

INITIAL INDIVIDUAL DOSE ASSESSMENT FOLLOWING A NUCLEAR ACCIDENT

C. CHALLETON-DE VATHAIRE, E. QUENTRIC, D. DIDIER, E. BLANCHARDON, E. DAVESNE,
A. RANNOU, M. AGARANDE, V. RENAUD-SALIS, D. FRANCK

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[CONTEXT

Accident on a nuclear power plant (NPP)

crédit Arnaud Bouissou/MEDDE/Médiathèque IRSN



- large amounts of radioiodine can be released
- It concentrates in the thyroid and can increase the rate of thyroid cancer, as after the Chernobyl accident

- In the early phase of a nuclear reactor accident, *in-vivo* monitoring of impacted population would be highly useful to detect potential contamination during the passage of the cloud



Crédit Philippe Dureuil/Médiathèque IRSN

- Incorporated ^{131}I will be easily detectable at the thyroid level if the measurement is performed during the few weeks following the intake

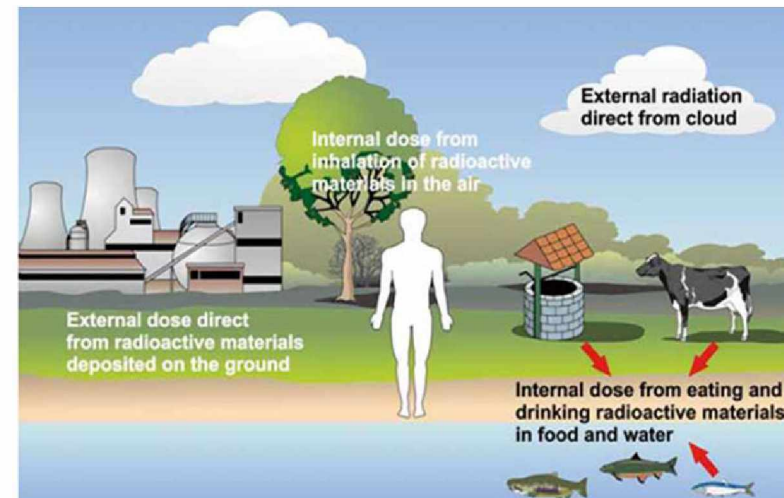
[CONTEXT

^{131}I measured in the thyroid will allow calculation of the thyroid equivalent dose and of the effective dose due to the inhalation of ^{131}I

However, short-lived radionuclides other than ^{131}I ($^{132}\text{Te}/^{132}\text{I}$, ^{133}I and ^{135}I), present in the release after a nuclear reactor accident, may be responsible for a significant part of the thyroid dose and/or of the effective dose received during the dispersion of the plume

Moreover, exposition to ionizing radiation will also be due to :

