Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems

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Nuclear Facilities in Ukraine

- nuclear power plants
- uranium mining enterprise
- spent fuel storage facilities
- RAW storage facilities and RAW management plants
- research reactors

Main types of facilities in Ukraine

- 4 operating NPPs (15 power units):
  - *Zaporizhzhya NPP (6 units WWER 1000)*

    (largest NPP in Europe)
  - *South-Ukrainian NPP (3 units WWER 1000)*
  - *Rivne NPP (2 units WWER 440, 2 units WWER 1000)*
  - *Khmelnitsky NPP (2 units WWER 1000)*
- Chornobyl NPP *(3 Units at the stage of Decommissioning)*

Main types of facilities in Ukraine (continuation)

- State owned "Eastern Mining and Processing Complex" (SkhidGZK)

  (largest uranium mining enterprise in Europe), which includes Hydro-Metallurgical Plant, Ingul'skaya and Smolinskaya mines

- 2 Spent Fuel Storage Facilities *in operation*

  at Zaporizhya NPP and Chornobyl NPP

- RAW storage facilities and RAW management plants:

  6 Specialized Enterprises "Radon", State Specialized Enterprise "Complex", State Specialized Enterprise "Technocenter"

- 2 research reactors (*Kyiv, Sevastopol*)

Operating Nuclear Power Plants in Ukraine

NPP	Unit	Type	Capacity (MWe)	Commissioning
Zaporizhzhya NPP	1	WWER-1000/V-320	1000	Dec 1984
	2			July 1985
	3			Dec 1986
	4			Dec 1987
	5			Aug 1989
	6			Oct 1995
Rivne NPP	1	WWER-440/V-213	420	**Dec 1980**
	2		415	**Dec 1981**
	3	WWER-1000/V-320	1000	Dec 1986
	4			Oct 2004
South-Ukrainian NPP	1	WWER-1000/V-302	1000	**Dec 1982**
	2	WWER-1000/V-338		Jan 1985
	3	WWER-1000/V-320		Sep 1989
Khmelnitsky NPP	1	WWER-1000/V-320	1000	Dec 1987
	2			Aug 2004

Ukrainian Energy Strategy

National Strategy of Energy Development for the period up to the year 2030 approved by the government foresees:

- *Providing modernization measures for safety prolongation of operation period for currently operated NPPs with WWER-type reactors for 10-15 years*
- *Construction of new NPP units WWER-1000 and PWR-1000/1500 of high safety*

