Nuclear power safety
(after Chernobyl and Fukusima)

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Chernobyl lessons

Nuclear Safety Institute, Russian Academy of Sciences (IBRAE) was established after Chernobyl accident upon regulation of USSR Council of Ministers № 2198р dated 3rd of November, 1988 for fundamental research studies and independent analysis of nuclear and radiation safety.

Evolution of safety requirements

- More strict requirements to independence of different protection levels, possibility minimization for accident development at next levels
- Radiation hazard in all conditions and modes shall be comparable to the hazard from other industrial facilities, applied for similar purposes
- There should not be any need for evacuation beyond the site territory
- Requirements for nuclear facility siting should not contain additional limitations in comparison with other industrial facilities

Comparable effectiveness of protective measures to reduce radiation exposure

Countermeasure	Range of prevented individual doses, mSv	Reduced expenses in US dollars per 1 manSv	Experience (location, time)
Emergency transfer	13,000-23,000	300-600	Urals, October 1957
	100-3,000	1,000-15,000	Chernobyl, April-May 1986
Resettlement	40-200	6,000-100,000	Urals, November 1958
	50-100	130,000-500,000	Chernobyl, 1990-1991
Resettlement of children and pregnant women	< 1-40	4,000-400,000	Chernobyl, May-September 1986
Protective shed	5-100	0.02-1	Pripyat, 26th and 27th April, 1986

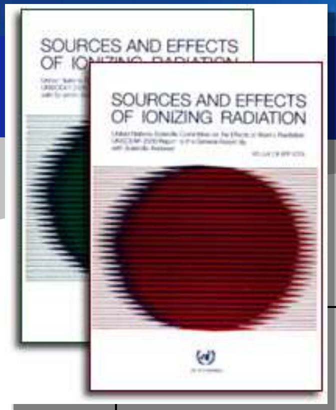
Chernobyl experience

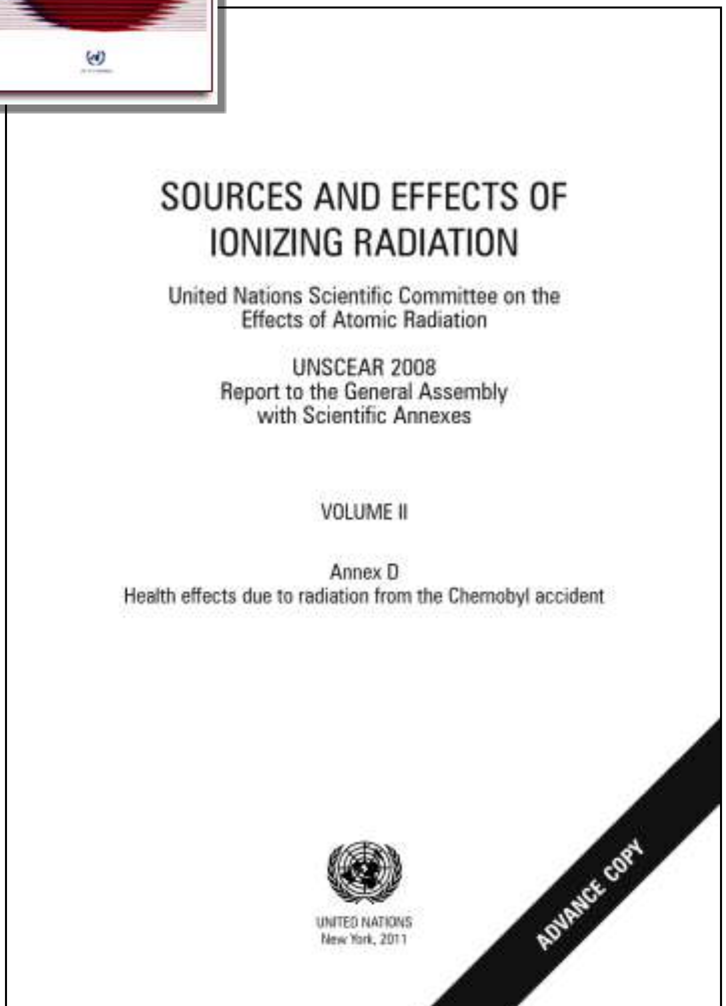
Contamination density	Average dose, mSv	Area, km^2	Population, thous. people
> 15 Ci/km^2 (555 kBq/m^2)	10	11000	85
> 40 Ci/km^2 (1480 kBq/m^2)	40	3620	7

Territories contaminated by Cs over 1 Ci/km2 in 1991 as per "Chernoby law" were referred to impacted areas.
Total square of such areas made 160 thousand km2 with population about 3 mln.

