C.LEMESRE
30.10.2017

- Managing radioactive waste
- Transporting radioactive substances
- Accident Management

First part

MANAGING RADIOACTIVE WASTE

Outline

I. Radioactive waste
II. Waste management and guiding value
III. Waste management and half-life
IV. ALARA Principle

Outline

I. **Radioactive waste**
II. Waste management and guiding value
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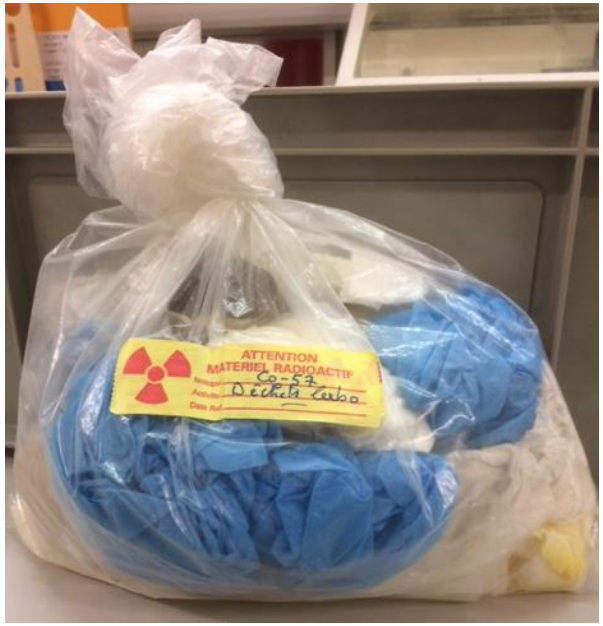
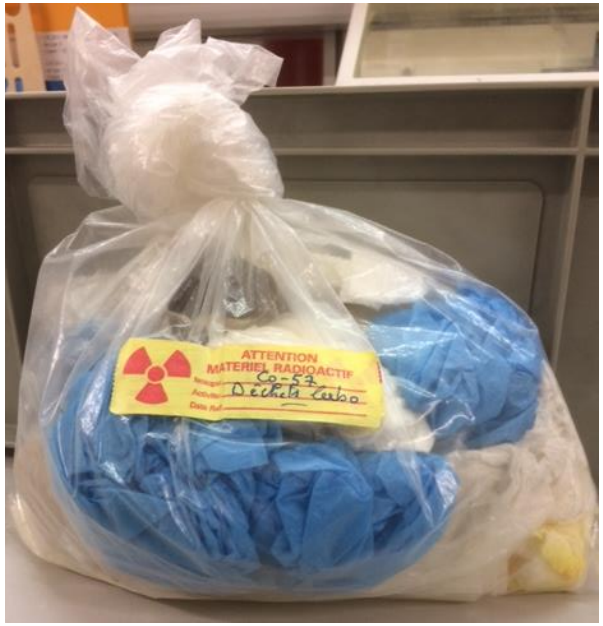
Radioactive waste

