ENVIRONMENTAL CONSEQUENCES OF MAJOR NUCLEAR ACCIDENTS: THE IAEA OUTLOOK ON LESSONS LEARNED

Volodymyr Berkovskyy, Diego Telleria, Gerhard Proehl and Sergey Fesenko

International Atomic Energy Agency

Vienna International Centre, PO Box 100, 1400 Vienna, Austria

For more information visit: http://www.iaea.org/newscenter/focus/chernobyl/; http://chernobyl.info/; http://www.iaea.org/newscenter/focus/fukushima/

INTRODUCTION

The accident which happened at the Chernobyl nuclear plant in April 1986 was the most severe in the history of the nuclear power industry and caused the radioactive contamination of around 200 000 km^2 in Europe[*].

The IAEA, in its role of a specialised nuclear-related technical UN agency, has been involved in the mitigation of Chernobyl accident consequences since early May 1986. During the 26 years since the accident happened, the IAEA has implemented a number of programmes to mitigate the environmental consequences in connection therewith.

The UN acknowledged the IAEA for the work it is doing on behalf of the countries affected by the Chernobyl accident and in 2007 the UN General Assembly commended the IAEA's efforts in providing assistance and information in connection with remediation of agricultural and urban environments, cost effective agricultural countermeasures and the monitoring of human exposures in areas affected by the Chernobyl accident.

The accident which happened at the Fukushima-Daiichi nuclear plant (Japan) in March 2011, also led to extensive contamination of the environment. Since the first hours of the accident the IAEA has been working extensively, serving as the international focal point for assistance, information-sharing and follow-up.

An IAEA Ministerial Conference on Nuclear Safety, devoted to the Fukushima Daiichi accident, took place in Vienna in June 2011. The Conference adopted a Ministerial Declaration aimed at strengthening nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide. That Declaration formed the basis of the IAEA Action Plan on Nuclear Safety, which was endorsed by the IAEA's Member States in September 2011.

Current international arrangements

- *The Convention on Environmental Impact Assessment in a Trans-boundary Context (Espoo, 1991) and The Protocol on Strategic Environ-mental Assessment (Kyiv, 2003) place an obligation on States which are Contracting Parties to notify and consult each other on all major projects that may have a significant adverse environmental impact across boundaries.*
- *The Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency (Vienna, 1986) establish a notification system for nuclear accidents which have a potential for transboundary release and set out an international framework for cooperation among Contracting Parties and with the IAEA to facilitate the prompt assistance and support in the event of nuclear accidents.*

[*] Areas where the surface deposition of ^{137}Cs exceeded 37 kBq/m^2

LESSONS LEARNED

- A potential impact of major releases of radioactive materials from a nuclear facility on the public and the environment should be exhaustively analysed before the commissioning of a new nuclear facility. A comprehensive set of scenarios of potential accidents and the associated estimates of public exposure are important elements of environmental and safety assessment documentation.
- In a case of major releases to the environment, the off-site monitoring systems and programmes should ensure that the public exposure is adequately assessed and the public and decision makers are informed in a timely fashion, specifically:
  - The operator's monitoring systems and programmes should be considered as an integral part of the facility's design and should have an adequate redundancy and robustness;
  - The national environmental monitoring programme and related resources, should be sufficient for the large-scale monitoring, particularly mobile thyroid counters and car-based WBCs, laboratory facilities and radiological assessment capacities should be available;
  - The staff involved in a large-scale monitoring programme must be appropriately trained and should be provided with the clear instructions on monitoring procedures, such as the sampling strategy, data reporting and interpretation.
- Among the key factors governing the extent of public exposure are the following:
  - Atmospheric conditions (e.g. vertical profiles of the wind direction and speed, air temperature, temporal-spatial pattern of precipitations);
  - Topographical characteristics, forestation, land use, features of the soil, agricultural practices, food production and distribution, seasonality, etc.;
  - Characteristics of water bodies and their role for the irrigation, supply of drinking water, fishery and seafood production;
  - Human habits and features of living environment (e.g. food consumption rates, consumption of domestic foodstuffs, time spent indoor/outdoor, protective characteristics of houses);
  - Effectiveness of protective measures, including their timely implementation.

  These factors should be considered in the design of monitoring programmes, environmental assessments, planning and implementation of protective measures.
- The current radioecological data are focused on a temperate environment. However, for many other areas, in particular for Pacific and tropical environments, the available data are scarce and insufficient for producing reliable radiological assessments. Such data should therefore be collected within the framework of the preoperational monitoring programme.
- The experience gained from major accidents demonstrates that large areas beyond 30 km can be seriously affected. It therefore necessitates the careful consideration of the low-probability events, which may cause major radioactive releases to the environment, as well as the unfavourable dispersion conditions in the environment.
- The existing international arrangements provide the possibilities for international cooperation on the assessments of radiological impact on the environment, implementation of the large-scale monitoring programmes and exchange of information in the case of major releases of radioactive materials, particularly:
  - The IAEA, within its statutory functions, establishes the International Safety Standards, provides the assistance for their implementation and serves in a capacity of international focal point for the assistance, information-sharing and follow-up in the case of a nuclear emergency.
  - At the request of its Member States, the IAEA provides international peer reviews and advisory missions related to the radiological part of Environmental Impact Assessments, Safety Assessments, design and implementation of facilities and nation-wide environmental monitoring programmes.
  - The IAEA Action Plan on Nuclear Safety includes a number of steps to make nuclear safety more robust and, in particular, anticipates the development of the advanced environmental assessment and monitoring methodologies, as well as further support by means of the IAEA's programme on Modelling and Data for Radiological Impact Assessments (MODARIA).
  - A shared stock of environmental monitoring equipment, laboratory facilities and assessment capabilities (including the roster of qualified experts) could be created and maintained within the framework of existing international arrangements.