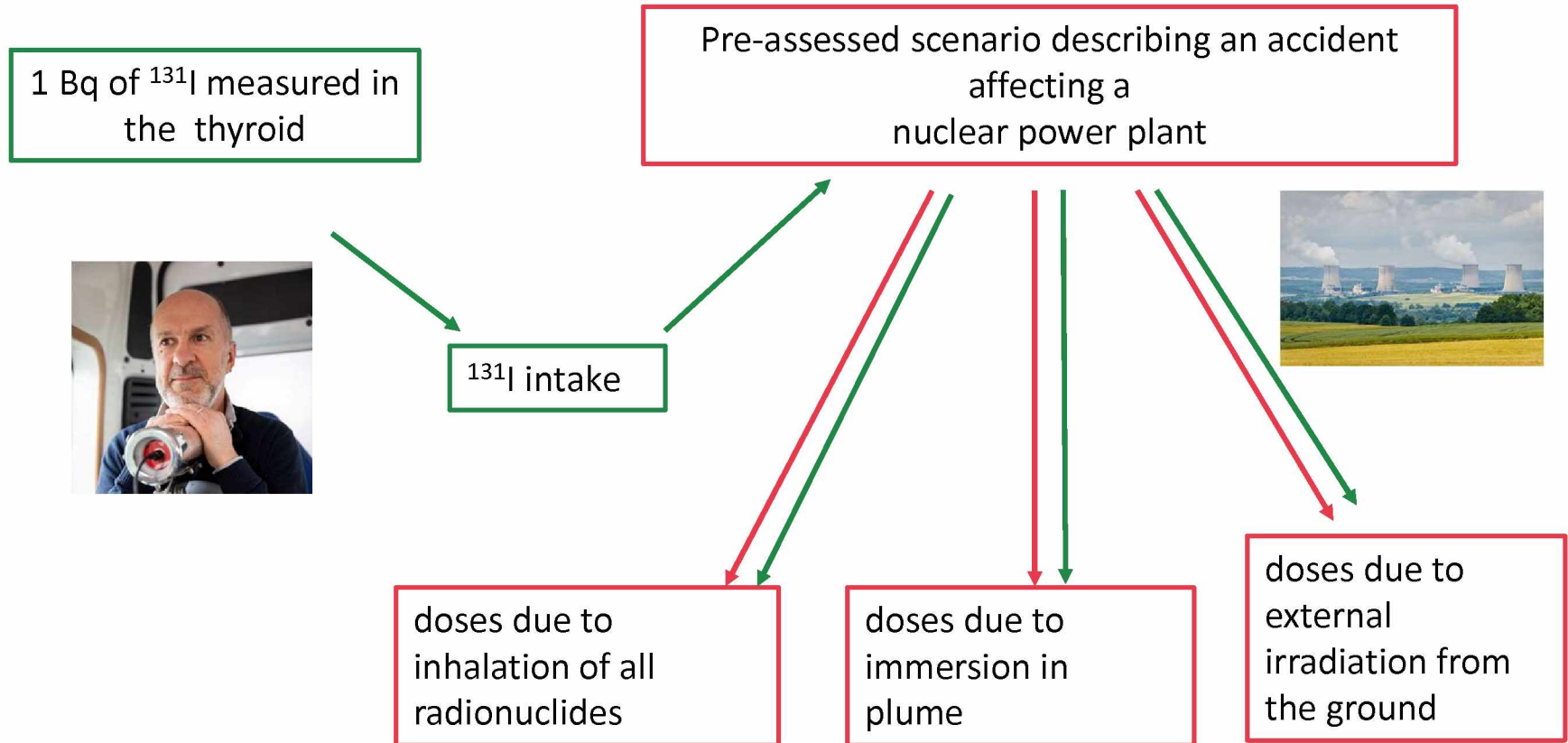
- Inhalation of RN others than iodine and tellurium
- external irradiation from radionuclides present in the air (immersion)
- external irradiation from radionuclides deposited on the soil (ground shine)



[OBJECTIVE

- To calculate coefficients which could be used to rapidly convert *in-vivo* ^{131}I measurement results directly into doses, not only from inhalation of ^{131}I but also from inhalation of all radionuclides present in the releases and from all sources of exposure
- Doses
 - Equivalent dose to the thyroid
 - Effective dose
- Pre-assessed scenarios, established by IRSN, for which **projected doses**, including those due to the inhalation of ^{131}I , have been calculated via radioecological and dosimetric impact modelings

[METHOD



[TWO SCENARIOS OF ACCIDENT AFFECTING A NUCLEAR POWER PLANT

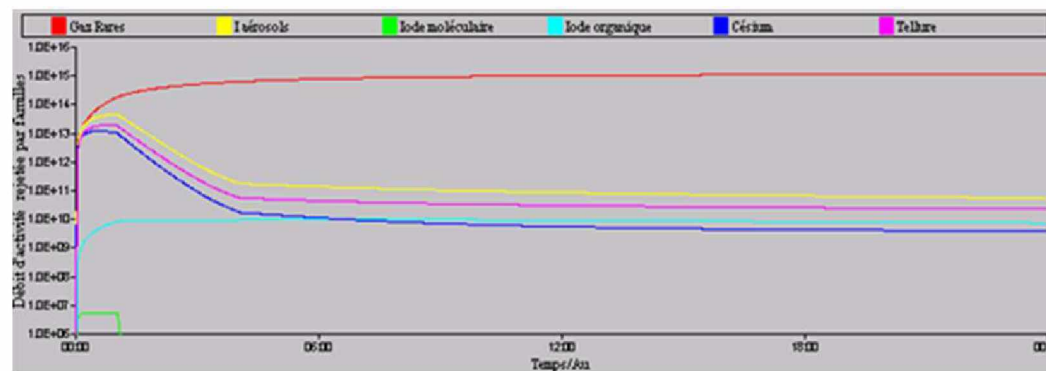
■ a loss-of-coolant accident (LOCA) leading to core meltdown

