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20 Years after Chernobyl Accident

On 26 April, 1986, the Chernobyl nuclear power station, located in Ukraine, suffered a major accident which was followed by a prolonged release to the atmosphere of large quantities of radioactive substances.

This had serious consequences for the populations of Belarus, Ukraine and Russia. Although the radiological impact of the accident in other countries was generally very low, and even insignificant outside Europe, this event had, however, the effect of enhancing public apprehension all over the world on the risks associated with the use of nuclear energy.

The reactor core design of the Chernobyl RBMK type of reactors was not inherently safe, and at that time inadequate safety precautions by the staff during tests had lead to the disaster. However, it is known that the USSR authorities started enormous efforts to protect the public. The short-term counter-measures were provided efficiently and later on the "sarcophagus" was erected over the ruins of Chernobyl-4 structures. The situation is now controlled by the Ministry of Emergency of Ukraine.

The reader will find in this newsletter, besides brief information on important lessons learned in the international community, an invited article of Dr. Bondarenko on the current occupational exposure situation in the Chernobyl Exclusion Zone, and a note on a report to be published by the NEA in 2006 on "Lessons from 20 Years after Chernobyl". These topics will be of interest to the newsletter recipients, as they may be on the front line of any local questioning in relation to the 20th year commemorations.

The engineering of modern nuclear power plants with inherent safety design of the reactor core is far from the Chernobyl type which used to be acceptable in former USSR. After the TMI accident, which had almost no radiological consequences to the environment, the modern nuclear power plants improved their safety, and later-on many of them have introduced severe accident management guidelines to be able to reduce consequences also in a case of a hypothetical accident.

Due to the problems with tightness and long term stability of the Chernobyl "sarcophagus", there is a plan of the current Ukrainian government to build, with the help of international donors through the Chernobyl Shelter Fund, a New Safe Confinement over the destroyed structures by 2010.

Lessons learned at the international level

(based on the information available at www.nea.fr)

The Chernobyl accident was very specific in nature and it should not be seen as a reference accident for future emergency planning purposes. However, it was very clear from the reactions of the public authorities in the various countries that they were not prepared to deal with an accident of this magnitude and that technical and/or organisational deficiencies existed in emergency planning and preparedness in almost all countries.

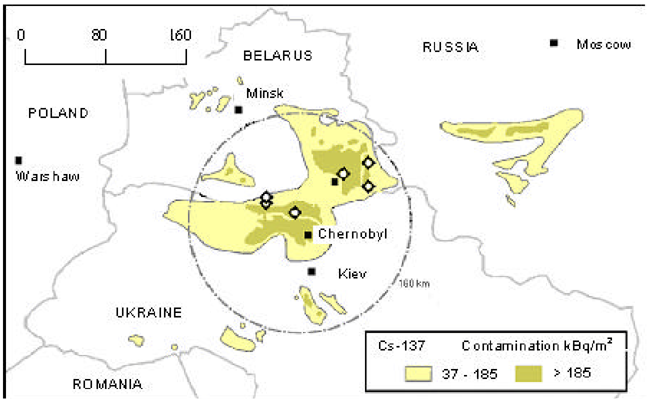


Figure 1: Contamination map of the situation after the accident (37 kBq is equivalent to 1 microCi); in km scale.

The lessons that could be learned from the Chernobyl accident were, therefore, numerous and encompassed all areas, including reactor safety and severe accident management, intervention criteria, emergency procedures, communication, medical treatment of irradiated persons, monitoring methods, radio-ecological processes, land and agricultural management, public information, etc.

However, the most important lesson learned was probably the understanding that a major nuclear accident has inevitable transboundary implications and its consequences could affect, directly or indirectly, many countries even at large distances from the accident site. Major improvements have been achieved since the accident, and important international mechanisms of co-operation and information were established, such as the international conventions on early notification and assistance in case of a radiological accident by the IAEA and the EC, the international nuclear emergency exercises (INEX) programme by the NEA, the international accident severity scale (INES) by the IAEA and NEA, and the international agreement on food contamination by the FAO and WHO.

In the scientific and technical area, besides providing new impetus to nuclear safety research, especially on the management of severe nuclear accidents and the source term behaviour, this new climate led to renewed efforts to expand knowledge on the harmful effects of radiation and their medical treatment and to revitalise radioecological research and environmental monitoring programmes.