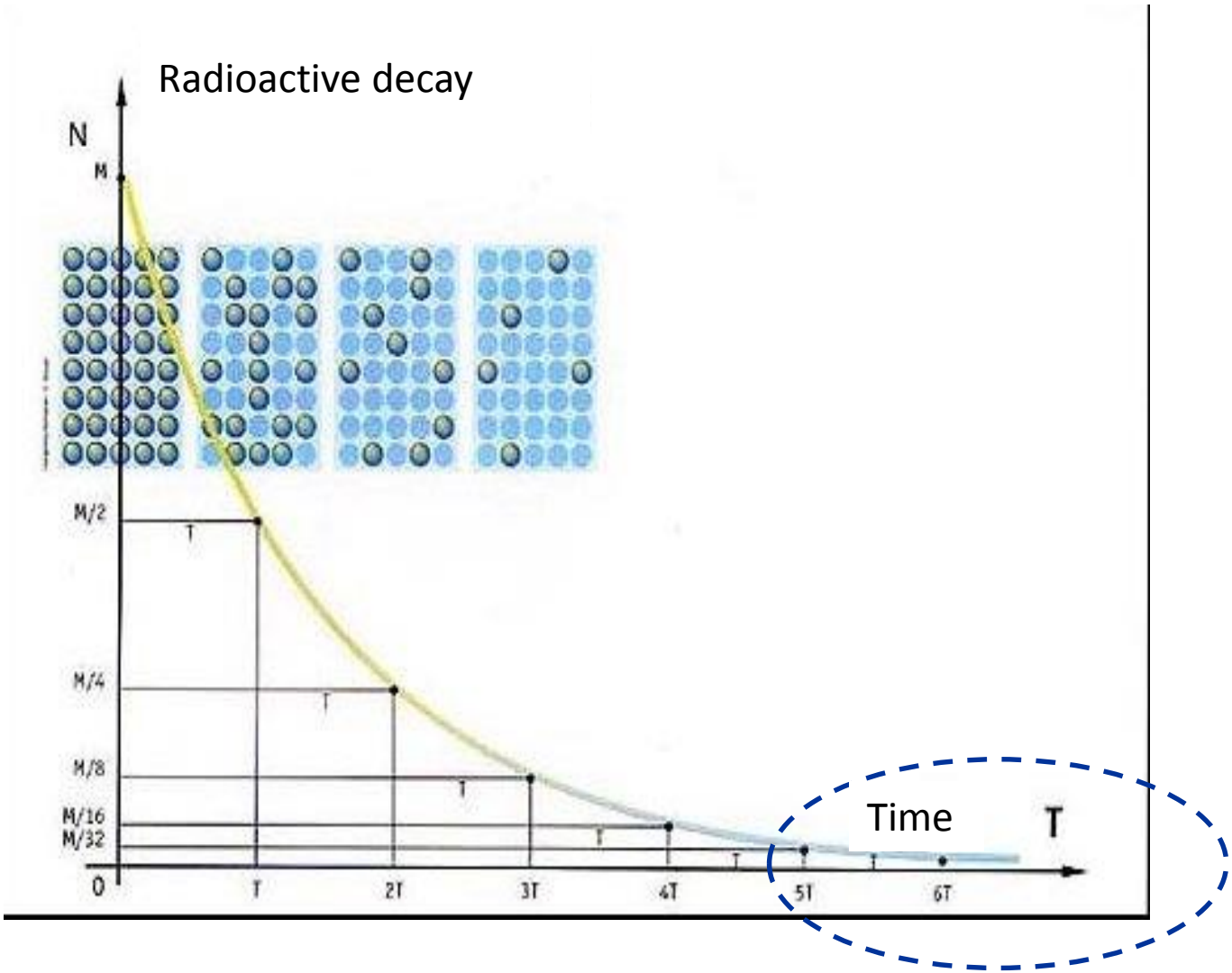


Radioactive waste



- Can they be disposed of as conventional waste?
- If not, what should be done?

Radioactive waste



Outline

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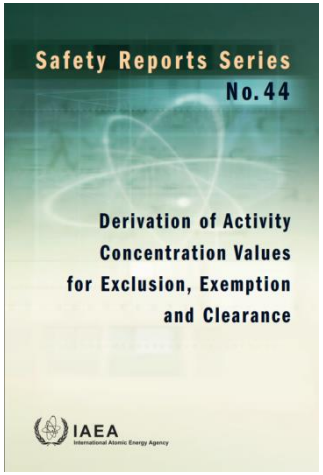
Waste management and guiding value

LL - Clearance limit

Is the value corresponding to the specific activity level of a material below which handling of this material is no longer subject to mandatory licensing or, accordingly, supervision.

Chosen according to IAEA Safety reports 44:



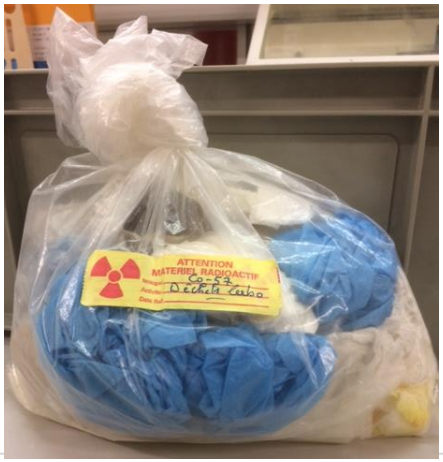
Radionuclide	Half-life	Type of decay/ radiation	Assessment quantities					Clearance limit		Licensing limit	Guidance values			Unstable daughter nuclide
			e_{inh} Sv/Bq	e_{ing} Sv/Bq	h_{10} (mSv/h)/ GBq at 1 m distance	$h_{0,07}$ (mSv/h)/ GBq at 10 cm distance	$h_{c,0,07}$ (mSv/h)/ (kBq/cm^2)	LL Bq/g		LA Bq	CA Bq/m^3	CS Bq/ cm^2	
1	2	3	4	5	6	7	8	9		10	11	12	13	
H-3, OBT	12.32 a	β$^-$	4.10 E-11	4.20 E-11	<0.001	<1	<0.1	1.E+02		1.00 E+08	2.00 E+05	1000		
H-3, HTO		β$^-$	1.80 E-11	1.80 E-11	<0.001	<1	<0.1	1.E+02		1.00 E+08	5.00 E+05	1000		
H-3, gaz [7]		β$^-$	1.80 E-15		<0.001	<1	<0.1			1.00 E+12	5.00 E+09			
Be-7	53.22 d	ec / ph	4.60 E-11	2.80 E-11	0.008	<1	0.1	1.E+01		1.00 E+08	2.00 E+05	100		
Be-10	1.51 E6 a	β$^-$	1.90 E-08	1.10 E-09	<0.001	2000	1.6	1.E+02		1.00 E+05	4.00 E+02	3		
C-11	20.39 min	ec, β$^+$ / ph	3.20 E-12	2.40 E-11	0.160	1000	1.7	1.E+01	[1]	7.00E+07	7.00 E+04 [3]	3		
C-11 monoxide			1.2 E-12							7.00E+07	7.00 E+04 [3]			
C-11 dioxide			2.2 E-12							7.00E+07	7.00 E+04 [3]			
C-14	5.70 E3 a	β$^-$	5.80 E-10	5.80 E-10	<0.001	200	0.3	1.E+00		9.00E+06	1.00 E+04	30		
C-14 monoxide			8.00 E-13							6.00E+09	1.00 E+07			
C-14 dioxide			6.50 E-12							8.00E+08	1.00 E+06			
N-13	9.965 min	ec, β$^+$ / ph			0.160	1000	1.7	1.E+02	[1]	7.00E+07	7.00 E+04 [3]	3		
O-15	122.24 s	ec, β$^+$ / ph			0.161	1000	1.7	1.E+02	[1]	7.00E+07	7.00 E+04 [3]	3		
F-18	109.77 min	ec, β$^+$ / ph	9.30 E-11	4.90 E-11	0.160	2000	1.7	1.E+01	[1]	7.00E+07	7.00 E+04 [3]	3		
Na-22	2.6019 a	ec, β$^+$ / ph	2.00 E-09	3.20 E-09	0.330	2000	1.6	1.E-01		3.00E+06	4.00 E+03	3		
Na-24	14.9590 h	β$^-$ / ph	5.30 E-10	4.30 E-10	0.506	1000	1.9	1.E+00		9.00E+06	2.00 E+04	3		
Mg-28 / Al-28	20.915 h	β$^-$ / ph	1.70 E-09	2.20 E-09	0.529	2000	3.1	1.E+01	[2]	3.00E+06	5.00 E+03	3		

Radiological Protection Ordinance https://www.admin.ch/opc/en/classified-compilation/20163016/index.html

Waste management and guiding value

Type of waste	Specific activity (Bq/g)	Absolute activity (Bq)
Solid and liquid waste	A < LL and < 0,1 μSv/h at 10 cm	A < 1 kg x LL (or A < 10 kg x LL if licenced) and < 0,1 μSv/h at 10 cm

Complying to one column is sufficient !



see ORaP art 106 and following

Waste management and guiding value

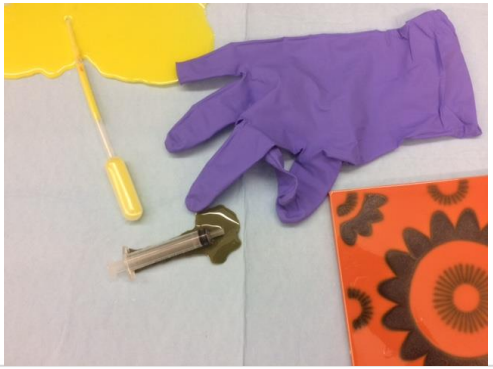
Type of waste	Specific activity (Bq/l)
Discharge in waste water	A < LI eaux licensing authority shall specify maximum permissible discharge rates and, where appropriate, discharge activity concentrations for each discharge site on a case-by-case basis (ORaP art 112).

Waste management and guiding value

Managing radioactive waste means **compare its activity to the LL** to know if it (or when it) can be disposed of as conventional waste.

Data needed :

- Nuclide
- LL
- Activity
- Date



Exercice

When will you be allowed to dispose of a solid waste of I-125 with an activity of 10 MBq (ref date 11.11.2018) as conventional waste, considering that you own a license for the handling of radioactive material ?