Chernobyl experience reveals that excessive and unjustified measures in terms of radiation protection (first of all population evacuation) can result in sharp increase of negative psychological, social and economic consequences.

Conclusions of UNSCEA




SOURCES AND EFFECTS OF IONIZING RADIATION

United Nations Scientific Committee on the Effects of Atomic Radiation

UNSCEAR 2008
Report to the General Assembly
with Scientific Annexes

VOLUME II

Annex D
Health effects due to radiation from the Chernobyl accident

UNITED NATIONS
New York, 2011

ADVANCE COPY

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Main conclusions from UNSCEAR 2000 report "Health effects due to radiation from Chernobyl accident":

- **Population did not experience health consequences as a result of radiation from the Chernobyl accident;**
- **Registered and expected effects are not considered as health care priority tasks, but referred to radiation epidemiology.**

UNSCEAR report 1988 , Attachment to Annex G, 'Early effects in man of high radiation doses', Acute radiation effects in victims of the Chernobyl accident;

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation. 2000 Report to General Assembly, volume 2, Effects;

UNSCEAR 2008 Report to General Assembly, volume 2 Annex D. Health effects due to radiation from the Chernobyl accident , New-York, 2008

Summary Data for Major (> 5 Victims) Accidents in the Power Industry in 1969–2000

	OECD countries			Non-OECD countries		
Type	Accidents	Victims	Victim/GW	Accidents	Victims	Victim/GW
Coal	75	2259	0.157	1044	18 017	0.597
Coal (data for China, 1994-1999)				819	11 334	6.169
Coal (excluding China)				102	4831	0.597
Oil	165	3713	0.132	232	16 505	0.897
Natural gas	90	1043	0.085	45	1000	0.111
Oil & gas	59	1905	1.957	46	2016	14.896
Hydropower	1	14	0.003	10	29 924	10.285
Nuclear power	0	0	-	1	31*	0.048
Total	390	8934		1480	72 324	

* Instant deaths only

Number of deaths due to radiological accidents

(Based on published data, with the exception of improper activity and nuclear tests)

Type of accident	1945–1965	1966–1986	1987–2007	Total	Committee findings regarding the report completeness
Accidents at nuclear facilities	16 deaths	40 deaths*	3 deaths	59 deaths	Most of the deaths were likely reported.
Industrial accident	0 deaths	20 deaths	5 deaths	25 deaths	A number of deaths and injuries were not likely reported.
Incidents with abeyant IRS	7 deaths	10 deaths	16 deaths	33 deaths	A number of deaths and injuries were not likely reported.
Accidents during research works	0 deaths	0 deaths	0 deaths	0 deaths	A number of deaths and injuries were not likely reported.
Accidents during medical use	Unknown	3 deaths	42 deaths	45 deaths	It is evident that many deaths and a significant number of injuries were not reported.

Total:	23	73	66	162

*) Table 10 p.52, Annex R.671, UNSCEAR Report, 2008

Problem scale

What do you know about victims of military and peaceful atom?

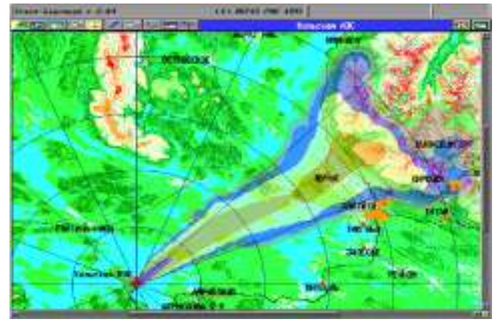
Event	Actual number of victims	Estimates of students
 Hiroshima	Instant and quick death – 210 thousand people	About 300 thousand people
	Late effects among 86572 hibakushas – 421 people	750 thousand people
 Chernobyl	Instant and very quick death – 31 persons	40 thousand people
	Late effects (accident responders and population) ≈ 60 people	250 thousand people

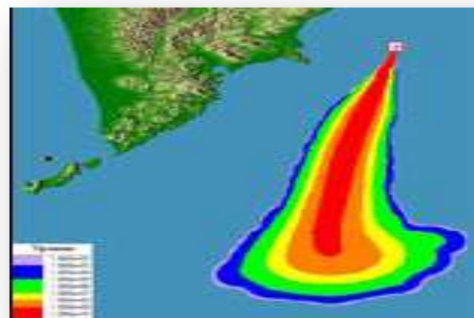
What is not right?