Substantial improvements were also achieved in the definition of criteria and methods for the information of the public, an aspect whose importance was particularly evident during the accident and its aftermath. At the national level, many countries have established nationwide emergency plans in addition to the existing structure of local emergency plans for individual nuclear facilities.

Impressive is the progress made concerning the distribution of stable iodine near nuclear power plants, a subject that was more or less taboo before the accident. Here the NEA Committee on Radiation Protection and Public Health (CRPPH) advised how very important it is to involve all social partners. This idea, which originated in the context of accident management, has been taken up by many other disciplines, including the management of nuclear waste. This fundamental point is also one of the positive lessons learned from the accident.

Another lesson of policy significance concerns the reclamation of contaminated land. As has been seen, contamination, particularly in forest environments, has tended to reach ecological stability. While it was previously thought that contamination levels would decline due to natural removal processes, this has not proven to be the case generally, such that policy makers will be forced to deal with such problems for longer periods.

The decrease of contamination levels from now on will be mainly due to radioactive decay indicating that radioactive caesium will be present for approximately 300 years (10 half-lives of Cs-137). Because of this persistence of contamination, the importance of stakeholder involvement in the development of approaches to living in the contaminated territories has been highlighted.

Radiation Exposure Monitoring in the Chornobyl Exclusion Zone

Oleg O. Bondarenko, PhD, Deputy Director of main Radiation Safety Service of Chornobyl Radioecological Centre

Introduction

The territory of the Chornobyl Exclusion Zone (CEZ) was formed as a result of evacuation occurring between 27 April and August 1986 of 90784 inhabitants of 69 settlements (67 villages and towns Prypiat and Chornobyl) located in the Chornobyl and Polisski districts of the Kiev region, and of 7 villages located in the Narodychi and Ovruch districts of the Zhytomyr region (including 49360 inhabitants from Prypyat town). The CEZ is a territory of special jurisdiction and is run according to the Law of Ukraine "On the legal regime of the territory contaminated as a result of the Chornobyl Catastrophe" as well as many other legal acts by the State Department – Administration of the CEZ of the Ministry for Emergency of Ukraine.

Information on the Exclusion Zone

Radiation remains to these days a main factor of potential detriment for the population living in adjacent territories as well as for the whole population of Ukraine and neighboring countries. A large part of the activity released as a result of the accident at the Chornobyl NPP is located within the CEZ. An estimate of accumulated radionuclide activity distributed at different areas within the CEZ is shown in the Table 1. With respect to nuclear fuel material, there are also 21284 spent fuel assemblies stored at the Chornobyl NPP site.

Table 1 – Distribution of the total activity by main objects and components of the CEZ

Objects / Areas	Activity in PBq
Territory	8.1
Cooling pond	0.2
Radioactive waste storage facilities	5.5
Radioactive waste temporal localization facilities	2.1
Object "Shelter"	740

The best way to comprehend the complexity of radiation exposure monitoring in the CEZ is to look at the statistics presented in Table 2 below.

Table 2 – Data of Chornobyl Exclusion Zone (CEZ)

Area	2600 km^2
Borders	Length of the border of the exclusion zone is 441.2 km including the international border with Belarus of 154.5 km and 36.9 km of water borders
Personnel	Up to 15,000 workers of almost 100 organizations (including subcontractors) are registered annually. Their typical fields of work include all aspects of radioactive waste and nuclear material management, civil engineering, water and forest resource management, radiation safety, scientific research, administration, guarding, life sustenance, infrastructure maintenance, etc.
Visitors	More than 20,000 visitors enter the exclusion zone annually including former local citizens (evacuees)
Transport	About 100,000 motor cars and 1500 railway carriages are checked up annually at exit

About 3500 personnel arrive daily to the Chornobyl NPP site by train and cars from Slavutych town. Slavutych is located approximately 70 km North-West from the site. A similar number of personnel use Chornobyl town as a camp for living and work throughout all the CEZ territory. The shift of the permanent personnel in Chornobyl occurs on a weekly and fortnight basis. Naturally, the Chornobyl NPP site is one of the most contaminated place in the CEZ – within the isoline of 37 MBq?m^{-2} of primary fallout of ^{137}Cs. Chornobyl has lower contamination levels – between isolines of 0.37 and 0.74 MBq?m^{-2}. However, all the routes and stationary workplaces were decontaminated and have been strictly maintained at accordingly safe levels.