Outline

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Waste management and half-life

But if A > LL and 1 kg x LL ?

T < 100 day	T > 100 day
Storage for decay and then normal elimination	Annual collection campaign is organized by the Federal Office of Public Health and the PSI

Waste management and half-life

Storage

Container is closed and labeled :

- Name and address of the waste producer;
- Radionuclide(s) present;
- Approximate activity;
- Date the container was closed;
- Physical and chemical nature of the waste.

Waste management and half-life

Collection campaign FOPH/PSI

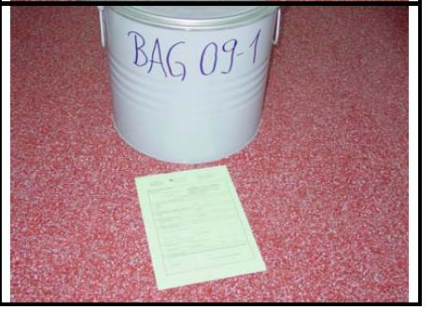
Emballer les déchets solides dans des sacs en plastique. Utiliser de la masse de remplissage.

Une carte d'accompagnement rouge par emballage intérieur (EI).

Mettre les déchets liquides dans des bouteilles et placer celles-ci dans un conteneur en PE (spécification de l'OFSP).

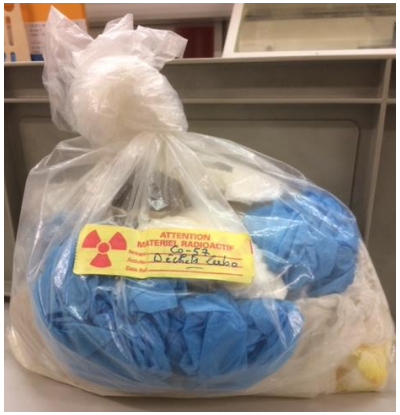
Entourer le conteneur en PE de coussins absorbants: 20l de capacité d'absorption par 10l de liquide.

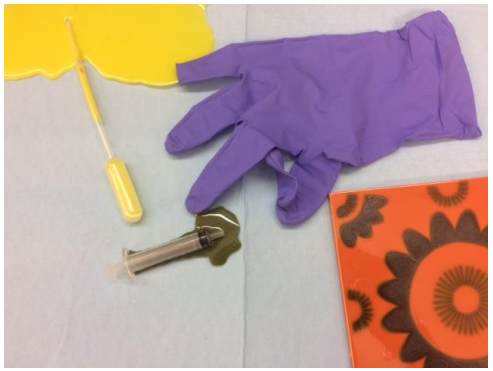
Une carte d'accompagnement verte par emballage (E)



Waste management and half-life

Managing radioactive waste means **define how long the waste should be stored**.





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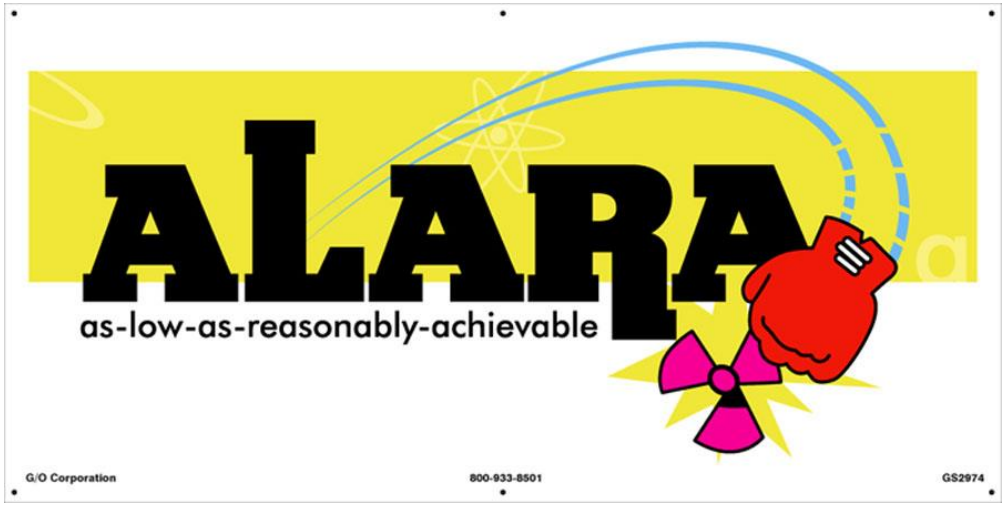
ALARA Principle



Reduce the amount of waste to a necessary minimum, lowest activity and volume.

