



Federal Environmental, Industrial and Nuclear Supervision Service

Scientific and Engineering Centre  
for Nuclear and Radiation Safety



**EUROSAFE** | 2019

**ETSON** | EUROPEAN  
TECHNICAL SAFETY  
ORGANISATIONS  
NETWORK

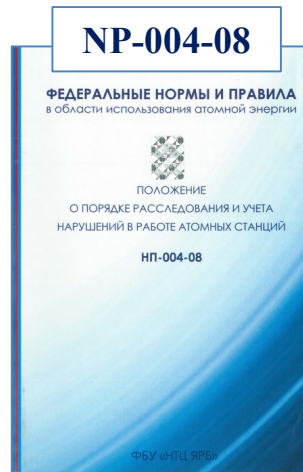
## The software implementation of the method for determining the level of nuclear and radiological events in the INES scale

Andrey Kirkin  
Head of laboratory

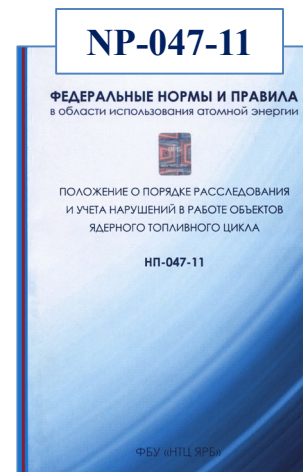
# Regulatory Framework



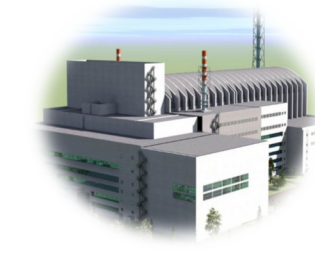
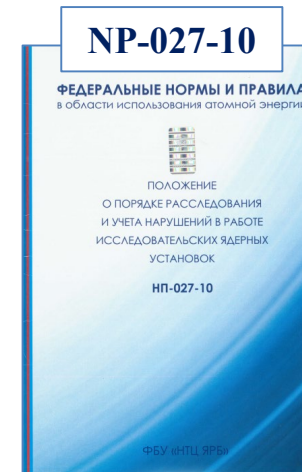
## Provisions on the Procedure of Investigation and Accounting of Operational Occurrences