Radiation Exposure Controls

The State specialized enterprise "Ecocentre" was founded by the Ministry of Ukraine for Emergencies to provide radiation safety and radiation-ecological monitoring in the CEZ. The enterprise operates according to national requirements of quality assurance, it owns laboratories and methods (certified or metrology attested), appropriated work licenses and qualified staff of about 280 employees. Safety service work covers more than 100 different objects, including temporal radioactive waste facilities in the CEZ. The enterprise maintains 6 stationary dosimetric check-points. Up to 100 000 transport units per year passed radiation control.

External exposure - Last year's individual dose monitoring covered approximately 6000 workers in the CEZ (a similar number is covered by the radiation safety service of the Chornobyl NPP). Almost the same number of personnel passes through whole body monitoring to control incorporation of ^{137}Cs. External exposure of professionals as well as the number of personnel has been gradually decreasing since the accident.

During the last five years the average individual dose has been between 1 and 2 mSv. Each year several thousand radiation dose reports are prepared for people from Ukraine and the Former Soviet Union countries. External exposure (average individual and collective dose) of the personnel of enterprises engaged within the CEZ (except the Chornobyl NPP) is provided in the Figure 2.

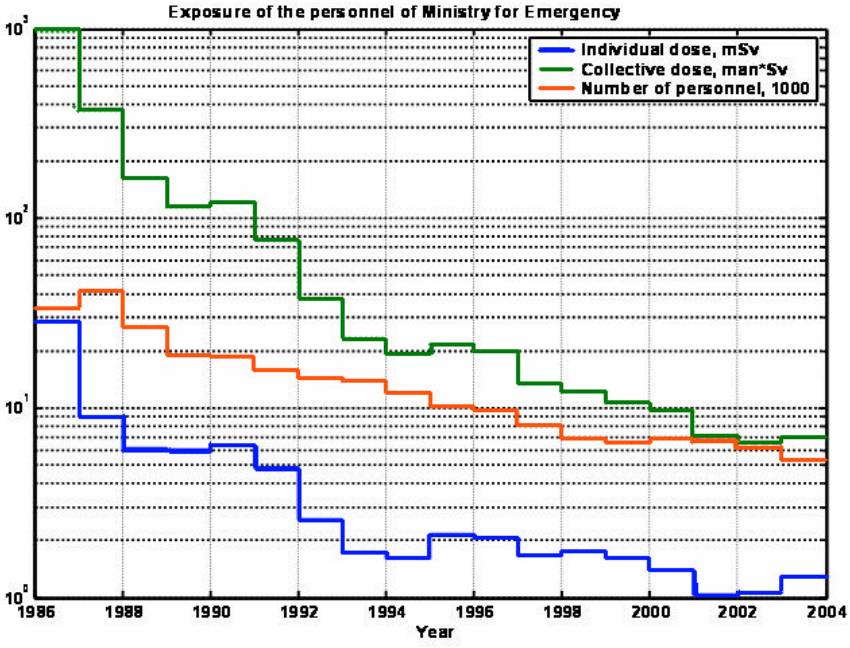


Figure 2 – Average individual dose, collective dose and number of enterprise personnel engaged within the CEZ (except the Chornobyl NPP)

Though these data include emergency action doses of 1986, they are not complete. At that time several dose registers of different Soviet Ministries existed. The three dose register left at the Chornobyl site are not yet consolidated. A certain amount of data is not available or is lost.

Many people worked as emergency workers in 1986-1987 and later applied for their individual dose records. For those whom instrumental records cannot be found, the procedure of retrospective dose restoration is applied.

Internal exposure- The issue of internal dose monitoring is still an unresolved problem within the CEZ. Measurement of ^{137}Cs in the human body is the main instrument for internal dose monitoring. However, considering ^{137}Cs as a tracer of the whole radionuclide mix with a use of whole body counters is not helpful for the several reasons:

- The correlation between ^{137}Cs and transuranic radionuclides (TRU) is not constant (variation of ^{137}Cs/TRU ratio can be described by the ratio of the 95% to 5% percentiles of ^{137}Cs/TRU; from some observations this variation is about 15, whereas the maximal variation (i.e. max/min) can reach 1000),
- The difference in metabolism is very significant, and
- ^{137}Cs intake into a human organism via the food chain essentially lowers the possibility of identifying the inhalation intake of the whole radionuclide mix using ^{137}Cs as a tracer.