- Use only the minimum activity necessary
- Reduce to a bare minimum the number of objects coming into contact with the radioactive substance
- Strictly separate contaminated waste from non-contaminated waste

Second part

TRANSPORTING RADIOACTIVE SUBSTANCES


RADIOACTIVE
TDI

Outline

I. Legislation
II. Types of package
III. Safety obligations of the consignor
    I. Marking packages
    II. Labelling packages
    III. Transport document
IV. Safety obligations of the carrier
    I. Placarding of the vehicle
    II. Instructions in writing
    III. Equipment for personal protection
V. Safety obligations of the driver

Outline

Legislation

Transport beyond the company

741.621

Ordonnance relative au transport des marchandises dangereuses par route (SDR)

du 29 novembre 2002 (Etat le 1er janvier 2015)

Le Conseil fédéral suisse,

vu les art. 30, al. 4, 103 et 106, de la loi fédérale du 19 décembre 1958 sur la circulation routière[1],
vu l'art. 48*a*, al. 1, de la loi du 21 mars 1997 sur l'organisation du gouvernement et de l'administration[2,3]
arrête:

Section 1 Dispositions générales

Art. 1 Objet et champ d'application

[1] La présente ordonnance règle les transports de matières et d'objets dangereux (marchandises dangereuses) effectués par des véhicules automobiles et leurs remorques ou par d'autres moyens de transport sur les routes ouvertes à ces mêmes véhicules automobiles.

[2] Elle s'applique:

a. aux fabricants de marchandises dangereuses;

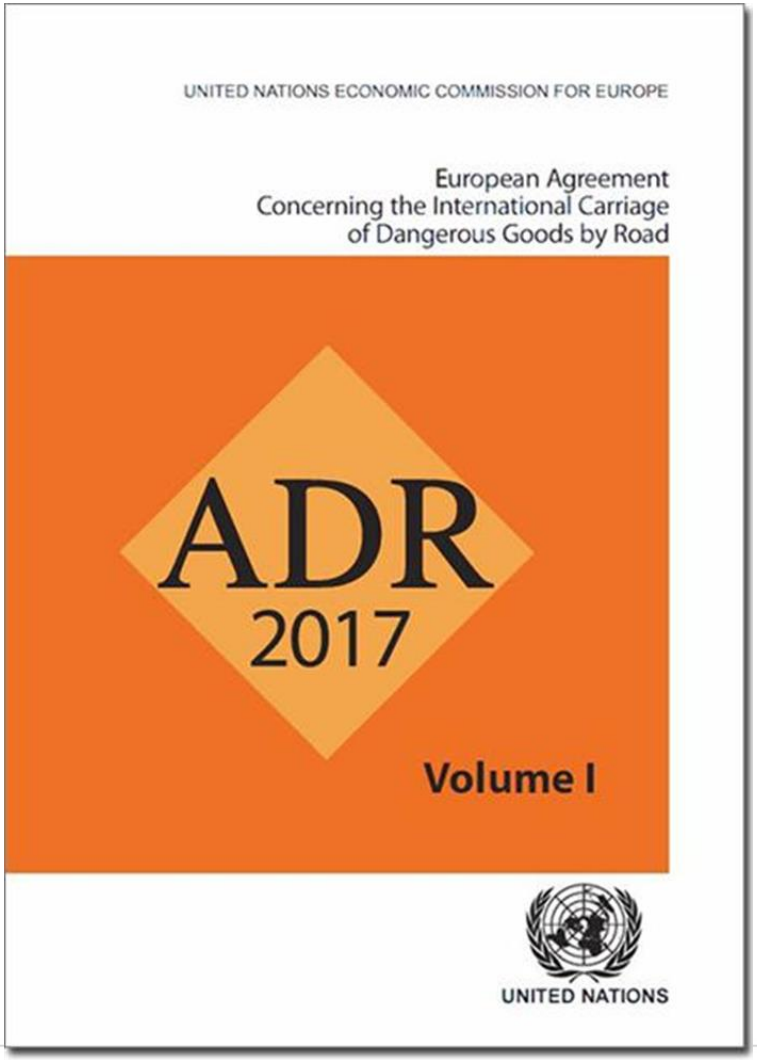
b. aux expéditeurs et aux destinataires de marchandises dangereuses;

c. aux personnes qui assurent le transport et la manutention de marchandises dangereuses;

d. aux fabricants et aux utilisateurs des emballages, citernes ou moyens de transport servant à transporter des marchandises dangereuses.