**Nuclear Power Plants**



**Nuclear Fuel Cycle Facilities**



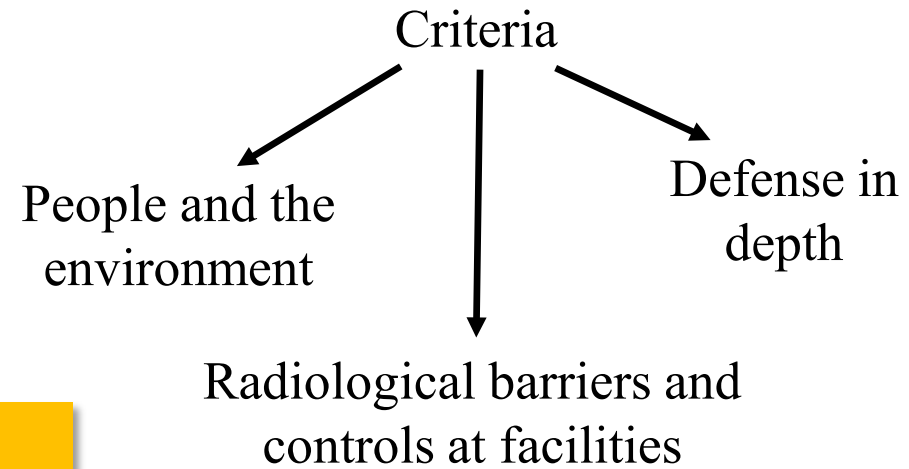
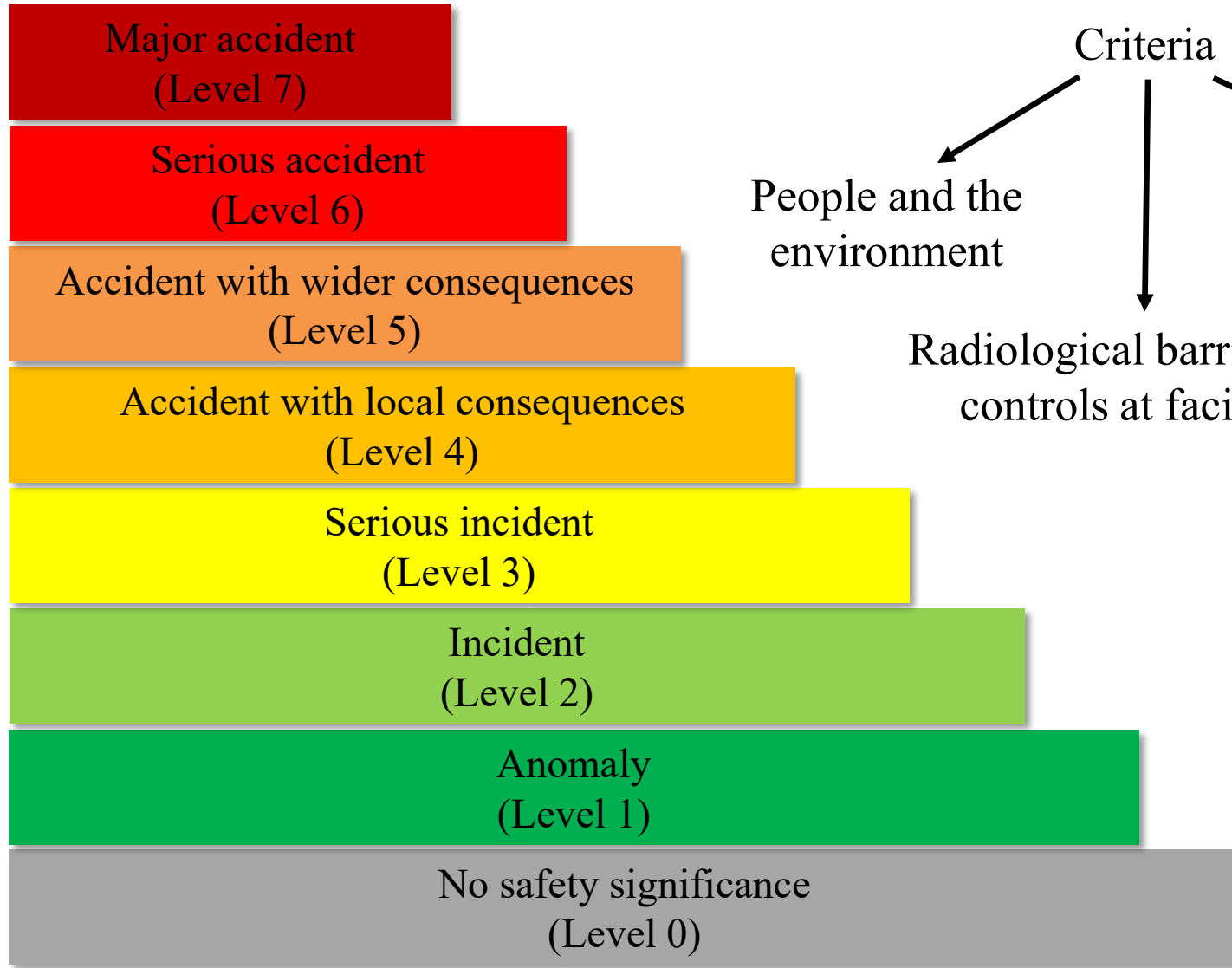
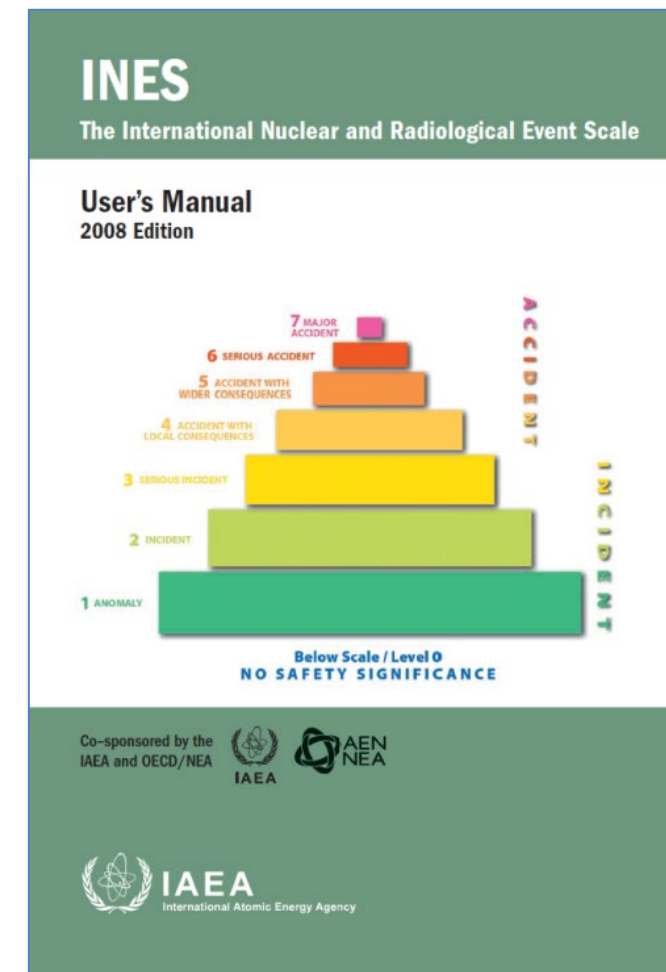
**Research Reactors**