Thus using the ^{137}Cs-based methods makes the level of false alarms unacceptably high. Typical ^{137}Cs contamination of the human body does not exceed 3 – 6 kBq (99% confidence interval). At the same time, from 2/3 to 3/4 of the measured personnel have a ^{137}Cs body content below the minimal detectable value (about 500 Bq). Nevertheless, several cases showing excess of 50 kBq are usually registered annually. Conducted investigations of all these cases show that the only reason of such an elevated activity is the unauthorized consumption of local "Chornobyl" food (mushrooms, fish, etc.).

The main risk for internal exposure of personnel is due to transuranic radionuclides (TRU) – $^{238\text{-}241}$Pu and ^{241}Am. The presence of Cm isotopes with respect to dosimetric considerations is negligible. Table 3 shows the contribution to internal exposure from inhalation intake for radionuclides of the Chornobyl mix for S and M types of systemic uptake of aerosols.

Table 3 – Contribution to internal exposure from inhalation intake for radionuclides of the Chornobyl mix for two types of systemic uptake of aerosol

Radionuclide(s)	Radionuclide composition, %	Contribution factors to dose	
		Type S (%)	Type M (%)
^{137}Cs	59	5	0.5
^{90}Sr	29	17	1.6
^{241}Pu	11	8	16
a emitting TRU	1	70	82

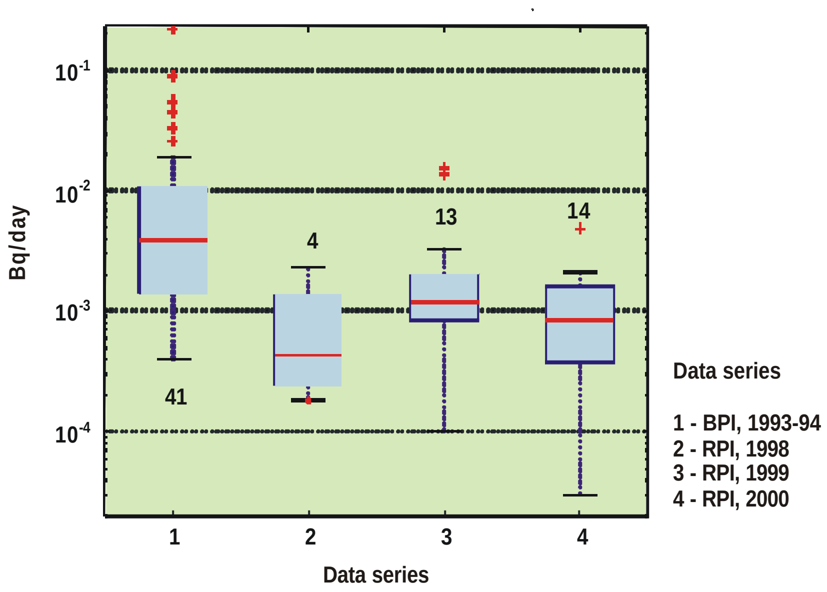
Regarding the type of systemic uptake, the ICRP recommendations for particular radionuclides is quite definite, e.g. ^{137}Cs – F, ^{241}Am – M. However, for Chornobyl, this might not be the case because of encapsulation of radionuclides in minute particulates of spent nuclear fuel. At industrially controlled conditions these particulates are usually described as hardly soluble. However, the Chornobyl case gives another pattern: for many years the released nuclear fuel has been in direct contact with atmospheric highly humid air or with wet soil (or other materials). Thus the issue of assigning a particular type of systemic uptake to aerosol of Chornobyl origin is still open, primarily because of a deficit of reliable experimental information.

Calculations related to Table 3 were done for factual values of the aerodynamic diameter observed inside the Object "Shelter". Though a wide range of aerodynamic diameters was observed, from submicron up to almost 10 micron, the effective aerodynamic diameter was assessed to be about 1 micron. The radionuclide ^{241}Pu is mentioned separately because it is a pure beta-emitter.

Figure 3 - Statistics of daily urine excretion rate of $^{239,\,240}$Pu, measured for workers of the Object Shelter Radiation Safety Shop.

