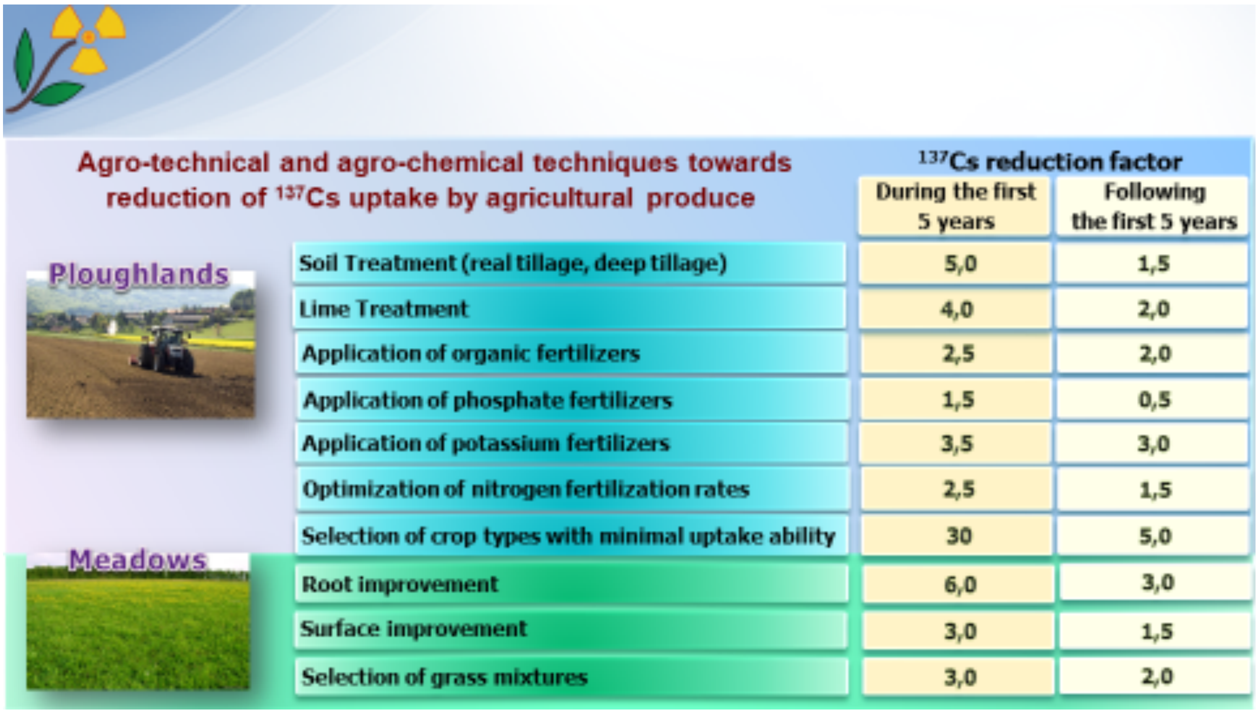
The pre-slaughter low-caesium concentration feeding approach applied on a large scale in contaminated areas almost completely excludes the cases of rejected cattle, when animals are not accepted by meat processing plants and slaughterhouses due to increased results of on-site live animal dosimetry.





Slide 11: It is due to the preservation and consistency of protective measures, that most of the present-time ^{90}Sr-contaminated farmlands can produce all sorts of regulatory clean foodstuffs (^{90}Sr contamination 60 % arable area and 70 % meadow area).

The rest of the lands contaminated by ^{90}Sr are also able to give regulatory clean products, but they are restricted to certain crop varieties and specific purposes of using the end product.

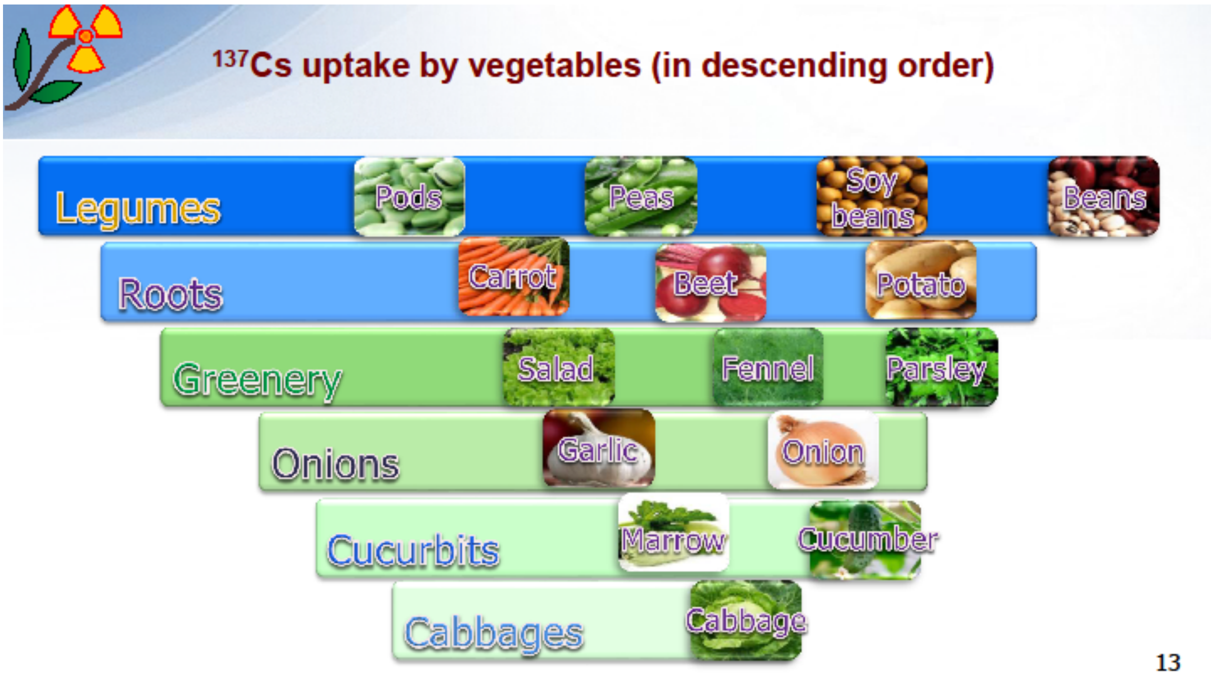


Agro-technical and agro-chemical techniques towards reduction of ^{137}Cs uptake by agricultural produce		^{137}Cs reduction factor	
		During the first 5 years	Following the first 5 years
Ploughlands	Soil Treatment (real tillage, deep tillage)	5,0	1,5
	Lime Treatment	4,0	2,0
	Application of organic fertilizers	2,5	2,0
	Application of phosphate fertilizers	1,5	0,5
	Application of potassium fertilizers	3,5	3,0
	Optimization of nitrogen fertilization rates	2,5	1,5
	Selection of crop types with minimal uptake ability	30	5,0
Meadows	Root improvement	6,0	3,0
	Surface improvement	3,0	1,5
	Selection of grass mixtures	3,0	2,0

Slide 12: Agricultural countermeasures applied during the first post-Chernobyl years (1986–1992) provided that the transfer of ^{137}Cs into agricultural crops could be lowered 3 – 8 times.