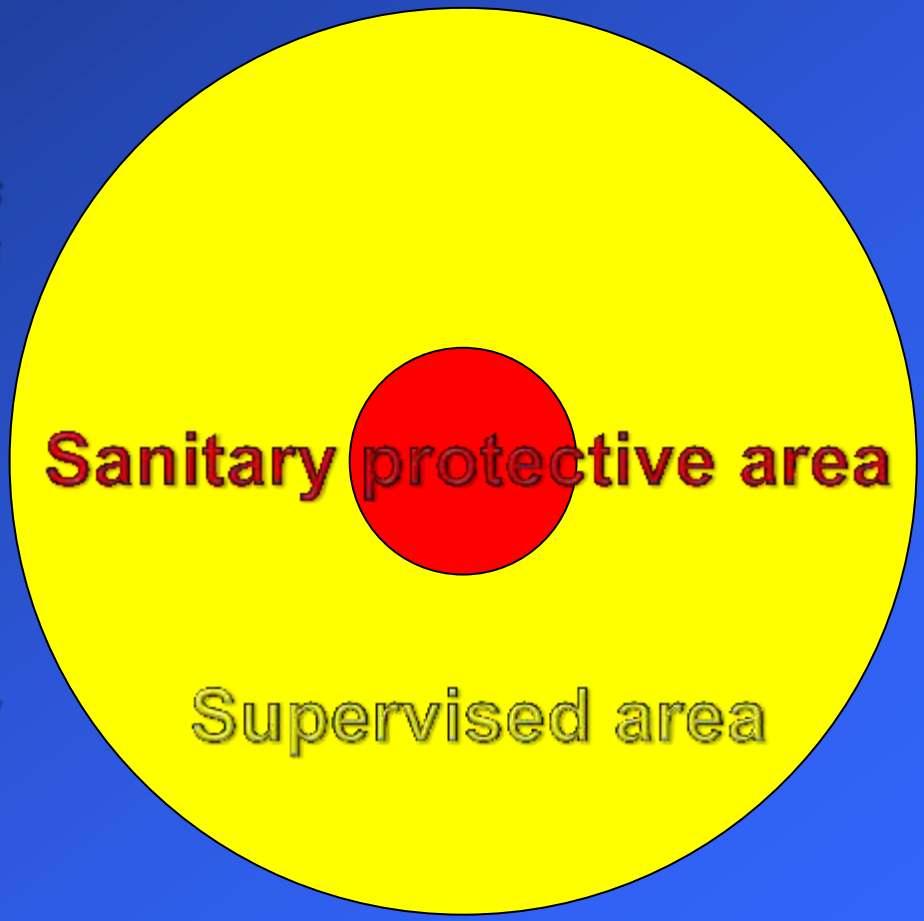
Main regulatory requirements

- *The Law of Ukraine «On the Use of Nuclear Energy and Radiation Safety" from 08.02.1995 No 39/95-BP;*
- *Radiation Safety Standards of Ukraine;*
- *Radiation Safety Standards of Ukraine, addition: Radiation protection from sources of potential exposure;*
- *Basic sanitary rules for Radiation Safety in Ukraine;*
- *General regulations of safety of nuclear power plants;*
- *Safety requirements for the choice of site for the nuclear power plant*;
- *Methods for Assessing of Scales and Significance of Accident Airborne and Liquid Releases of Nuclear Power Plants to an Environment (Standard of State enterprise National Nuclear Energy Generating Company ENERGOATOM);*
- *Requirements on determination the sizes and boundaries of supervised areas for nuclear power plants.*

Sanitary protective area and Supervised area

Sanitary protective area

residence of population is prohibited, restrictions on industrial activity, which is not related to radiation-nuclear facility, is established



SPA should be of sufficient size to ensure non-exceeding following levels outside of SPA:

- *during normal and abnormal operation, at the decommissioning stage –*

  quota of dose limit for members of the public (80 mkSv·a^{-1});

- *under design basis accidents –*

  criteria for countermeasures.

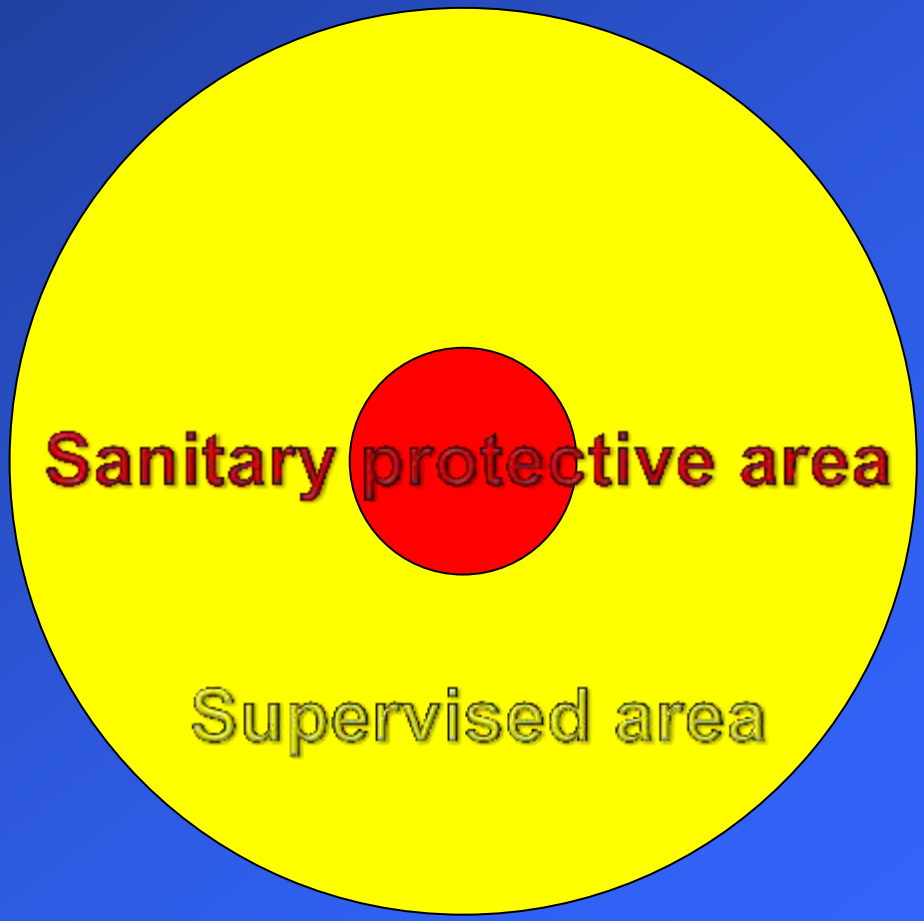
Sanitary protective area and Supervised area (continuation)