Note 1: BPI – Biophysics Institute, Moscow, RPI – Radiation Protection Institute, Kiev;

Note 2: the number below or above each bar indicates number of measurements.



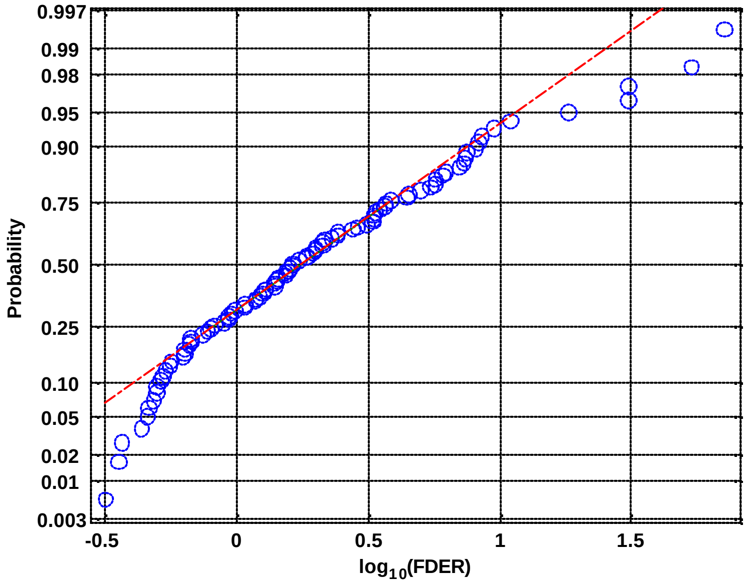


Figure 4 – Distribution of the fecal daily excretion rate (FDER, mBq/day) of $^{239,\,240}$Pu, measured for workers of the Object Shelter Radiation Safety Shop by RPI in 2005.

Figure 3 and 4 show some available data for TRU individual internal dosimetry. Dose calculations show that the excretion values shown in the figures are meaningfu and in certain realistic conditions might have meant exceeding of the dose limits.

Although research has been carried out for more than decade it should be noted that an applicable routine dosimetric method has yet to be developed. The main impartial obstacle on the way to implementing a practicable routine method for individual dose monitoring is a very high level of individual uncertainty of existing approaches. Since discussion on this issue is out of the scope of the given paper it can be definitely stated that there is still a need for future assistance and international expertise in this particular area.

Radiation Monitoring

Radiation-ecological monitoring is provided by sampling of 4500-5000 probes a year as well as over 10000-11000 radionuclide analyses. The system of radiation-ecological monitoring in the exclusion zone covers 146 points of observations (personnel work places, landscape testing areas, hydrological points, near-surface atmosphere air sampling points and radioactive fallout points etc.), 138 ground-water observation wells, 11 settlements, and 28 points of the automated system for monitoring of radiological situation (ASMRS).

Contamination of the CEZ is extremely heterogeneous, as can be seen from Table 4. There is in use a quite robust dose rate conversion factor for external dose assessment: 8E-11 Sv/h/(kBq/sq.m). This conversion factor is empirically inferred for CEZ conditions and can be used for outdoor work. The activity of Cs-137 in the surface soil is used in this case as a reference value.

Table 4 – Distribution of soil surface layer contamination of ^{137}Cs for 2002 within the borders of the CEZ and an estimate of the total dispersed activity

Soil contamination, ^{137}Cs MBq m^{-2}	**Area km^2**	**Relative area, %**	**Activity PBq**	**Relative activity, %**
0.074	200	7.7	0.01	0.3
0.185	700	26.9	0.13	2.2
0.37	510	19.6	0.19	3.3
0.74	410	15.8	0.30	5.3
1.85	340	13.1	0.63	10.9
3.7	210	8.1	0.78	13.5
7.4	130	5.0	0.96	16.7
18.5	70	2.7	1.30	22.4
37.0	20	0.8	0.73	12.7
> 37.0	10	0.4	0.74	12.8
TOTAL	**2600**	**100.0**	**5.77**	**100.0**

Air - The radiological state of the ground layer of atmospheric air is determined by soil contamination, meteorological conditions and human activity. ^{137}Cs prevails in radionuclide composition of aerosols at about 70 %. The volume concentration is averaged over 1 – 2 week period of time, with values in the vicinity of the Chornobyl NPP in the range of 10^{-5} - 10^{-2} Bq·m^{-3}, at locations of radioactive waste management facilities up to 1 Bq·m^{-3}, and in Chornobyl in the range of $2x10^{-6}$ – $2x10^{-4}$ Bq·m^{-3}. These levels are typical for natural re-suspension of aerosol. Volume concentration values exceeding reference and permissible levels are observed as a rule during forest fires, dusts storms or works related to radioactive waste management (including works on the Object Shelter). In the last 10 years the maximal concentration of alpha emitting TRU of 50 Bq·m^{-3} was registered in 1999 during work for B1-B2 beam stabilization at the Object Shelter.