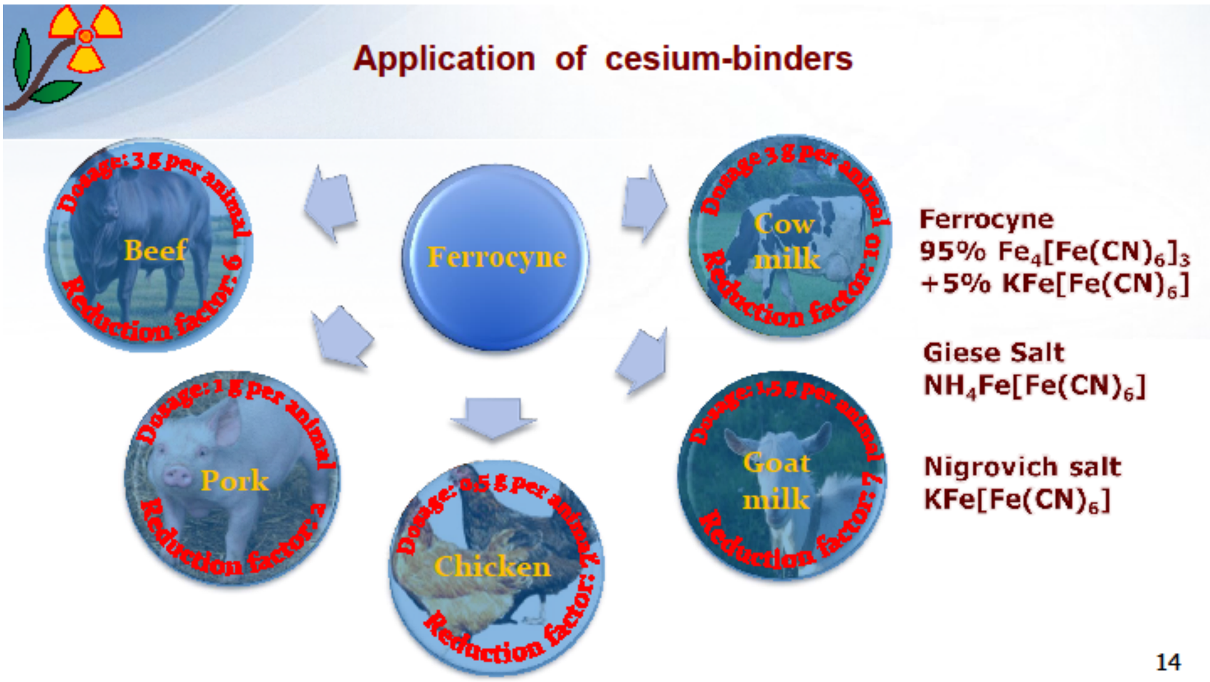
During the next period (1992–2010), the contribution of natural processes such as fixation of caesium by clay minerals and radioactive decay, prevailed over the effect from countermeasures. During those years, the efficiency of protective measures dropped, on average, by 50–80%.

Nowadays, the main contribution to the decrease of caesium concentrations in farm products belongs to radioactive decay.

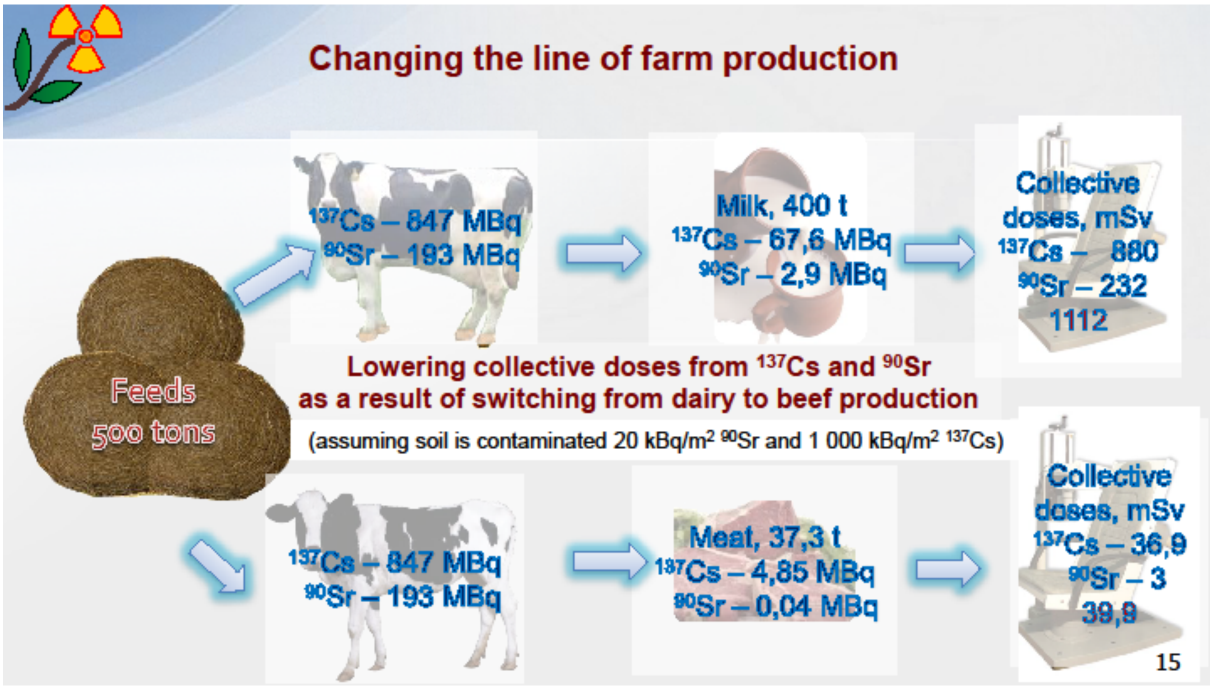


Slide 13: Selection of green crops with the lowest ^{137}Cs accumulation abilities is the most available means of reducing its impact on the output. Using this approach, and based on a vegetable crop, it is possible to reduce ^{137}Cs contamination up to 30 times.

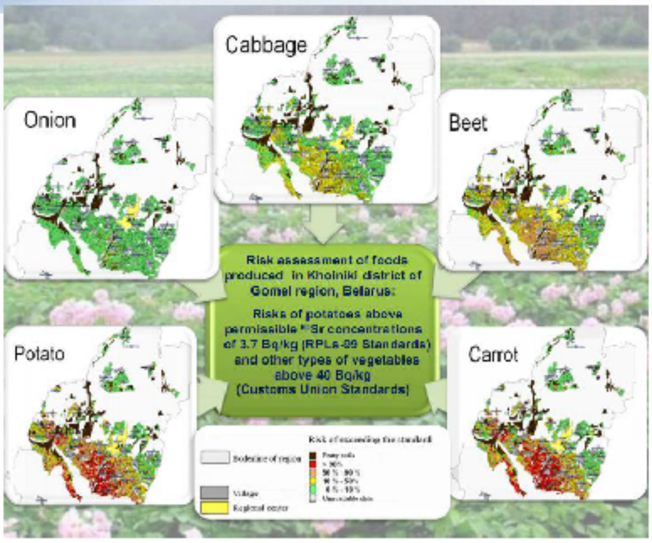
The right choice of what vegetables to grow can provide from 2 to 3 times less radionuclides accumulated in the output product.



Slide 14: An important countermeasure applied in animal farming was using special caesium-binding feed additives and preparations. As a result, the caesium concentrations in milk, meat, eggs and other products could be from 2 to 11 times reduced.



Models and software: RISKAgro (designed by RIR)



RISKAgro is a special forecast tool designed by RIR to make rapid, real-time predictions of radiation levels in major vegetables and assess risk of output contamination levels above the existing national and other food safety standards.