<i>Family of radionuclides</i>	<i>Activity released over 24 hours (Bq)</i>
Noble gases	2.2×10^{16}
Iodine	5.6×10^{13}
Cesium	1.4×10^{13}
Tellurium	2.4×10^{13}

Iodine isotopes are supposed to be released as aerosol or as methyl iodide

Dispersion conditions

<i>Parameter</i>	<i>Value</i>
Releases height	at ground level
Diffusion class	weak
Wind speed at 10 m	3 m/s
Precipitation	None
Wind meandering factor	3



[TWO SCENARIOS OF ACCIDENT AFFECTING A NUCLEAR POWER PLANT

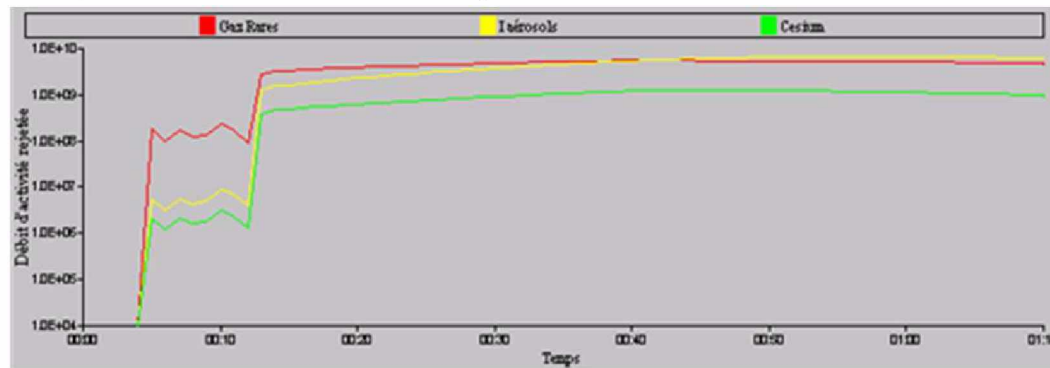
■ steam generator tube rupture (SGTR) accident

<i>Family of radionuclides</i>	<i>Activity released over 1 hour (Bq)</i>
Noble gases	2.0×10^{13}
Iodine	2.1×10^{13}
Cesium	4.0×10^{12}

■ Iodine isotopes are considered to be released entirely in aerosol form

Dispersion conditions

<i>Parameter</i>	<i>Value</i>
Releases height	Ground level
Diffusion class	weak
Wind speed at 10 m	5 m/s
Precipitation	Rain 2 mm/h
Wind meandering factor	none



[MODEL-BASED PROJECTED DOSES THE TWO SCENARIO

- six fictive persons of the public (6 ICRP age class)
- with a breathing rate depending on its age category
- stationed at a fixed location at a distance of 1 km downwind
- exposed for the first 24 hours after the beginning of the radioactive releases
- receiving no protection from personal equipment or shielding effect.

- Doses provided :
 - thyroid equivalent dose due to inhalation of all radionuclides
 - effective dose due to inhalation of all radionuclides
 - effective doses due to immersion in plume
 - effective dose due to external irradiation from the ground
 - effective dose due to all exposure pathways

[¹³¹I INTAKE FOR 1 Bq MEASURED AT THE THYROID

intakes of ¹³¹I which result in the measurement of 1 Bq of ¹³¹I at the thyroid level, $I_{I131,1Bqme}$ are calculated by dividing 1 Bq by the fraction of ¹³¹I, $m(t)$, retained in the thyroid at time t as predicted by the biokinetic model

$$I_{I131,1Bqme} = \frac{1}{m(t)}$$

- time t is the delay between the contamination, by inhalation, and the *in-vivo* measurement
- calculations are performed
 - for the six age ranges
 - for 18 times t : days 1 to 10, 12, 14, 16, 18, 20, 23, 26 and 30

[RESULTS

Table 11b – Thyroid equivalent dose due to the inhalation of all radionuclides for 1 Bq of ¹³¹I measured *in-vivo*, from the first (D1) to the thirtieth day (D30) after the accident, in the LOCA scenario (Sv).