Surface water - ^{137}Cs and ^{90}Sr are the main contributors to the radionuclide contamination of surface water. Since 1988 the ^{90}Sr concentration $^{\text{has}}$ prevailed over ^{137}Cs, being in recent years 60-75% of the total activity of river water. The concentration of these two radionuclides in Prypiat river water at the cross line of Chornobyl town has been stabilized in recent years, with averages for ^{137}Cs and ^{90}Sr of about 100 and 300 – 350 Bq·m^{-3} respectively.

Underground water - Contamination of underground waters of Eocene and Lower Cretaceous aquifers with radionuclides of the Chornobyl origin is not registered plausibly. The concentration of ^{137}Cs and ^{90}Sr in water supply points of the Chornobyl NPP and Chornobyl town is in range 3 – 16 and 4 – 26 Bq·m^{-3}, respectively. Outside the radioactive waste disposal site, the concentration of ^{137}Cs and ^{90}Sr of the Quarter aquifer is in the range 40 – 70 and 100 – 300 Bq·m^{-3}, respectively. Inside the radioactive waste disposal sites the concentration of ^{137}Cs and ^{90}Sr in 2002 was observed in the range 40 – 500 and 100 – 1800 Bq·m^{-3}, respectively. Inside the territory of so called sites for temporal localization of the radioactive wastes that were urgently created in 1986 (without complete civil engineering works) the considerable contamination of underground waters has continued: for ^{137}Cs, up to 4 kBq·m^{-3} and for ^{90}Sr, in range of 200 – 400 kBq·m^{-3}.

Monitoring of squatter residences - Foodstuff grown at squatter residences at different parts of the CEZ do not meet the requirements of the national standard for foodstuff DR-97. In the last years, the excess of DR-97 is observed at a level of 45% for ^{137}Cs in milk and 80% for ^{90}Sr in vegetables.

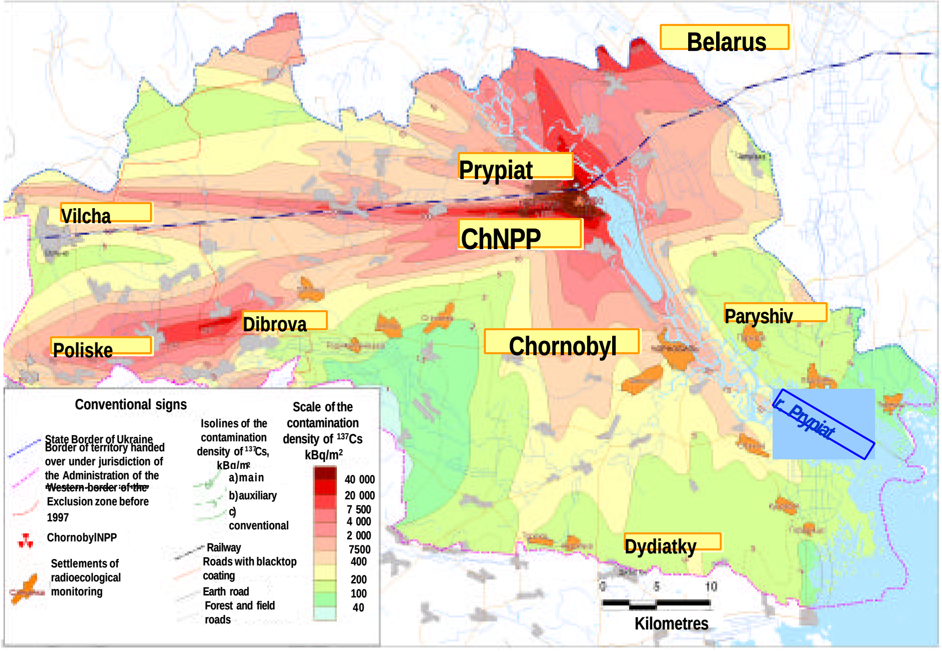
Change of Organization

Having accomplished the historical circle Ukraine is uniting national efforts for undertaking the tasks facing it. As evidence, we have just this year witnessed the transfer of the Chornobyl NPP and the Chornobyl Exclusion Zone under the jurisdiction of a single Ministry for Emergency of Ukraine. In its turn this reorganization launched the discussion about creating a united regional radiation safety and radioecological monitoring service for the whole Zone. In this case some similar international experiences should be exchanged.