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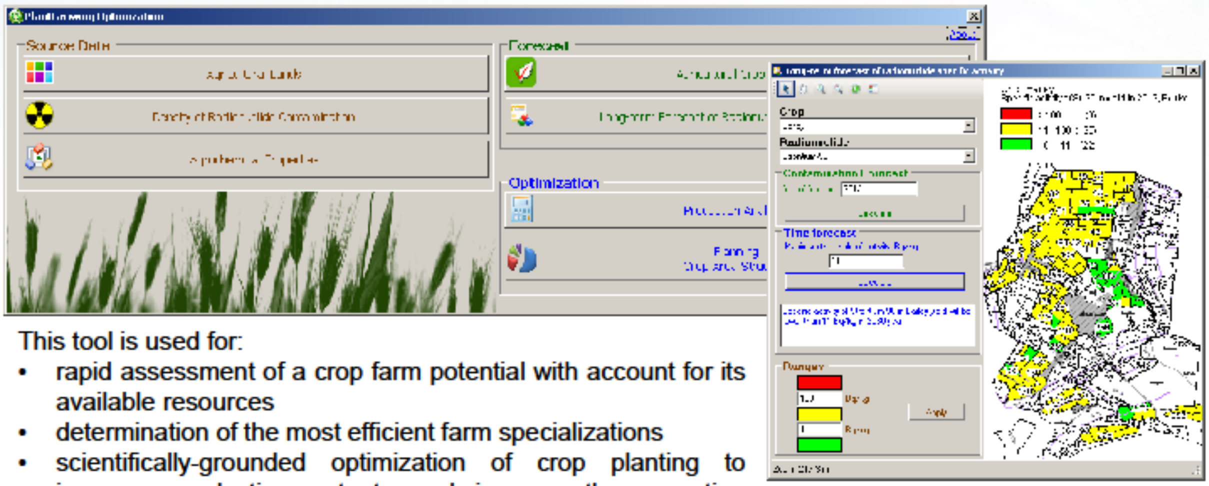
Models and software: AgroOptimization tool: efficient use of arable lands (designed by RIR)



This tool is used for:

- rapid assessment of a crop farm potential with account for its available resources
- determination of the most efficient farm specializations
- scientifically-grounded optimization of crop planting to increase production outputs and improve the operating efficiency of a farm enterprise