**Nuclear Floating Vessels**

- provision of instructions to the public in case of an accident at the nuclear facilities
- nuclear and radiological emergency should be analyzed in order to improve emergency arrangements

# INES Overview

**INES**  
The International Nuclear and Radiological Event Scale

**User's Manual**  
2008 Edition

Below Scale / Level 0  
NO SAFETY SIGNIFICANCE

Co-sponsored by the IAEA and OECD/NEA

IAEA International Atomic Energy Agency

AEN NEA

# People and the environment



- radioactive release (large releases of radioactive material into the environment)

Event	INES Level			
	4	5	6	7
Release of Radiological Equivalent $I^{131}$ , TBq	$20 \leq \text{Release} \leq 2 \times 10^2$	$2 \times 10^2 \leq \text{Release} \leq 2 \times 10^3$	$2 \times 10^3 \leq \text{Release} \leq 2 \times 10^4$	$\text{Release} \geq 2 \times 10^4$

- exposure of a worker and the public (all other situations)

Event	INES Level					
	1	2	3	4	5	6
Cumulative exposure of <i>W</i> or <i>P</i> in excess of statutory annual dose limits	$\geq 1$					
Exposure of a <i>P</i> in excess of statutory annual dose limits or Exposure of a <i>W</i> in excess of dose constraints	$< 10$	$\geq 10$	$\geq 100$			
Exposure of a <i>P</i> leading to an effective dose in excess of 10 mSv or Exposure of a <i>W</i> in excess of statutory annual dose limits		$< 10$	$\geq 10$	$\geq 100$		
Exposure leading to an effective dose greater than ten times the statutory annual whole body dose limit for <i>W</i>			$< 10$	10–99	$\geq 100$	
The occurrence or likely occurrence of a non-lethal deterministic effect						
The occurrence of a lethal deterministic effect or the likely occurrence of a lethal deterministic effect as a result of a whole body absorbed dose of the order of a few Gy				$< 10$	10–99	$\geq 100$



# Radiological barriers and controls



- ➔ Accidents resulting in severe damage to such physical barriers as fuel matrix, fuel element cladding and primary-system boundary
- ➔ Accidents resulting in radioactive release or dose rate increase. Fuel matrix, fuel element cladding and primary-system boundary remain undamaged