Final Remark

On the eve of the 20th anniversary of the tragic event – explosion of the fourth reactor block of the Chornobyl NPP – no one can say that the main goal of the remedial actions – transfer of all the highly radioactive spots including the Object Shelter into a safe controllable state – has yet been attained.

Map of surface soil Cs-137 contamination in the CEZ (December 2002)



Stakeholders and Radiation Protection: Lessons from 20 Years after Chernobyl

The NEA has for some time actively addressed the issues and implications arising from the Chernobyl accident. The attached bibliography lists the reports related directly to the accident, as well as those related to improving emergency planning, preparedness and management in NEA member countries. The NEA's latest work in this area concerns the learning of lessons related to the interactions of radiation protection professionals with stakeholders affected by large-scale contamination. Although the Chernobyl-affected populations (in Belarus, Norway and the UK) were the subject of this work, the lessons would be applicable to any accidental or terrorist-caused large-scale contamination situation. The report will be published in mid 2006.

The NEA report shares the experiences of radiation protection professionals who used stakeholder involvement to reach out, in the twenty years since the 16 April 1986 accident, to some residents living in the radioactively contaminated environment near to the accident site, notably in Belarus, to assist them to become knowledgeable and active managers of their radiation exposures. This more humanized approach to decision-framing and issue resolution, using stakeholder involvement instead of the more traditional and prescriptive top-down approach to managing such a situation allowed the affected residents to gain greater control over and feel more positive about their future and thus enhance their quality of life. As an example of the effects much further afield, the report also covers impacts in Norway and the UK and how stakeholders were involved in these locations. The lessons learned in dealing with the aftermath of the accident have broad application to any situation with the potential to expose people or populations to risk from a release of toxins to the environment.

Starting from an overview on the Chernobyl accident and its impacts in the affected areas, and on actions taken by the NEA to enhance emergency preparedness in response to the accident, the report then provides an historical perspective on the transition from top-down management during the crisis phase of the accident, to more participatory management during recovery and rehabilitation using stakeholder involvement in pilot projects. Examples of how stakeholder involvement enhanced the lives of various stakeholders in responding to the challenges of living with contamination are presented, as well as an overview of the key lessons learned in stakeholder involvement. An account of the evolution of the NEA International Emergency Exercise (INEX) program to enhance international and national preparedness to nuclear emergencies is included. Finally, the report discusses the role of the radiation protection professional and presents possible opportunities for implementing lessons learned in stakeholder involvement to further define the role and responsibilities of the radiation protection professional of the future.

The report also shows the complexity of dealing with long lasting contamination for all parties, and particularly for the radiation protection profession, for which stakeholder involvement becomes a key tool of first consideration in establishing a more inclusive and open decision process to lead to sustainable decisions. The use of stakeholder involvement however calls for new expertise for policy makers and the radiation protection and other professionals in order to assure its successful implementation.

NEA International Nuclear Emergency Exercises: INEX 3

Twenty years after the Chernobyl accident, consequence management remains a difficult challenge for emergency managers. To address this, the INEX 3 tabletop exercises were developed by NEA and conducted in 2005 by its member countries and other invited participants. Earlier INEX series focused primarily on the short-term phase of a nuclear emergency. The INEX 3 series examined the decision-making processes employed after serious radiation contamination has taken place based on a generic "footprint" radiation contamination pattern. Seventeen participating countries used this footprint to examine how they might, following such contamination, implement agricultural countermeasures, apply food restrictions, adopt countermeasures such as travel, trade and tourism controls, deal with public information and move towards recovery. A workshop to evaluate the results of the exercises will be held in May 2006 in Paris. Participants will share their national experiences, analyse the basis for commonalities and differences in approaches, and the implications of any differences on decisions, and identify strategies for ways forward.

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