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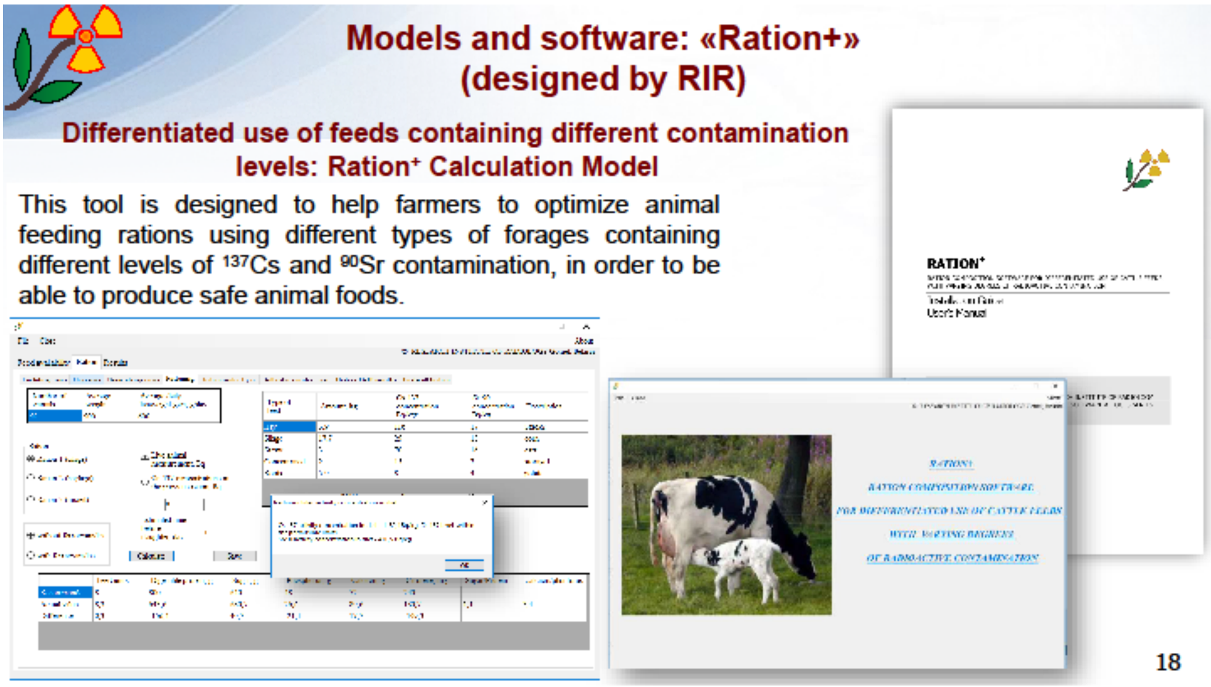
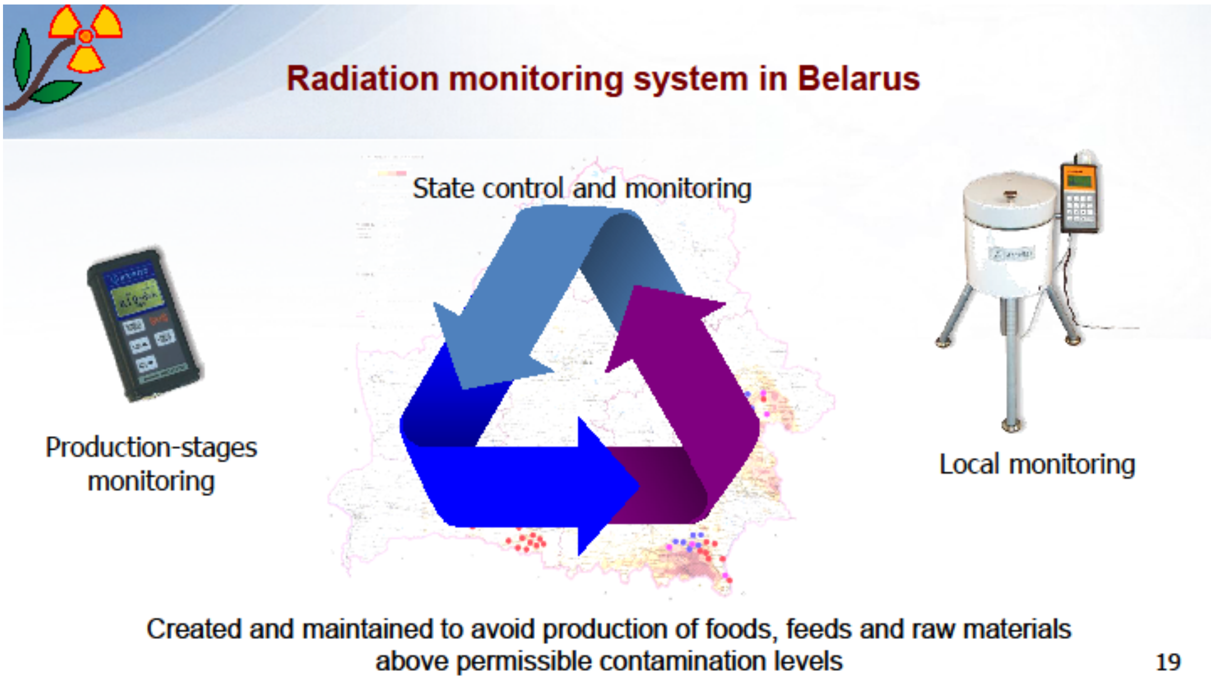
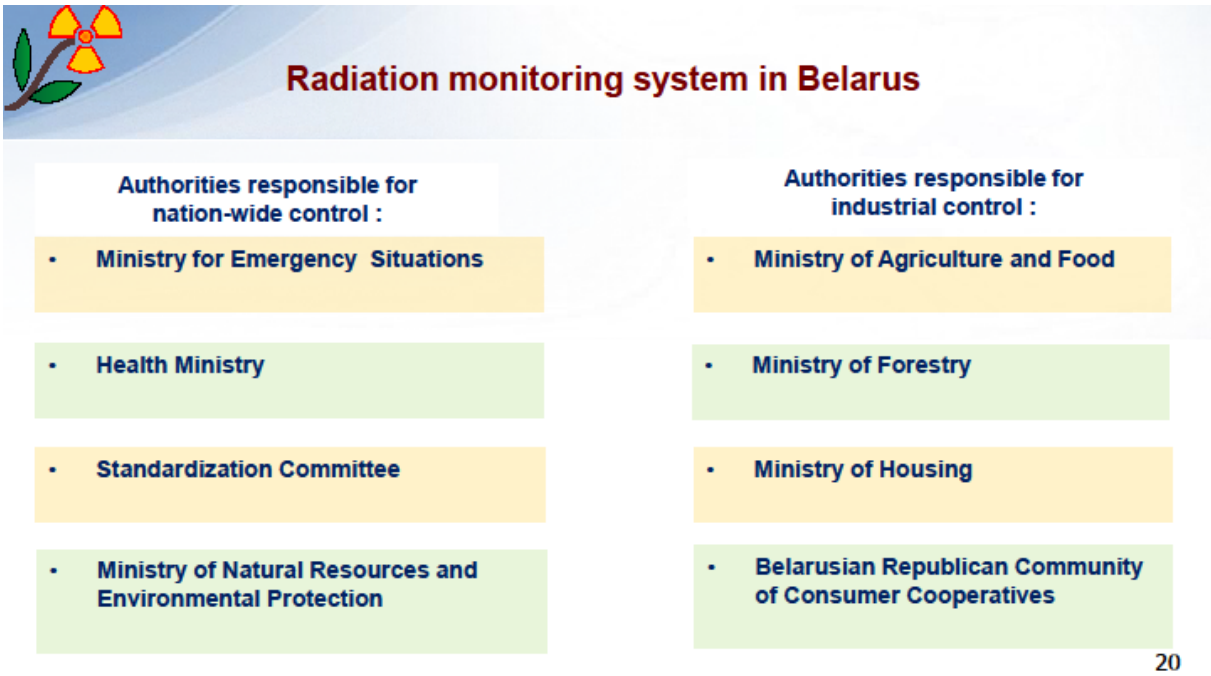
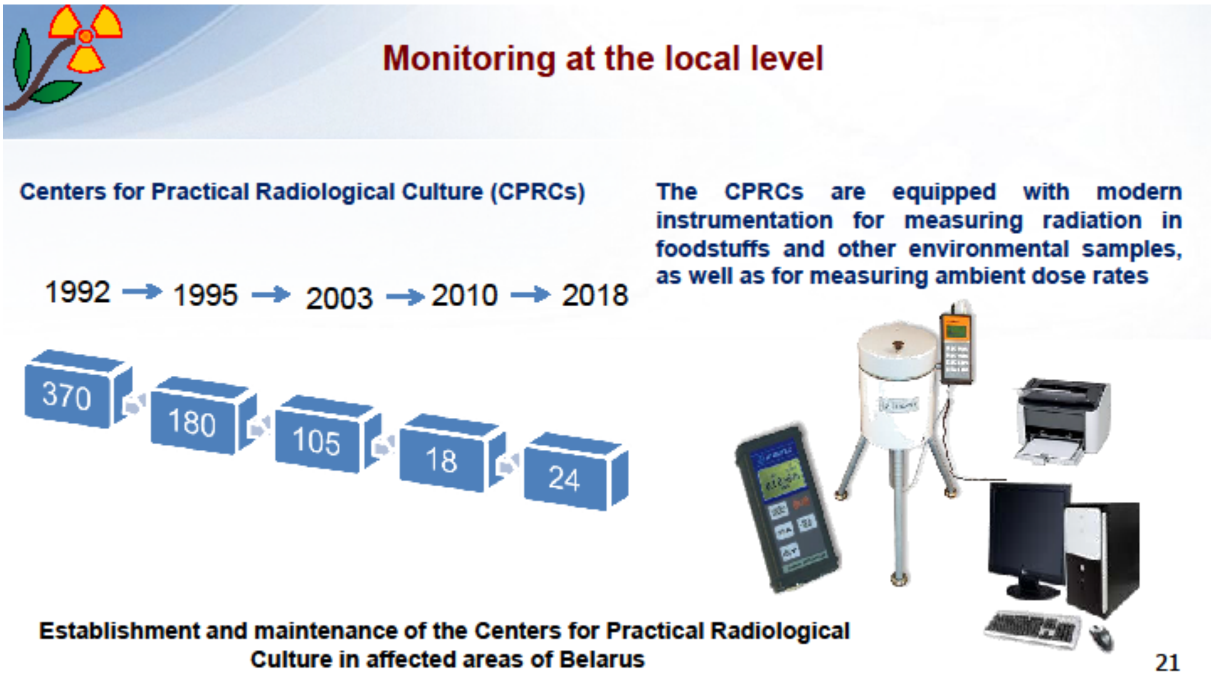
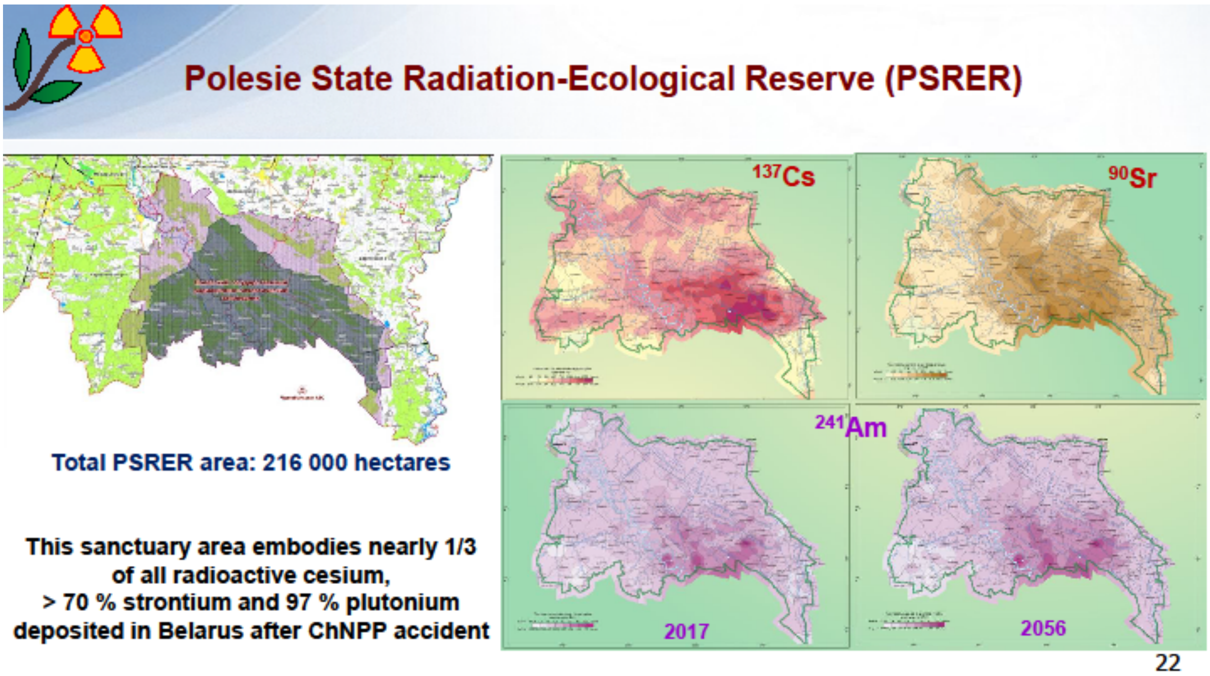

Models and software: «Ration+»
(designed by RIR)
Differentiated use of feeds containing different contamination levels: Ration+ Calculation Model
This tool is designed to help farmers to optimize animal feeding rations using different types of forages containing different levels of 137Cs and 90Sr contamination, in order to be able to produce safe animal foods.
RATION+
RATION+
RATION COMPOSITION SOFTWARE
FOR DIFFERENTIATED USE OF CATTLE FEEDS
WITH VARYING DEGREES
OF RADIOACTIVE CONTAMINATION
18