**Level 5:** «An event resulting in the melting of more than the equivalent of a few per cent of the fuel of a power reactor or the release of more than a few per cent of the core inventory of a power reactor from the fuel assemblies»

**Level 3:** «An event resulting in the sum of gamma plus neutron dose rates of greater than 1 Sv per hour in an operating area (dose rate measured 1 metre from the source)»

**Level 2:** «An event resulting in the presence of significant quantities of radioactive material in the installation, in areas not expected by design and requiring corrective action»

TABLE 4. RADIOLOGICAL EQUIVALENCE FOR FACILITY CONTAMINATION

Isotope	Multiplication factor for airborne contamination based on <sup>131</sup> I equivalence	Multiplication factor for solid contamination based on <sup>137</sup> Cs equivalence	Multiplication factor for liquid contamination based on <sup>99</sup> Mo equivalence
Am-241	2000	4000	50 000
Co-60	2.0	3	30
Cs-134	0.9	1	20
Cs-137	0.6	1	12
H-3	0.002	0.003	0.03
I-131	1	2	20
Ir-192	0.4	0.7	9
Mn-54	0.1	0.2	2
Mo-99	0.05	0.08	1
P-32	0.3	0.4	5
Pu-239	3000	5000	57 000
Ru-106	3	5	60
Sr-90	7	11	140
Te-132	0.3	0.4	5
U-235(S) <sup>a</sup>	600	900	11 000
U-235(M) <sup>a</sup>	200	300	3000
U-235(F) <sup>a</sup>	50	90	1000
U-238(S) <sup>a</sup>	500	900	10 000
U-238(M) <sup>a</sup>	100	200	3000
U-238(F) <sup>a</sup>	50	100	1000
Unat	600	900	11 000
Noble gases	Negligible (effectively 0)	Negligible (effectively 0)	Negligible (effectively 0)

<sup>a</sup> Lung absorption types: S – slow, M – medium, F – fast. If unsure, use most conservative value.

# Defense in depth

- ➔ Events that do not have any direct impact on people or the environment, but with a set of measures designed to prevent accidents, were not implemented as planned

*Level 1: «Missing radioactive source, device or transport package subsequently recovered intact within an area under control»*

*Levels 0 ÷ 3: «Events where a source remains accidentally exposed, and there are no effective procedures in place to cope with the situation, or where such procedures are ignored»*

*Level 1: «Absence of or serious deficiency in records such as source inventories, breakdowns in dosimetry arrangements»*