age category	D1	D2	D3	D4	D5	D6	D7	D8	D9
3 months	2.4 x 10 ⁻⁵	2.6 x 10 ⁻⁵	2.9 x 10 ⁻⁵	3.3 x 10 ⁻⁵	3.8 x 10 ⁻⁵	4.4 x 10 ⁻⁵	5.0 x 10 ⁻⁵	5.7 x 10 ⁻⁵	6.5 x 10 ⁻⁵
1 year	2.2 x 10 ⁻⁵	2.3 x 10 ⁻⁵	2.6 x 10 ⁻⁵	3.0 x 10 ⁻⁵	3.4 x 10 ⁻⁵	3.8 x 10 ⁻⁵	4.3 x 10 ⁻⁵	4.9 x 10 ⁻⁵	5.5 x 10 ⁻⁵
5 years	1.2 x 10 ⁻⁵	1.3 x 10 ⁻⁵	1.4 x 10 ⁻⁵	1.6 x 10 ⁻⁵	1.8 x 10 ⁻⁵	2.0 x 10 ⁻⁵	2.3 x 10 ⁻⁵	2.5 x 10 ⁻⁵	2.8 x 10 ⁻⁵
10 years	5.9 x 10 ⁻⁶	6.1 x 10 ⁻⁶	6.7 x 10 ⁻⁶	7.4 x 10 ⁻⁶	8.2 x 10 ⁻⁶	9.0 x 10 ⁻⁶	9.9 x 10 ⁻⁶	1.1 x 10 ⁻⁵	1.2 x 10 ⁻⁵
15 years	3.8 x 10 ⁻⁶	4.0 x 10 ⁻⁶	4.3 x 10 ⁻⁶	4.8 x 10 ⁻⁶	5.2 x 10 ⁻⁶	5.8 x 10 ⁻⁶	6.4 x 10 ⁻⁶	7.0 x 10 ⁻⁶	7.7 x 10 ⁻⁶
adult	2.5 x 10 ⁻⁶	2.5 x 10 ⁻⁶	2.8 x 10 ⁻⁶	3.1 x 10 ⁻⁶	3.4 x 10 ⁻⁶	3.7 x 10 ⁻⁶	4.1 x 10 ⁻⁶	4.5 x 10 ⁻⁶	4.9 x 10 ⁻⁶

10 tables

age category	D10	D12	D14	D16	D18	D20	D23	D26	D30
3 months	7.4 x 10 ⁻⁵	9.6 x 10 ⁻⁵	1.2 x 10 ⁻⁴	1.6 x 10 ⁻⁴	2.1 x 10 ⁻⁴	2.7 x 10 ⁻⁴	4.1 x 10 ⁻⁴	6.0 x 10 ⁻⁴	1.0 x 10 ⁻³
1 year	6.2 x 10 ⁻⁵	7.9 x 10 ⁻⁵	1.0 x 10 ⁻⁴	1.3 x 10 ⁻⁴	1.6 x 10 ⁻⁴	2.1 x 10 ⁻⁴	3.0 x 10 ⁻⁴	4.2 x 10 ⁻⁴	6.8 x 10 ⁻⁴
5 years	3.1 x 10 ⁻⁵	3.9 x 10 ⁻⁵	4.8 x 10 ⁻⁵	6.0 x 10 ⁻⁵	7.4 x 10 ⁻⁵	9.3 x 10 ⁻⁵	1.3 x 10 ⁻⁴	1.8 x 10 ⁻⁴	2.7 x 10 ⁻⁴
10 years	1.3 x 10 ⁻⁵	1.6 x 10 ⁻⁵	1.9 x 10 ⁻⁵	2.4 x 10 ⁻⁵	2.9 x 10 ⁻⁵	3.5 x 10 ⁻⁵	4.6 x 10 ⁻⁵	6.1 x 10 ⁻⁵	8.9 x 10 ⁻⁵
15 years	8.4 x 10 ⁻⁶	1.0 x 10 ⁻⁵	1.2 x 10 ⁻⁵	1.5 x 10 ⁻⁵	1.8 x 10 ⁻⁵	2.2 x 10 ⁻⁵	2.9 x 10 ⁻⁵	3.8 x 10 ⁻⁵	5.6 x 10 ⁻⁵
adult	5.4 x 10 ⁻⁶	6.5 x 10 ⁻⁶	7.8 x 10 ⁻⁶	9.4 x 10 ⁻⁶	1.1 x 10 ⁻⁵	1.4 x 10 ⁻⁵	1.8 x 10 ⁻⁵	2.4 x 10 ⁻⁵	3.5 x 10 ⁻⁵