Radiation monitoring system in Belarus
State control and monitoring
Production-stages monitoring
Local monitoring
Created and maintained to avoid production of foods, feeds and raw materials above permissible contamination levels
19

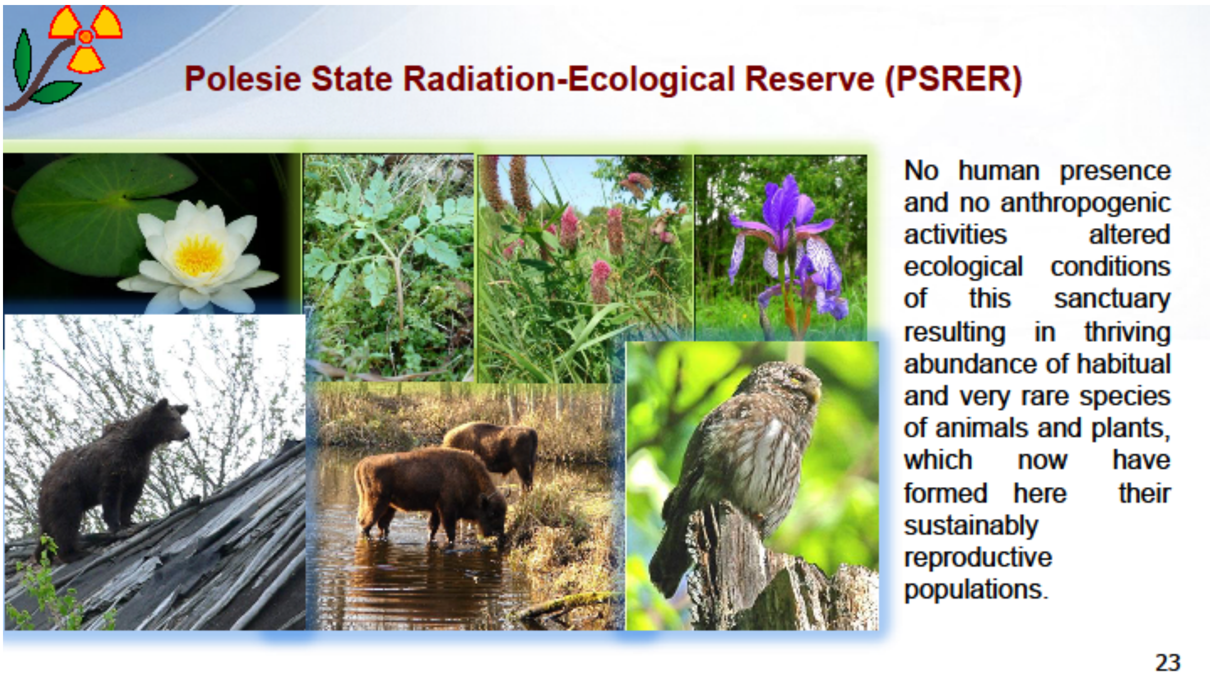




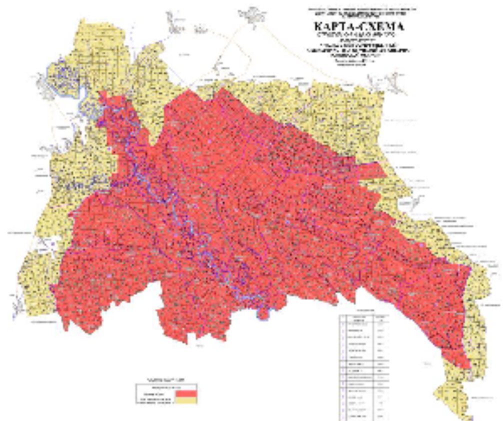
Slide 21: The main objective is to educate children of the basics of radiology, teach them how to measure radiation levels in foods, feeds, soil samples, wild berries and mushrooms, measure ambient dose rates, and to pass the information through children to their parents and friends.



Slide 22: Despite all scientific efforts and achievements, some of the affected territories will never be used for economic purposes not now and not even in the long term, due to their contamination by transuranic elements.



Radiation-Ecological Reserve: unique grounds for science and experimental activities



sanctuary (147.7 thous. ha)

experimental grounds (68.4 thous. ha)

This area is a unique experimental site for studying the effects of radioactive contamination on natural ecosystems and former agricultural lands. Reserve's experimental facilities include the experimental grounds for wood processing, crop planting, horse farming and bee keeping

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Summary and conclusions

- Post-accident experience of Belarus following the Chernobyl NPP disaster has shown that agricultural protective measures were, in general, highly effective: about 40 percent averted internal radiation dose.
- Implementation of countermeasures in agriculture revealed critical areas with prevailing boggy, sandy and peaty soils, where even relatively low soil contamination by long-lived radionuclides can lead to significant contamination of crops and animal products due to the increased transfer of radionuclides from soil into plants.
- Protective measures such as improving soil fertility and maintaining soil properties at their optimal level are strategically important because of their long-term effect on ensuring regulation-wise clean food products.
- Information-sharing and direct involvement of rural residents in the recovery processes and decision-making is an important added-value factor that contributes to overall optimization of protective measures and improvement of the life quality.

25

7 SUMMARY

Prepared by Dr. Helena Janžekovič

on behalf of the
Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of Experts[5]

7.1 Introduction

This chapter provides the rationale of the seminar, summarises the presentations and the conclusions of the round-table discussion, and identifies the potential implications of the Scientific Seminar on "*Management of long-term exposure after a nuclear or radiological accident*", held in Luxembourg on 14 November 2018. It takes into account the discussions that took place during the seminar and during the subsequent meeting of the Article 31 Group of Experts, although it is not intended to report in an exhaustive manner all the opinions that were expressed. The document has been submitted for comments to the lecturers, as far as their contributions were concerned.

7.2 The Article 31 Group of Experts and the rationale of the Scientific Seminars

The Article 31 Group of Experts is a group of independent scientific experts referred to in Article 31 of the Euratom Treaty, which assists the European Commission in the preparation of the EU Basic Safety Standards for the protection of the health of workers and members of the public against the dangers arising from ionising radiation. This Group of Experts has to give priority to the protection of health, to safety and to the development of the best available operational radiation protection. To this end, the Group of Experts is committed to proactively scanning new or emerging issues in science and technology, and ongoing developments in the area of radiation protection and informing the European Commission on potential policy implications.

In this context, a Scientific Seminar is devoted every year to emerging issues in Radiation Protection – generally addressing new research findings with potential policy and/or regulatory implications. Following suggestions from the Working Party on Research Implications on Health and Safety Standards (WP RIHSS), the Article 31 Group of Experts selects the topic of the seminar. The WP RIHSS is charged with the preparation and the follow up of the seminar. Leading scientists are invited to present the status of scientific knowledge in the selected topic. Additional experts, identified by members of the Article 31 Group from their own country, take part in the seminars and act as peer reviewers. The Commission convenes these seminars in conjunction with a meeting of the Article 31 Group of Experts, in order to allow the Group to discuss the potential implications of the presented scientific results. Based on the outcome of the Scientific Seminar, the Group of Experts referred to in Article 31 of the Euratom Treaty may recommend research, regulatory or legislative initiatives. The European Commission takes into

5 Besides H. Janžekovič (who was acting as rapporteur for the seminar), the following members of the Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of Experts contributed to the preparation of this overview: L. Lebaron-Jacobs, F. Bochicchio, R. Huiskamp, P. Krajewski, and P. Smeesters. They were assisted by S. Mundigl from the European Commission.

account the conclusions of the Experts when setting up its radiation protection programme. The Experts' conclusions are also valuable input to the process of reviewing and potentially revising European radiation protection legislation.