*Levels 0 ÷ 3: «Radioactive material in a supposedly empty package»*

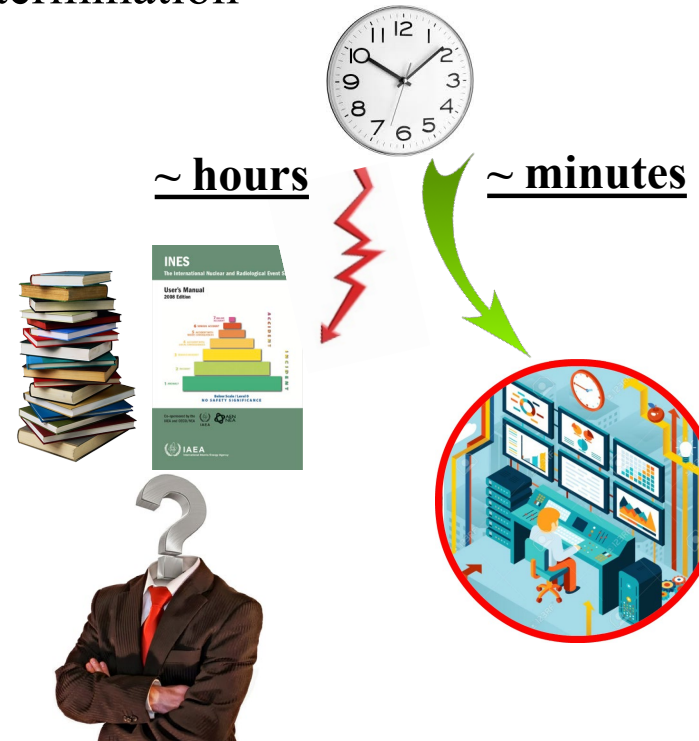
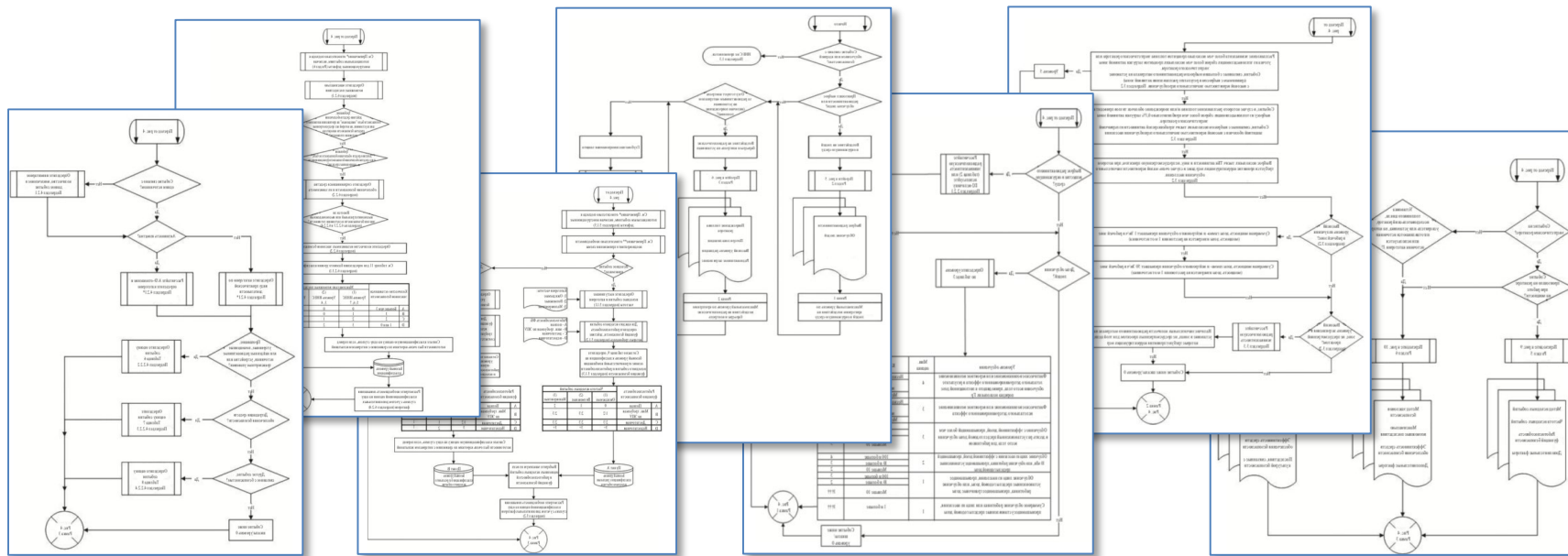
TABLE 1. GENERAL CRITERIA FOR RATING EVENTS IN INES