Supervised area

radiation monitoring of external exposure rate, determination of radionuclides in environment and foodstuffs

Supervised area should be of sufficient size to ensure that under beyond design basis accidents (which probability >10^{-7}) the non-exceeding criteria for countermeasures:

- *effective dose - 50 mSv;*
- *equivalent doses:*
  - *to thyroid:*
    - *for children - 50 mSv;*
    - *for adults - 200 mSv;*
  - *to skin - 500 mSv.*



Assessment of accident consequences

Dispersion models:

- atmospheric releases:
  - ‘puff’-model (‘Gaussian-based’ model);
  - turbulent diffusion;
- liquid releases:
  - ‘plume’-model.
  - liquid releases:
- Site-specific conditions (with potential changes in the future)

Food chain models:

- ‘ECOSYS-based’ model;

Dosimetric models:

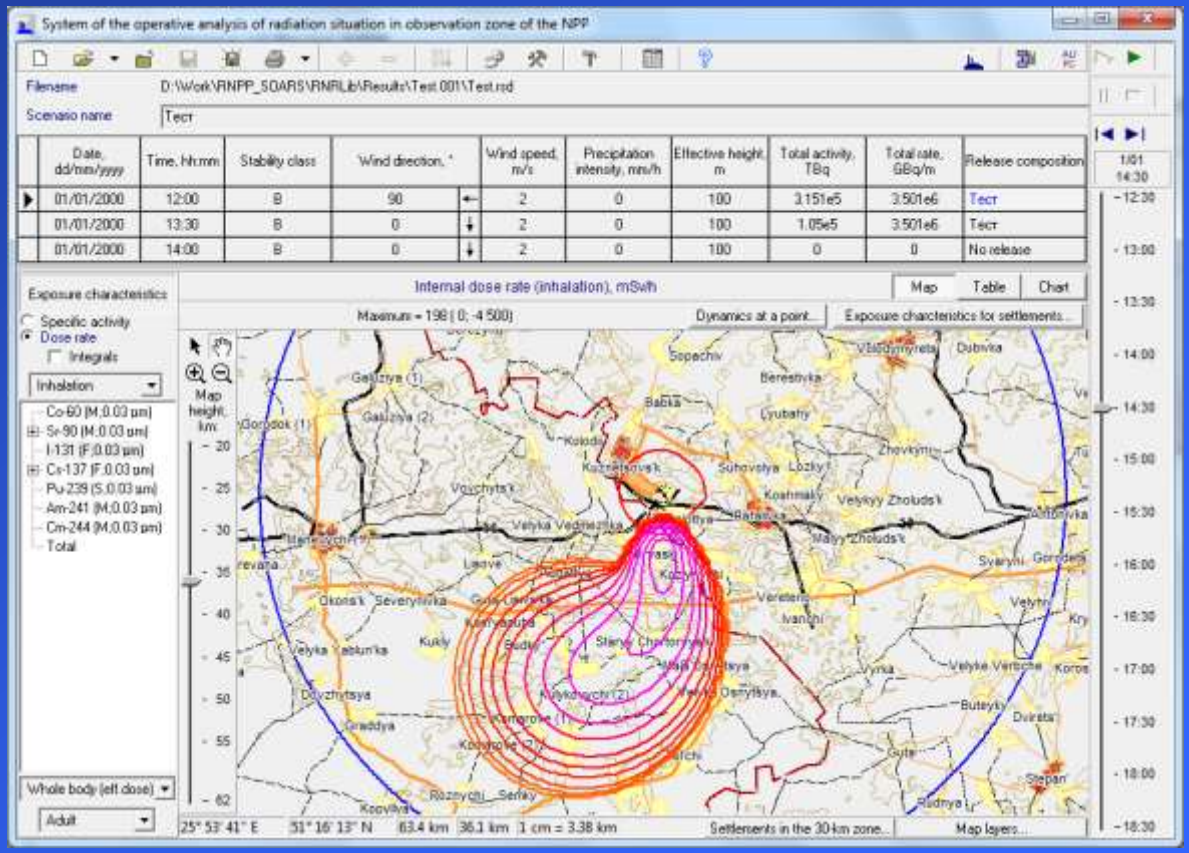
- ICRP models (dose coefficients)