7.3 Key Highlights of Presentations at Scientific Seminar on Risk Communication

Bharat Patel – *The European context: Requirements on the management of long-term exposure in the BSS Directive*

Directive 2013/59/Euratom (BSS Directive) strengthened emergency preparedness and response (EPR) requirements. This is complemented by Directive 2011/70/Euratom which includes the management of radioactive waste resulting from an accident. In the BSS Directive, several articles including two Annexes are dedicated to EPR. The Directive introduces reference levels, addresses protection of emergency workers, emergency exposure situation, emergency response, information to the public, emergency management system, emergency preparedness and international cooperation. The time dimension regarding management of an emergency is considered under:

- emergency phase and emergency exposure situation;
- transition phase;
- long-term consequences management and existing exposure situation.

The emergency management systems should include provisions for the transition phase including recovery and remediation. Cooperation with other Member States and third countries should be allowed for in the transition phase.

The management of long-term consequences should be focused on the establishment of strategies and the objectives to be pursued. The BSS Directive gives a comprehensive set of requirements regarding, amongst others, optimised protection strategy for managing contaminated areas, delineation of areas, assessment of protective measures, identification of affected public and assessment of doses. Appropriate reference levels for existing exposure situations shall be set, generally in the range 1 – 20 mSv/y. Management of long-term consequences should address areas with residual contamination and return to normal activities. An environmental monitoring program should be in place. In particular, the BSS Directive foresees that once the existing exposure situations are identified, implementation of the strategies takes place through coordination among different parties and involvement of stakeholders. The management should include support to the affected population and information provision and should incorporate self-protective actions, provisions enabling individuals to manage their own exposure, monitoring and remedial measures.

Patrick Smeesters – *Objectives of the seminar and introduction to the topic*

Questions related to nuclear emergencies have been discussed in previous EU Scientific Seminars: Fukushima: lessons learned and issues, in 2014; Risk communication, in 2015; Emerging issues with regard to organ doses, in May 2017; Epigenetic effects – potential impact on radiation protection, in November 2017, which allowed to identify a lot of issues that have a potential impact on management of long-term exposure after a nuclear or radiological accident.

An important issue that was highlighted in the 2014 and 2015 seminars is related to social aspects and communication with local populations. Trust is a key factor and to create it, there is a need for transparent and balanced scientific information, including uncertainties, and to recognize that expert and non-expert value judgement about risk may differ. Experts and decision makers among themselves also differ in their value judgment about risk: some (currently the majority) tend to emphasize the possibility of false positives (i.e. of overestimating the risk), while other underline the possibility of false negatives (i.e. of underestimating it) and the need of precaution. To bridge the gaps, there is a need for an arena for stakeholder participation to enhance the understanding about arguments and positions.

These last years, several EURATOM research programmes focused on specific studies which allowed better understanding on radiation-induced effects, particularly non-cancer effects. The most relevant results were presented and discussed during the last two EU Scientific Seminars in 2017. Radiation-induced effects on the brain, the cardiovascular system and the lens of the eye have been observed at low (less than 100 mSv) and intermediate (100-500 mSv) doses. Studies are ongoing to elucidate the mechanisms implicated in the genesis of these effects, such as epigenetic mechanisms and the role of the mitochondria. Similar mechanisms are suspected to induce other radiation induced chronic non-cancer effects, particularly in childhood cancer survivors, such as metabolic diseases (i.e. diabetes). While clear radiation-induced health effects are observed at intermediate doses (100 to 500 mSv), biological effects (with an uncertain link to health outcomes) are already observed at lower doses in the order of a few tens of mSv.

This has a potentially important impact for radiation-induced brain effects after exposure of children and after in utero irradiation, including the early prenatal period. These effects present a cumulative character and are reinforced by exposure to other environmental agents.

Although many uncertainties still exist, the current knowledge is nevertheless sufficient for taking into account the risk of such effects in radiotherapy, interventional radiology and cardiology, paediatric radiology (CT), and in accidental situations (re-evaluation of criteria for protecting in particular pregnant women and children when managing long-term exposure after a nuclear or radiological accident, including evacuation and relocation levels).

Jean-Luc Godet – *Management of nuclear emergency and post-accident situations (population protection measures)*

In France, the regulatory strategies for the management of long-term exposure after a nuclear or radiological accident are under discussion. The *National response plan for major nuclear or radiological accidents* has been adopted in February 2014. It covers the emergency organisation, the strategy and main measures during the emergency phase and at the start of the transition phase, i.e. some of the actions from the emergency phase should be extended at the end of the early phase into the transition phase. The plan mentioned considers altogether eight accidental situations. The post-accidental phase has:

- transition;
- long-term phase.

The adoption of *National response plan for major nuclear or radiological accidents* resulted in a comprehensive list of activities in France, e.g. iodine tablets pre-distribution near NPPs and communication with stakeholders. The post-accident phase management doctrine has been published in November 2012. It was prepared by CODIRPA (*Comité directeur pour la gestion de la phase post-accidentelle*) established in 2005. CODIRPA has a pluralistic structure, e.g. it includes local and national authorities, institutional experts and associations. The updating of the doctrine took place in the period 2012 – 2018. Experience from the Fukushima accident, e.g. long-term release, is taken into account as well as existence of new techniques for monitoring, feedback from national exercises and introduction of reference levels for effective dose. The doctrine is based on post-accidental zoning.

In the doctrine from 2018, the reference level for relocation in the post-accident phase is updated and set to 20 mSv in the first year and then to 1 mSv/y excluding ingestion. The activities taking place to reduce the exposure of the population under the reference level of 1 mSv/y in the medium term include among others: issuing recommendations, reducing environmental contamination, developing monitoring programmes related to the environment and affected population and information programmes for different stakeholders, e.g. consumers and enterprises. The 2018 doctrine stipulates that home-grown foodstuffs are banned within the “conventional perimeter” at the end of the release. This perimeter is to be defined at the preparedness step and is going to be later updated taking into account monitoring results. Later, *Agricultural Production Surveillance Zones* are established based on European Maximum Permitted Levels for different food categories such as milk and leaf vegetables.

In the discussion after the presentation, an expert pointed out that during the post-accident phase the use of specially developed software related to contamination of agriculture products might facilitate the implementation of control over contaminated food. The experts also pointed out that it might be a challenge to assess 1 mSv/y in particular when ingestion should be taken into account and that predefined zoning might have drawbacks. They also noted that there is no harmonisation within Europe regarding transport in the post-accidental phase.

Jelena Mrdakovic Popic – *Risk evaluations of long-term exposure after a nuclear or radiological accident*

Numerous legacy sites all over the world offer an opportunity to learn how to manage long-term exposure after nuclear or radiological accidents. Environmental risk assessment typically covers human health assessment and ecological assessment. Regulatory decision-making covers three parts, i.e.

- planning, hazard recognition and problem formulation;
- analyses, i.e. technical steps;
- risk evaluation and decision making.

There is no universal approach on how to assess and how to manage radiation risk, i.e. there should be case specific approach based on prevailing circumstances. These circumstances include not only the radioactive source characteristics e.g. radionuclides involved, variation of pollution degree, volume and activity of waste, chemical and physical hazard, but also current standards and foreseen end use of the site. Further, it needs to be considered what, who, how and how long management should take place, and the appropriate allocation of resources. The paper presented an overview of the risk evaluation methodology in the regulatory approaches to management of long-term exposures, for two cases:

- long-term exposure situation in Norway due to the Chernobyl fallout after the accident in 1986;
- long-term exposure situation in the area of Mayak PA Facility due to complex radiation situation, consequence of combination of several historical factors.

Management of long-term exposure situations after a nuclear or radiological accident is not a linear process, rather a long, often messy process of uncertainty that uncovers further problems with its progress. Although the focus is mainly on radiation protection considerations, the complexity of post-accident situations, which cannot be managed without addressing all the affected domains of daily life, i.e., environmental, health, economic, social, psychological, cultural, ethical, and political should be understood and properly considered. It is necessary to acknowledge that we are living in a changing world and it is important, therefore, not to overpromise, but do the best in a holistic, the most transparent and consistent approach possible.