Description and INES Level	People and the environment	Radiological barriers and controls at facilities	Defence in depth
Major accident Level 7	- Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Serious accident Level 6	- Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with wider consequences Level 5	- Limited release of radioactive material likely to require implementation of some planned countermeasures. - Several deaths from radiation.	- Severe damage to reactor core. - Release of large quantities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire.	
Accident with local consequences Level 4	- Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. - At least one death from radiation.	- Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. - Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious incident Level 3	- Exposure in excess of ten times the statutory annual limit for workers. - Non-lethal deterministic health effect (e.g. burns) from radiation.	- Exposure rates of more than 1 Sv/hr in an operating area. - Severe contamination in an area not expected by design, with a low probability of significant public exposure.	- Near accident at a nuclear power plant with no safety provisions remaining. - Lost or stolen highly radioactive sealed source. - Misdeltivered highly radioactive sealed source without adequate radiation procedures in place to handle it.
Incident Level 2	- Exposure of a member of the public in excess of 10mSv. - Exposure of a worker in excess of the statutory annual limits.	- Radiation levels in an operating area of more than 50 mSv/h. - Significant contamination within the facility into an area not expected by design.	- Significant failures in safety provisions but with no actual consequences. - Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. - Inadequate packaging of a highly radioactive sealed source.
Anomaly Level 1			- Overexposure of a member of the public in excess of statutory limits. - Minor problems with safety components with significant defence in depth remaining. - Low activity lost or stolen radioactive source, device or transport package.
No safety significance (Below scale/Level 0)			

# Difficulties in applying the INES manual



- ➔ the difficulty to assess the level of event by INES
- ➔ the risk of human errors during determination of the INES emergency level
- ➔ large time and human resources during INES emergency level determination
- ➔ lack of automation of the assessment process

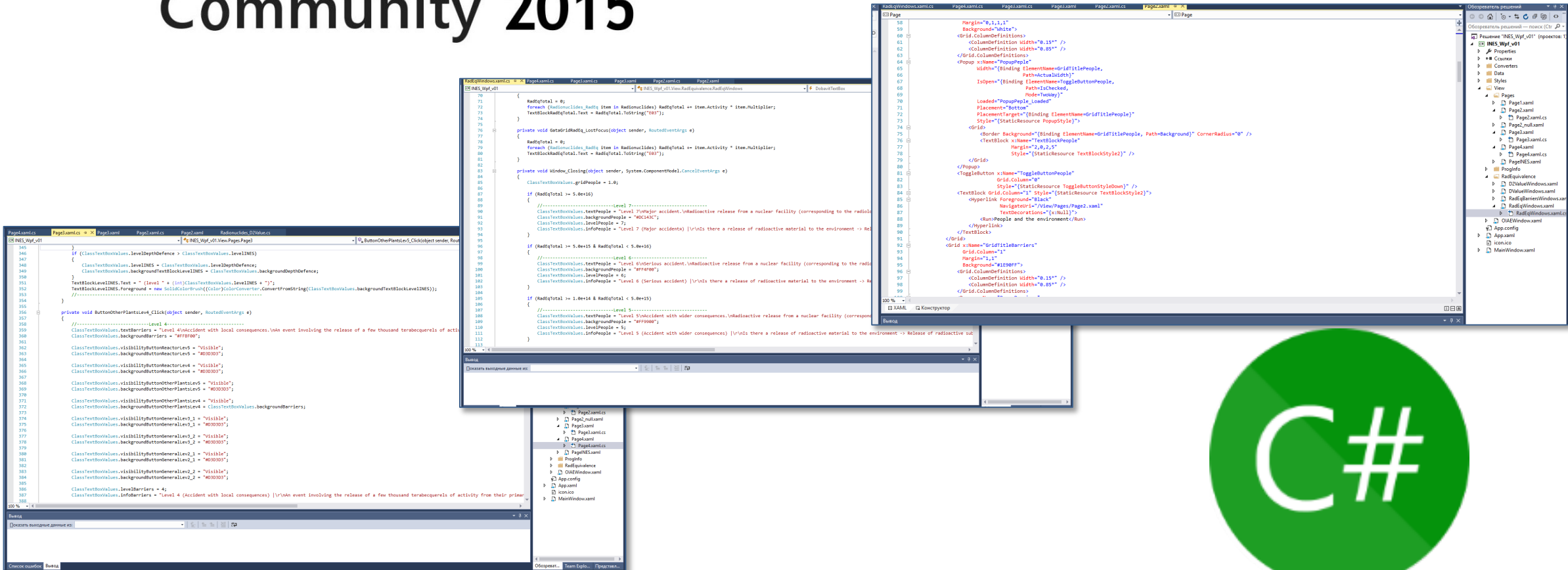


# INES Classifier



Visual Studio  
Community 2015

Windows  
Presentation Foundation





# INES Classifier



## Features of the “INES Classifier”:

- user-friendly interface
- built-in INES manual and program user guide
- simple description of INES levels
- automatic generation of event assessment on INES (on separate categories as well as final assessment)
- colored visualization of an event current INES level
- automatically generated report with short description of an assessed event