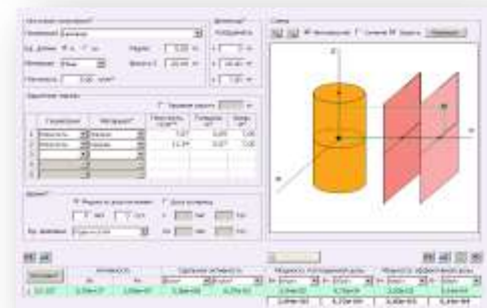
- Main safety task – population protection from hyper-admissible exposure – is formulated inaccurately.
- Accidents with core melting and low or zero overexposure level usually were followed by large scale consequences due to population incompetence, conflicts of radiation protection norms, poor communication with population.

Software and hardware complexes (S&HC)

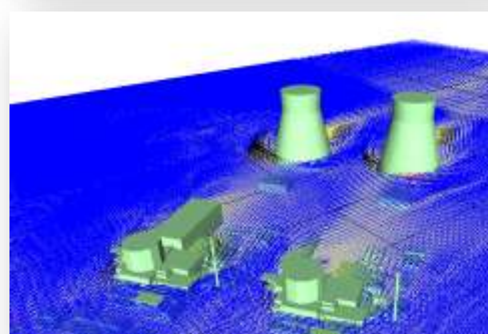
S&HC for SC “Rosatom” rescue subdivisions to assess impact on population and environmental (air, water) consequences of radiological accidents

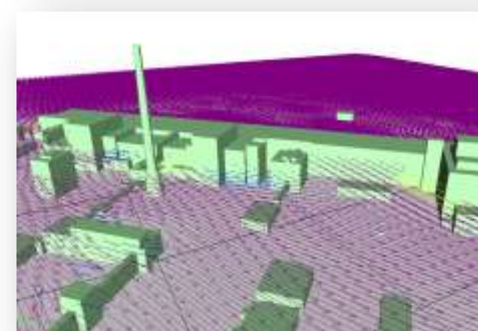






S&HC with 3-D models to assess consequences of radiological accidents in complicated industrial environment





Emergency response and radiation monitoring systems in RF regions

The regional systems are established in those regions of RF where operated NPPs and NPPs under construction are located to support work of local administration and demonstrate NPP safe operation (emergency response and independent radiation monitoring system)

Content and scope of work:

- **Establishment of crisis centers;**
- **Establishment of regional automated system for radiation monitoring;**
- **Development and equipping of software and hardware systems;**
- **Establishment of mobile laboratory complexes;**
- **Training and drills.**

Fukushima lessons

The worst scenario of Fukushima 1 accident

The worst (unlikely) weather conditions were selected for calculation:
Wind speed – 10 m/s, wind direction - 115 degrees, isothermalicy category – E, intensity of local precipitations in the area of Vladivostok - 10 mm/h.

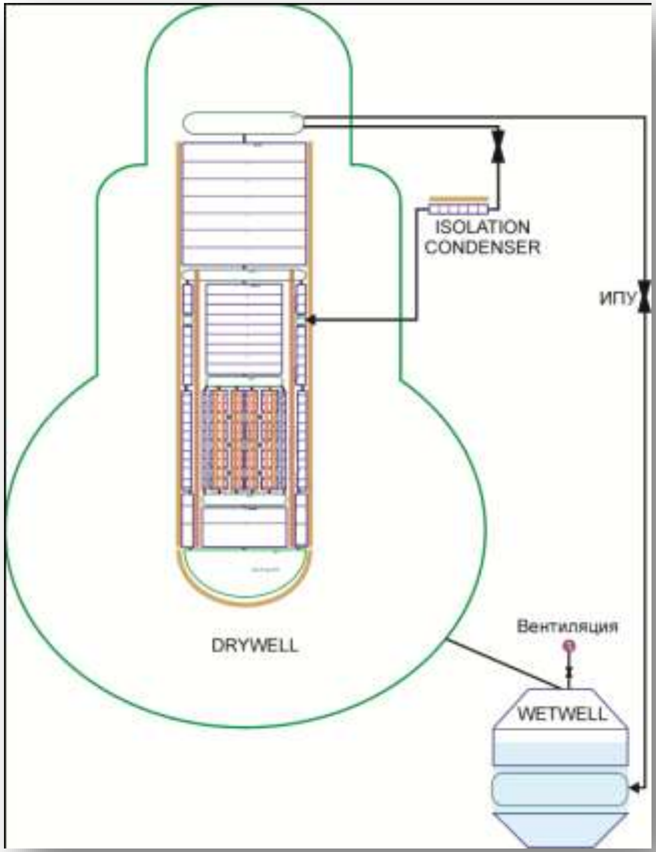
Complete effective annual dose (children 1-2 years) within 10 mSv