Risk communication is internationally recognised as an issue of great significance in the long-term existing exposure situations. Public risk perceptions and the level of anxiety over long-term radiation exposure change depending on the complexity of situation. Confidence and trust in the authorities and their decision-making should be based on transparency, efficient communication and involvement of variety of stakeholders, especially local community in the management process. Stakeholder involvement and confidence related to nuclear legacy management are important issues, deserving additional focus.

In the discussion following the presentation, it was noted that post-accident management in a more complex situation, for example with a view to respecting the Sami culture, requires open discussions in particular on local levels and transparency in all steps of decision-making.

Elisabeth Cardis – *Health surveillance strategies for long-term exposure after a nuclear or radiological accident*

There are clear indications that accidents, remediation situations, dosimetric and health surveillance can have an impact on health. The affected population has stress due to various reasons. They experience, for example, uncertainties and conflicting information about the related health effects; worry about the effect of relocation (loss of home, social relations, work, control on one's life), or the contamination levels of milk, food, water food and the environment. The related health impact includes an increase in morbidity, e.g. serious mental health impact, obesity, and mortality, e.g. through accidents and suicides.

As part of the H2020 research programme, the SHAMISEN project, *Nuclear Emergency Situations – Improvement of Medical and Health Surveillance* has been initiated with the objective to

- build upon lessons learned from experiences of populations affected by Chernobyl, Fukushima and other radiation accidents;
- develop recommendations for medical and health surveillance of populations affected by previous and future radiation accidents.

SHAMISEN resulted in 28 *Recommendations* for health surveillance and medical follow-up of affected populations, with particular attention to dose assessment supporting and improvement of living conditions of affected populations.

The programme also aimed at improving estimates of radiation-induced risk after accidents.

The researchers analysed health surveillance programmes following the Chernobyl and Fukushima accidents in order to draw up the recommendations. The recommendations cover three phases: the preparedness phase, early and intermediate phase, and the long-term phase.

Health screening programmes need to be well justified and well designed in advance. These programmes need to follow biomedical ethical principles and take into account the WHO principles for systematic screening. The objective of health screening programmes should be clear, e.g. identification of cancer, other radiation-related health effects, non-radiation-related health effects, and psycho-social effects. The focus should not only be on radiation related effects, but also on psychosocial and socio-economic impacts induced by the accident. A systematic thyroid cancer screening, for example, is not recommended but it must be available with appropriate consulting for those who would request it. A clear distinction needs to be made between health surveillance programmes and epidemiological programmes.

Long-term follow-up should be based on exposure levels sufficiently high to cause adverse health effects. The experts preparing and conducting the programme should recognise and address the positive and negative consequences of health surveillance, engage with affected populations in designing health surveillance programmes, provide access to and advice on use of personal dosimetry and monitoring. They should also respect autonomy, empowerment and free choice and identify the needs, concerns and communication requirements of different groups.

After the presentation, the experts debated the possibility to share equipment in cases for large-scale screening programmes.

Jean-Christophe Gariel – *Stakeholder involvement and research needs*

Lessons learnt from recovery phases of large-scale accidents demonstrated the need to enhance stakeholder involvement. Experience from the ICRP meetings in Fukushima prefecture (2012 – 2018) demonstrates:

- human dimension of the accident and its consequences;
- enhanced stakeholder's engagement, i.e. local authorities and local communities organized themselves;
- existence of co-expertise process i.e. processes where experts and stakeholders work together;
- development of practical radiation protection culture, e.g. interpreting measurement results and building benchmark against radioactivity in daily life.

The Fukushima accident stressed the important role of stakeholders in recovery situations. Efficiency and sustainability of protective measures are improved when stakeholders are involved. It also demonstrated that it is demanding for an expert to learn how to communicate with local stakeholders. Further analyses of social, ethical and economic aspects are clearly needed.

Recent on-going EU research programmes (2015 – 2020) addressing stakeholder involvement include PREPARE, CAThyMARA, SMAMISEN, CONFIDENCE, TERRITORIES, SHAMINSEN-SINGS, and ENGAGE. In all these projects, stakeholders are involved through participation in panels (experts, decision makers, public through NGO…) that, usually, review and debate the recommendations proposed by the consortium. However, the representativeness of such panels can be questioned. It may be useful to involve stakeholders already during definition and implementation of a research project.

NERIS roadmap identified research needs in the EU, namely:

- improvement in radiological impact assessment;
- countermeasures and countermeasures strategies;
- transparency and inclusive framework for preparedness.

In France, the COR (Research Policy Committee) has been established to give advice to the IRSN board of directors. The members of the COR gave advice on recovery situations. They pointed out a list of recommendations to be studied, e.g. to increase the individual measurements (citizen science), to improve long-term collaboration with stakeholders in relation to transfer of radionuclides in the environment, to address ethical issues regarding health surveillance, to develop health registry, to address issues regarding people who do not want to stay or return, and to address issues of people working on contaminated areas and cost/benefit analysis. They suggested that all reports and publications from IRSN should be in free-access and should be better publicized among the public, as well as the creation of a portal that would gather all IRSN work on recovery and work from CODIRPA and ANCCLI (National association of Local Information Committees).

After the presentation, experts pointed out a problem related to the definition of "multidisciplinary" research. They also noted difficulties when searching for stakeholders, e.g. the decision which groups are relevant and which are not.

Victoria Drobyshevskaya – *Experience with the management of long-term exposure after a nuclear accident*

The releases from the Chernobyl accident resulted in the contamination of Belarus among other countries. Today the total contaminated area covers 13 % of the Belarus territory. Due to natural decay, the radioactive contamination decreased 1.7 – times compared to the initial deposition. Radionuclides identified include not only Cs-137 but also Sr-90 and Pu-238, Pu-239 and Pu-240. In Belarus, different reference levels for Cs-137 and for Sr-90 concentrations applicable for different types of food, e.g. fish, bread and baby foods, were established. These reference levels were reviewed and revised over time and generally decreased as a rule.

A comprehensive system of protective actions in agricultural production has been initiated including:

- organisational measures, e.g. creation of cultural pastures and hayfields;
- technological measures, e.g. cleaning and washing of food;
- agrochemical measures, e.g. lime treatment of acid soils;
- veterinary measure, e.g. application of caesium binders such as ferrocyne.

The measures resulted in evident decreases of the contamination of the food samples which were above the national permissible levels.

Agro-technical and agro-chemical techniques were introduced to reduce Cs-137 uptake by food. The Cs-137 reduction factors during first 5 years showed differ considerably compared to those of the following 5 years. For example, by selecting crop types with minimum Cs-137 uptake, a reduction factor of 30 could be achieved in the first 5 years, while the reduction in the following 5 years was lowered to 5.0. The application of phosphate fertilisers resulted in a reduction factor of 1.5 in the first 5 years and only 0.5 in the following five years. Using caesium-binders, e.g. ferrocyne, giese salt or nigrovich salt, the Cs-137 contamination of meat and milk could be reduced up to a factor of 10.

Models and software tools have been developed to help farmers to manage the contamination, e.g.:

- RISKAgro for rapid, real time predictions of radiation levels in major vegetables;
- AgroOptimization for efficient use of arable lands;
- Ration+ Calculation Model to help farmers to optimize animal feeding using different types of forages containing different levels of Cs-137 and Sr-90 contamination.

A comprehensive monitoring programme and Centres for Practical Radiological Culture (CPRCs) equipped with modern instrumentation for measuring radiation in foodstuffs and other environmental samples, as well as for measuring ambient dose rates, have been established.