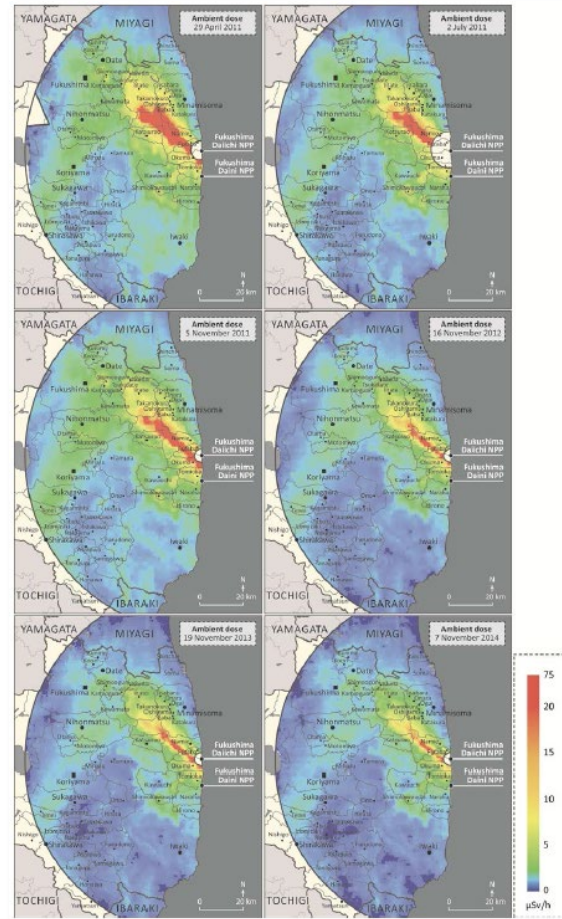
The screenshots show the INES Classifier 1.00 software interface. The main window displays the 'DESCRIPTION OF INES LEVELS' table, which is color-coded by level. The 'DETERMINATION OF INES LEVEL' window shows a grid of criteria for each level, with radio buttons for selection. The 'Radiological equivalent' window shows a table for calculating the radiological equivalent of I-131 based on the activity of various isotopes.

INES level	People and the environment	Radiological barriers and controls at facilities	Defence in depth
Major accident (Level 7)	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures		
Serious accident (Level 6)	Significant release likely to require implementation of planned countermeasures		
Accident with wider consequences (Level 5)	1) Limited release likely to require some... 2) Several deaths		
Accident with local consequences (Level 4)	1) Minor release of radionuclides likely to require planned... 2) At least one death		
Serious incident (Level 3)	1) Exposure in one or more areas of 10mSv 2) Non-lethal damage (e.g. burns) from radiation		
Incident (Level 2)	1) Exposure of a member of the public of 1mSv 2) Exposure of a worker of 50mSv		
Anomaly (Level 1)			

Criteria	Level 7	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1
People and the environment	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures	Significant release likely to require implementation of planned countermeasures	1) Limited release likely to require some... 2) Several deaths	1) Minor release of radionuclides likely to require planned... 2) At least one death	1) Exposure in one or more areas of 10mSv 2) Non-lethal damage (e.g. burns) from radiation	1) Exposure of a member of the public of 1mSv 2) Exposure of a worker of 50mSv	
Radiological barriers and controls at facilities							
Defence in depth							