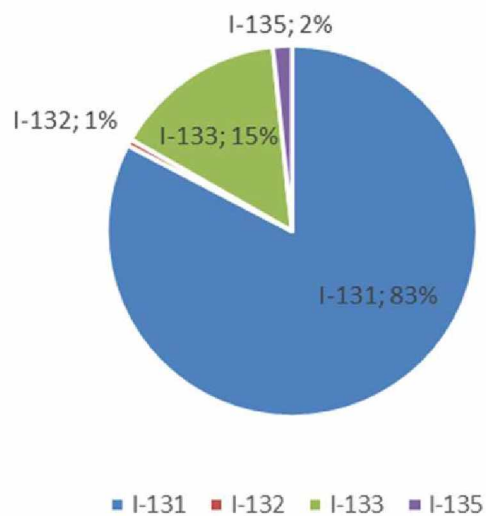
Challeton-de Vathaire C, Quentric E, Didier D, Blanchardon E, Davesne E, Rannou A, Agarande M, Renaud-Salis V, Franck D. INITIAL EVALUATION OF INDIVIDUAL DOSES IN THE EARLY PHASE OF A NUCLEAR REACTOR ACCIDENT BASED ON IN-VIVO MONITORING DATA AND SIMULATED RADIOLOGICAL CONSEQUENCES. Radiat Prot Dosimetry. 2019 Nov 30;185(1):96-108.

[RESULTS

Contributions of the different exposure component to the dose

SGTR accident

Thyroid dose



Effective dose due to all exposure pathways :

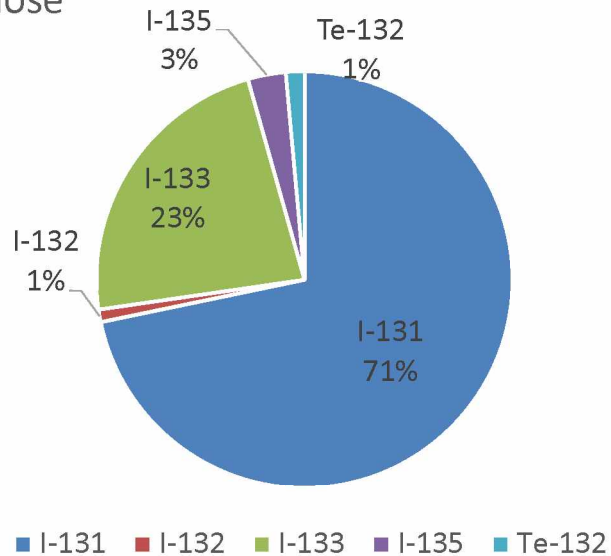
- 72% due to inhalation of all RN (47% due to inhalation of ^{131}I)
- 19% due to irradiation from the ground
- 7% due to immersion in the plume

[RESULTS

Contributions of the different exposure component to the dose

LOCA accident

Thyroid dose



Effective dose due to all exposure pathways :

- 26% due to inhalation of all RN (14% due to inhalation of ^{131}I)
- 10% due to irradiation from the ground
- 64% due to immersion in the plume

[CONCLUSION (1)

- Early interpretation of ^{131}I *in-vivo* measurement in the thyroid, as presented in this study, will give crucial indication on the real level of exposure of the population around the nuclear site during the emergency phase
- Data provided for two scenarios of accidents affecting a nuclear power plant are directly applicable to perform a first dosimetric assessment of the exposure for a person in whose thyroid ^{131}I has been detected and quantified in the aftermath of an accident related to one of the two scenarios considered (i.e. with similar activity releases and dispersion conditions)
- The study can be extended to other accident scenarios in the emergency preparedness phase
- During the emergency response phase of a real accident, the method can be used to create and adapt interpretation tables following the iterative assessments performed by the responders (based on modeling and available environmental measurements)

[CONCLUSION (2)

- In case of a real accident a more sophisticated dose assessment will have to be performed in a second time in order to evaluate individual health risk for long term medical survey and to provide a quantification of the exposure for epidemiological studies

- This assessment will take into account
 - the local isotopic composition of the contaminated cloud,
 - the time-pattern of the exposure,
 - exposure after the first 24 hours (from the radionuclides deposited on the ground),
 - subsequent individual measurements.



Thanks for your attention

IRSN