The Polesie State Radiation-Ecological Reserve (PSRER) is a protected area of 216 000 hectares contaminated with nearly 1/3 of the radioactive caesium, more than 70 % of the strontium and 97 % of the plutonium deposited in Belarus after the Chernobyl accident. Research is taking place in this unique experimental site studying the effects of radioactive contamination on natural ecosystems and former agricultural lands.

In general, post-accident agricultural protective measures were highly effective resulting in about 40 % averted internal radiation dose. Protective measures were based on characteristic of the soil affected. These measures were strategically important as their long-term effect ensured the production of food. Information-sharing and direct involvement of rural residents in the recovery processes and decision-making is an important added-value factor contributing to optimization of protective measures and improvement of the quality of life.

After the presentation, experts noted the huge effort related to the education of farmers, children in schools, and others living in these contaminated areas, demonstrating a practical implementation of the ALARA principle. Some experts also noted that lowering maximum permissible levels might in some situations be a challenge, although these were accepted by farmers and the population.

7.4 Roundtable discussion

René Huiskamp (Moderator), Bharat Patel, Jean-Luc Godet, Jelena Mrdakovic Popic, Elisabeth Cardis, Jean-Christophe Gariel, Victoria Drobyshevskaya, Zhanat Carr (WHO), J. Lochard (ICRP), M. Pinak (IAEA)

Ms Zhanat Carr from the World Health Organisation (WHO) presented a report on *Thyroid Health Monitoring after Nuclear Accidents* published by an International Agency for Research on Cancer (IARC) Expert Group on Thyroid Health Monitoring after Nuclear Accidents. In this report, the Expert Group recommends

- against population thyroid screening after a nuclear accident;
- consideration be given to offering a long-term thyroid monitoring programme for higher-risk individuals after a nuclear accident.

The Expert Group defines higher-risk individuals as individuals exposed in utero or during childhood or adolescence (younger than 19 years) with an estimated thyroid dose of 100 – 500 mGy or more.

Jacques Lochard reported that ICRP is currently preparing an update of ICRP 109 and 111. The updated publication shall contain clarifications on the transition from the emergency exposure situation to the existing exposure situation. It is further proposed that in the recovery phase the reference level should not exceed 10 mSv/y with the objective to progressively reduce exposures towards the range of 1 mSv/y. The new publication shall also address ethical dimensions at stake, protection actions in economic activities and protection of animals and pets. He emphasised the importance of the co-expertise process and the development of a practical radiological protection culture to involve stakeholders in the recovery process.

Miroslav Pinak summarised the IAEA General Safety Requirements related to exposure in long-term contaminated environments. He reported that the IAEA is preparing a document on the transition from an emergency exposure situation to an existing exposure situation. When managing long-term contamination environments as existing exposure situation it is important to allow for a transition to normality as soon as possible and to prevent the creation of any kind of stigma.

In the discussion that followed, it was noted that any monitoring program related to long-term exposure after a nuclear or radiological accident must be well justified and well prepared in order to avoid the development of any unnecessary concerns within the population.

ICRP experience in Fukushima suggests that stakeholder involvement is more efficient when working in small groups, i.e. up to 90 persons. In addition, experience shows that the publication of all dialogues on the web increases stakeholder’s involvement.

The need for further recommendations on how to go back to so-called “normal life” after an accident was raised. The return to “normal life” may either relate to all the measures that have been introduced in the recovery phase, meaning all measures are lifted at the same time, or only to one measure or a selection of measures, for example only food monitoring is no longer required. In the first case, “normal life” activities are the same as before the accident, in the latter, the creation of a “new normality” leads to life activities different to the ones before the accident. However, in both cases, vigilance is still very important, as the site will always be linked to the accident. Affected population plays an important role in this vigilance. With the necessary monitoring equipment, they can take control over the situation and care about themselves. Knowledge and appropriate infrastructure related to measurements must be maintained.

A regular estimation of risk is necessary to demonstrate that care is still taken of the affected population.

Regarding the Fukushima accident, the IAEA was engaged in preparing explanatory material for people affected encouraging them to try to build normality, i.e. “normal life”. FAO, IAEA and WHO are currently preparing a new TECDOC document on maximum permissible levels trying to unify approaches.

8 CONCLUSIONS

Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of Experts[6]

From the presentations and discussions, the members of the Working Party identified the following important issues.

- Every nuclear or radiological accident is different. Therefore, long-term exposure after a nuclear or radiological accident needs to be managed on a case-by case basis, taking account of the specific circumstances prevailing during and after the accident. Although lessons learned from other accidents need to be taken into consideration, these experiences may have limited value. For example, a different wind direction during the Fukushima accident would have resulted in a completely different contamination pattern.
- “Local” reference levels for the management of long-term exposure need to be developed based on the prevailing local circumstances of a specific nuclear or radiological accident.
- Managing long-term exposure implies the need for a holistic evaluation of the given situation, by assessing not only radiation doses and radiation risks to humans and the environment, but also social, psychological, ethical and economic impacts.
- Health surveillance programmes in particular long-term programmes might have also adverse effects on the screened population. These programmes should be justified, well designed, and based on well-defined goals.
  - The goal of health surveillance programmes is to evaluate whether individuals affected by an accident suffer or will suffer from some health conditions including psychosocial effects. Health surveillance programmes should not be confused with epidemiological studies. Epidemiological studies have different objectives, either evaluating whether the accident has impacted disease rates or improving our knowledge on effects of radiation and/or the accident through analytical studies.
  - Population wide thyroid screening is not recommended. It is recommended that thyroid-screening programmes are developed only for high risk groups such as individuals exposed in utero or during childhood or adolescence (younger than 19 years) with an estimated thyroid dose of 100 mGy or more. On demand, health surveillance should be available for all affected by the accident, however, it is recommended to consult an expert when providing such surveillance.
  - Countries should assess their capabilities to perform screening programmes, in particular, the availability of appropriate equipment for thyroid screening programmes.
- Stakeholder involvement in the decision making process is of vital importance to efficiently manage long-term exposure after a nuclear or radiological accident.
  - During the planning and preparedness phases, as well as when the real event occurs, stakeholder involvement is an absolute necessity. Several experiences,

[6] The following members of the Working Party on Research Implications on Health and Safety Standards of the Article 31 Group of Experts contributed to the preparation of these conclusions: H. Janžekovič, L. Lebaron-Jacobs, F. Bochicchio, R. Huiskamp, P. Krajewski, and P. Smeesters. They were assisted by S. Mundigl from the European Commission.

such as the one implemented by ICRP through the Dialogue meetings initiative, have shown the great interest of this involvement for both the experts and the affected people.

- Parties involved in the management of a long lasting radiological event such as a nuclear accident may never be fully ready to cope with the situation. But, these parties, including all stakeholders, should prepare themselves on different aspects based on past events (Chernobyl, Fukushima,…) and on research activities in order to gain in agility in case the accident happens.
- Discussions with stakeholders in relatively small groups have shown to be most effective, while at the same time the outcome of these discussions need to be made available to a larger audience, for example through publication on the web. Identification and selection of stakeholders, group of stakeholders or representatives of stakeholders remain a challenge.
- Experts need to learn how to communicate with the stakeholders and the affected population. Experiences from past nuclear and radiological accidents show that the effect of radiation on children's health is a major concern. Families with small children, for example, are concerned about whether it is safe to stay in affected areas or to return to affected areas. Expert communication and advice need to be transparent, modest and prudent.
- The majority of past and current European projects performing research activities in relation to recovery situations involved stakeholders through the constitution of panels that exchange on the results of the projects and provide recommendations. This involvement is a key factor for the credibility and the success of these projects, although some aspects, such as representativeness or the extent of their involvement, remain open.

• Risk estimates related to the long-term exposure after a nuclear or radiological accident should not be a one-off exercise, but repeated regularly, taking into account the development and re-evaluation of the situation that may change as well as new scientific data. Data and knowledge related to the management of long-term exposure of a specific case need to be preserved as long as possible, e.g. through an appropriate data and knowledge management system.

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