Isotope	Activity (Bq)	Multiplication factor	Radiological equivalent of I-131
Am-241	0	8000	0.00E+000
Co-60	0	50	0.00E+000
Cs-134	0	3	0.00E+000
Cs-137	0	40	0.00E+000
H-3	0	0.02	0.00E+000
I-131	0	1	0.00E+000
Ir-192	0	2	0.00E+000
Mn-54	0	4	0.00E+000
Mo-99	0	0.08	0.00E+000
P-32	0	0.2	0.00E+000
Pu-239	0	10000	0.00E+000
Ru-106	0	6	0.00E+000
Sr-90	0	20	0.00E+000
Te-132	0	0.3	0.00E+000
U-235(S)	0	1000	0.00E+000
U-235(M)	0	600	0.00E+000
U-235(F)	0	500	0.00E+000
U-238(S)	0	900	0.00E+000
U-238(M)	0	600	0.00E+000
U-238(F)	0	400	0.00E+000
U nat	0	1000	0.00E+000
Noble gases	0	0	0.00E+000

# Example of the INES Classifier use (accident at the Fukushima Daiichi NPP)



radiological equivalent I<sup>131</sup>  
1,2 × 10<sup>18</sup> Bq\*

\* - The Fukushima Daiichi Accident. Report by the Director General, IAEA, 2015

**DETERMINATION OF INES LEVEL**

<input type="radio"/> People and the environment	<input checked="" type="radio"/> Radiological barriers and controls at facilities	<input type="radio"/> Defence in depth
The impact on defence in depth for transport and radiation source events	The impact on defence in depth specifically for events at power reactors while at power	The impact on defence in depth for events at specified facilities

**DETERMINATION OF INES LEVEL**

<input type="radio"/> People and the environment	<input checked="" type="radio"/> Radiological barriers and controls at facilities	<input type="radio"/> Defence in depth
An event resulting in the melting of more than the equivalent of a few per cent of the fuel of a power reactor or the release...	An event resulting in the release of more than about 0.1% of the core inventory of a power reactor from the fuel assemblies, as a result of fuel...	For more information of the items have
		The frequency of the original event is classified as "unlikely"

**DETERMINATION OF INES LEVEL**

<input type="radio"/> People and the environment	<input checked="" type="radio"/> Radiological barriers and controls at facilities	<input type="radio"/> Defence in depth
Is there a release of radioactive material to the environment?	Are there doses to individuals?	
Release of radioactive substances from a nuclear installation	Radioactive release during radioactive	

Isotope	Activity (Bq)	Multiplication factor	Radiological equivalent of I-131
Am-241	0	8000	0.00E+000
Co-60	0	50	0.00E+000
Cs-134	0	3	0.00E+000
Cs-137	2E+16	40	8.00E+017
H-3	0	0.02	0.00E+000
I-131	4E+17	1	4.00E+017
Ir-192	0	2	0.00E+000
Mn-54	0	4	0.00E+000
Mo-99	0	0.08	0.00E+000
P-32	0	0.2	0.00E+000
Pu-239	0	10000	0.00E+000
Ru-106	0	6	0.00E+000
Sr-90	0	20	0.00E+000
Te-132	0	0.3	0.00E+000
U-235(S)	0	1000	0.00E+000
U-235(M)	0	600	0.00E+000
U-235(F)	0	500	0.00E+000
U-238(S)	0	900	0.00E+000
U-238(M)	0	600	0.00E+000
U-238(F)	0	400	0.00E+000
U nat	0	1000	0.00E+000
Noble gases	0	0	0.00E+000

Radiological equivalent of I-131: 1,200E+018 Bq

**7**

**5**

**3**

SCALE INES (level 3)

SCALE INES (level 5)

SCALE INES (level 5)

FINAL EVALUATION ON SCALE INES (level 7)

# Conclusion

## “INES Classifier” computer program:

- minimizes the risk of human errors
- simplifies the process of interaction with INES level assessment methodology
- reduces necessary time and human resources
- has been approbated during the emergency drills and exercises
- is available for request on OECD/NEA Databank site



INES Classifier available via link

<https://oecd-nea.org/tools/abstract/detail/nea-1904/>







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***Thank you for attention!***

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