Software for assessment of accident consequences

'System for the prognosis of the population doses due to emergency atmospheric release of Nuclear Power Plants' (Ukrainian name – KADO) was developed by Ukrainian Radiation Protection Institute for calculation of radiation situation in case of radiation accident at Ukrainian NPPs

The main purpose of the KADO is the decision support on countermeasures.

KADO is in operation on all Ukrainian NPPs



Software for assessment of accident consequences (continuation)

Results of calculation which KADO provides

For all territory in supervision area of NPP

Prognosis of spatial distribution and time changes of:

- radionuclides concentration in air and fallouts,
- dose rates and doses.

For settlements in NPP's supervision area (additionally)

Predictive values of :

- absorbed doses in organs (tissues) for the 2 days after accident (for emergency countermeasures),
- doses to whole body, thyroid and skin, averted for the 2 weeks after accident if a countermeasure was to be applied (for urgent countermeasures).

Examples of accident releases

SAR:
breakaway the cover of collector of steam generator

Radionuclide	Release, Bq
Kr-85m	1.60E+13
Kr-87	1.41E+12
Kr-88	5.62E+12
Xe-133	5.03E+14
Xe-135	7.73E+13
I-131	5.33E+13
I-132	1.32E+14
I-133	1.04E+14
I-134	7.62E+13
I-135	9.07E+13
Ru-103	8.36E+07
Ru-106	4.26E+06
Cs-134	1.20E+11
Cs-137	1.96E+11
Ce-144	3.61E+07
La-140	6.36E+08
Sr-90	4.96E+06

PSA-2:
bilateral rupture of the main circulation pipeline

Radionuclide	Release, Bq	Radionuclide	Release, Bq
Kr-85	1.4E+15	Zr-95	3.7E+11
Kr-85m	4.4E+13	Nb-95	2.7E+11
Kr-87	1.3E+12	Mo-99	2.5E+11
Kr-88	5.2E+13	Ru-103	2.7E+11
		Ru-106	1.1E+10
Xe-131m	5.7E+13	Rh-106	2.1E+08
Xe-133	1.0E+17	Te-131	9.5E+05
Xe-133m	2.3E+14	Te-132	4.7E+12
Xe-135	4.5E+14	Cs-134	1.3E+13
Xe-135m	1.9E+12	Cs-137	1.0E+13
Xe-138	3.7E+02	Cs-138	1.6E+08
		Ba-140	2.2E+12
Rb-88	1.2E+13	La-140	3.4E+11
Rb-89	3.1E+02	Ce-141	3.2E+11
Sr-89	1.1E+11	Ce-144	1.1E+09
Sr-90	7.3E+10	Pr-144	3.3E+08
Radionuclide	Methyl iodide	Elemental iodine	Aerosols
I-131	2.8E+13	1.3E+12	5.5E+12
I-132	1.8E+12	1.4E+11	5.9E+12
I-133	1.6E+13	7.0E+11	2.0E+13
I-134	1.2E+09	1.8E+08	9.7E+09
I-135	8.0E+11	4.3E+10	1.5E+12

Thank you for your attention!