Category	Chernobyl Unit 4 USSR, 1986	Fukushima Daiichi Japan, 2011[**]
Atmospheric release[1,2], PBq		
^{133}Xe	6 500	11 000
^{132}Te	1 150	0.8
^{131}I	1 760	160
^{134}Cs	~47	18
^{137}Cs	~85	15
^{89}Sr	~115	2
^{90}Sr	~10	0.14
^{241}Pu	~2.6	n/a
$^{239+240}$Pu	0.03	n/a
➢ Release pattern	Initial release with the thermal elevation; 10-day variable releases due to fire	Several initial releases due to venting and hydrogen explosions; Weeks of releases
➢ Atmospheric conditions	Variable wind direction; Complex multi-directional land deposition (dry and wet);	Variable wind direction; Dispersion toward the ocean (east) and land; Dry and wet deposition (incl. snow); Land deposition prevails in the north-west direction
Deposited materials		
➢ Within 30-km area	Fuel particles, volatile and non-volatile elements	Volatile elements
➢ Beyond 30-km area	Volatile elements	Volatile elements
max. surface deposition in settlements[3,4], kBq/m^2		
^{131}I	~8 000 – 20 000 ([5])	1 600 – 3 600 (Iitate)
^{137}Cs	4 000 – 6 200 ([5])	600 – 2 200 (Iitate)
Geographical characteristics	Central Europe; Flat land; Forest and agricultural fields; Moderate population density	Pacific coast of Japan; Complex orography; Forest and agricultural fields; High population density
➢ Distances to large settlements and their population (as on the time of the accident)	Prypiat city: 3 km (49 000) Chernobyl city: 15 km (14 000) Kyiv city: 100 km (2.5 mln) Gomel city: 130 km (450 000)	Settlements in Futaba district: 3–30 km (75 000) Fukushima city: 60 km (290 000) Greater Tokyo Area: 180 km, (35 mln)
Areas where early protective measures and the environmental remediation are required	187 evacuated settlements inside and outside 30-km Exclusion Zone (116 000); Other territories outside of 30-km Exclusion Zone	12 municipalities 20-km Restricted Zone (78 000) 30-km Planned Evacuation Zone (10 000) Emergency Evacuation Preparation Zone (Lifted on 30 Sept. 11) (58 000); Other territories outside of 30-km zone
➢ Transboundary impact	200 000 km^2 in Europe contaminated[1] with ^{137}Cs above 37 kBq/m^2	Negligible
Protective measures	Evacuation, "stay indoor" order, relocation; USSR: delay with protective measures causes substantial thyroid exposures; agricultural countermeasures in combination with radiological control of foodstuffs, incl. domestic market; Japan: restrictions on harvesting and food consumption, governmental procurements of contaminated foodstuffs	
Prevailing pathways of exposure during the first year after the accident	External exposure; Internal exposure: in many places it is a prevailing pathway due to consumption of domestic milk, vegetables, meat, forest products, etc. (late spring, intensive vegetation)	External exposure; Internal exposure: reduced because of (a) restrictions on harvesting and food consumption and (b) the time of the accident (early spring, non-intensive vegetation)
Thyroid exposure[6]		
➢ Average thyroid dose on contaminated area (^{137}Cs above 37 kBq/m^2) of Belarus, the Russian Federation and Ukraine	Pre-school children: 0.29 Gy Adult: 0.1 Gy Exposed individuals: 6.4 mln	Information is not available
➢ Number of individuals with the thyroid dose above 1 Gy	~6 000 (Belarus and Ukraine)	
Individuals with annual effective dose above 1 mSv	~100 000 (as on 2005)[1]	information is not available
Aquatic environment	Contamination of fresh water bodies due to fallouts and subsequent wash-out of radionuclides; USSR: Contamination of Prypiat and Dnieper rivers and Kiev reservoir; Local fresh-water fishery was substantially affected; Japan: Contamination of the marine waters due to fallouts, wash-out and liquid radioactive releases; Local fishery and seafood production were affected	

[1] International Atomic Energy Agency. *Environmental consequences of the Chernobyl accident and their remediation: twenty years of experience / report of the UN Chernobyl Forum Expert Group "Environment"*. Vienna : IAEA, 2006.

[2] NISA estimation of Radionuclides release to the air http://www.meti.go.jp/press/2011/08/20110826010/20110826010-2.pdf

[3] Imanaka,T., et al. Report on radiation survey in Iitate village area. KAGAKU. Jun.2011 Vol.81,No.6.http://www.rri.kyoto-u.ac.jp/NSRG/etc/Kagaku2011-06.pdf

[4] Manzon, D. Dynamics of the Cs-137 migration on Russian territories after the Chernobyl accident. PhD dissertation. Moscow, 2010.

[5] Zaborie, Briansk region, The Russian Federation.

[6] United Nations. Sources and effects of ionizing radiation. UNSCEAR 2008 Report. Volume II: Effects. New York: UN, 2011.

[*] Preliminary estimates