Calculated analysis of the accident for 1–3 units and 1–4 spent fuel pools at Fukusima Daichi (SOKRAT)

Not including cooling water

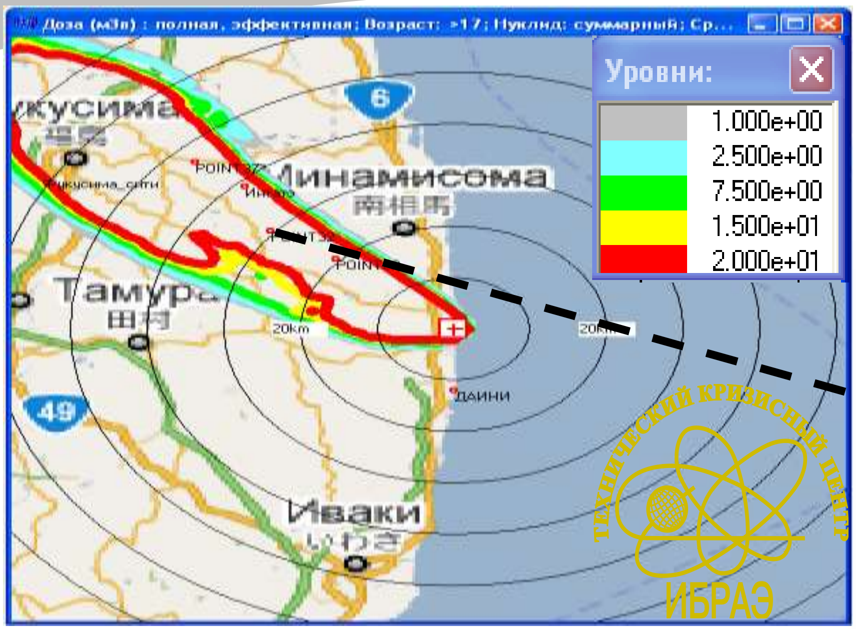
	Calculated time of explosion (hydrogen for 1, 2, 4)		Actual time of explosion (hydrogen for 1, 2, 4)	
Unit 1	**12.03**	**15:16**	**12.03**	**15:36**
Unit 2	**Pressure increase in containment** **15.03**	**05:45**	**15.03**	**06:14**
Unit 3	**14.03**	**08:00**	**14.03**	**11:01**
Unit 4 * (spent fuel pool)	**15.03.**	**4:00-05:00**	**15.03.**	**6:00**

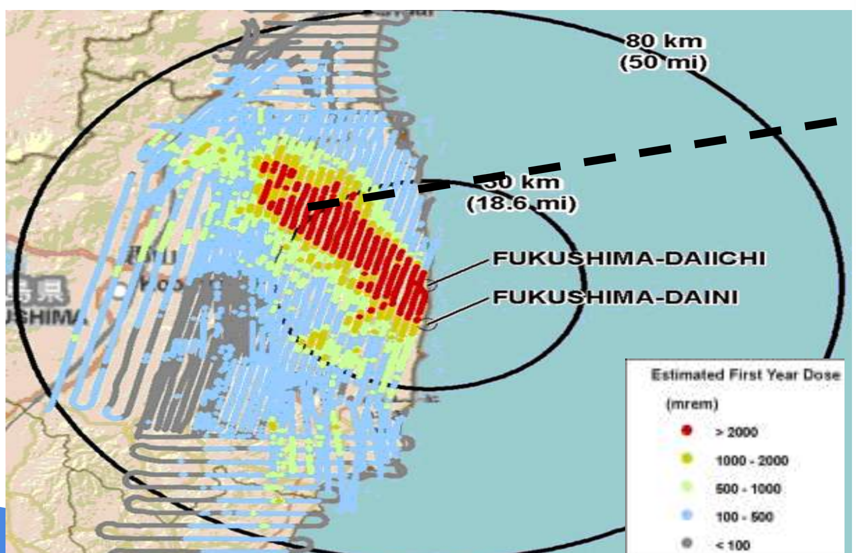
*** Information on water levels and temperature in spent fuel pool was missing.**



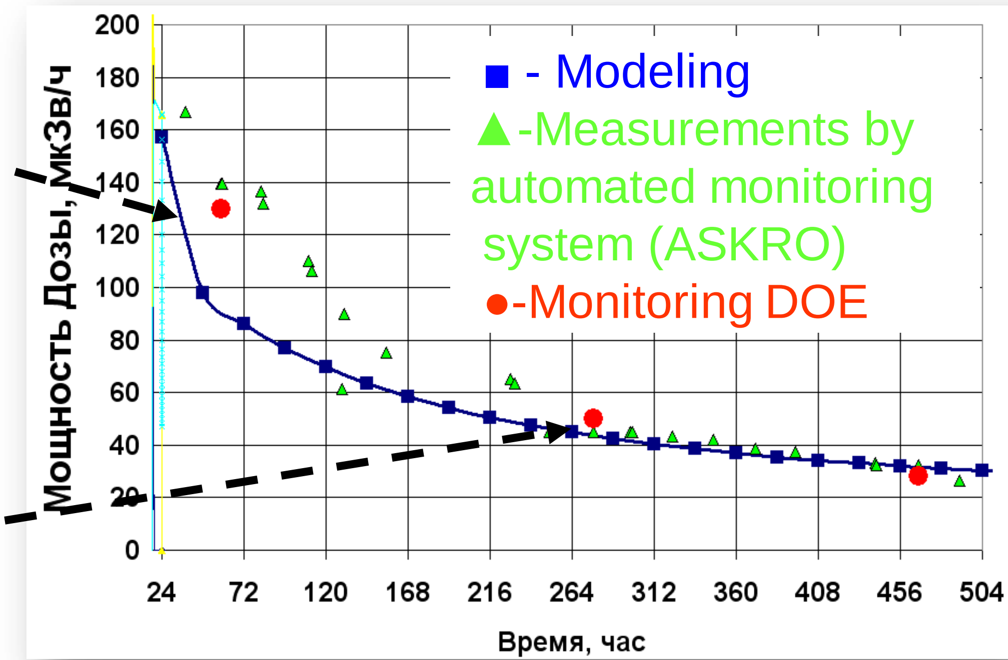
Reactor installation BWR/3 computing model for SOKRAT code

Modeling of atmospheric transfer by means of "Nostradamus" station taking into consideration detailed weather data in the territory of Japan. North-western trace.





Results of modeling and monitoring data



Results of Fukushima-Daichi accident

Now it is evident that many factors, that aggravated Fukushima accident were detected prior to the accident:

- Poor structure of severe accident planning and management ;
- Lack of safety enhancement measures;
- Inadequate estimate of external risk factors;
- Poor regulatory system;
- Insufficient personnel training on emergency preparedness.

Required measured to eliminate the above deficiencies were not undertaken.

Accident victims are missing.

Fukushima experience

Territories and population in the areas with the expected annual dose over 20 and 100 mSv after Fucushima accident

			Expected annual dose, mSv/year	
			> 20	> 100
20-km area	Area, km^2	Total	327	101
		Populated	109	24
	Population, people		43 700	8750
Beyond 20-km area	Area, km^2	Total	368	53
		Populated	84	11
	Population, people		16 300	4000
Total	Area, km^2	Total	695	154
		Populated	193	35
	Population, people		60 000	12 550

Fukushima experience

Recommendations on protective measures

- **For the most part of Japan total radiation exposure of population within 20 days after the accident did not exceed 0,1 mSv. Protective measures are not required.**
- **Total dose within 20 days in Ibaraki prefecture as the most contaminated one made 0,6-1,0 mSv. As a preventive measure it is recommended to monitor contamination of milk and vegetables within the first month.**
- **In north-western trace, on the boundary of 20 km area, maximal doses within 20 days could reach 50 mSv. Expected dose during the first year without protective measures could make 150 mSv in total. Personnel evacuation is not justified. Recommended measures include decontamination, regular monitoring of food and water contamination and some other measures.**

What needs to be done?

- Protective measures should be undertaken for severe accidents though they are the least possible.
- National technical centers shall support emergency response and population informing on radiological incidents in a professional manner.
- 100-fold difference should be eliminated between radiation effect threshold and regulatory documentation.
- Population education shall become essential condition for nuclear power use.
- Powerful tool for nuclear risk insurance should be incorporated.

Conclusions

- **NPP safety issue can be removed from the agenda in case the following conditions are met:**
- **To ensure acceptable level of technical safety**
- **To agree radiation protection rules and norms;**
- **To oblige governments permitting nuclear power use to ensure population education on actual hazard of radiation.**
- **To establish international nuclear insurance club for mutual responsibility insurance**