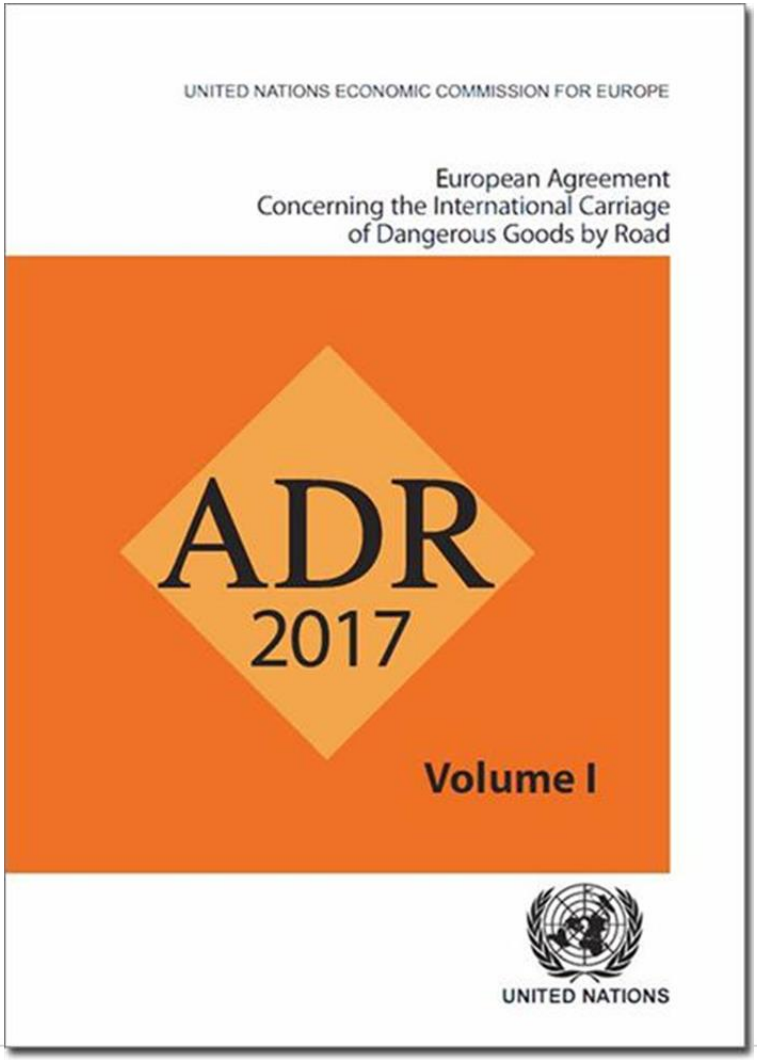
Art. 2 Délimitation par rapport à l'OCS

Les entreprises qui effectuent des opérations de transport, d'emballage, de remplissage, d'expédition, de chargement ou de déchargement de marchandises dangereuses sont en outre soumises aux dispositions relatives à la désignation, aux tâches, à la formation et à l'examen des conseillers à la sécurité qui figurent dans l'ordonnance du 15 juin 2001 sur les conseillers à la sécurité (OCS)[4].



Legislation

Transport beyond the company



Class 1	Explosive substances and articles
Class 2	Gases
Class 3	Flammable liquids
Class 4	Flammable solids
Class 5	Oxidizing Agents and Organic Peroxides
Class 6	Toxic and Infectious Substances
Class 7	**Radioactive material**
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances

Outline

I. Legislation

II. Types of package

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IV. Safety obligations of the carrier

- I. Placarding of the vehicle
- II. Instructions in writing
- III. Equipment for personal protection

V. Safety obligations of the driver

Types of package

Exempted material

Excepted packages

Type A packages

Type B packages

Type C packages (for air transport only)

Activity

Fire/water/falls/impacts resistance

The higher the activity,
The more safety measures needed,
The higher the cost of the transport.

Types of package

Step 1 : Exempt material

When at least one of the two limits is not exceeded.

Radionuclide (atomic number)	Activity concentration limit for exempt material (Bq/g)	Activity limit for an exempt consignment (Bq)
Actinium (89)		
Ac-225 (a)	1×10^{1}	1×10^{4}
Ac-227 (a)	1×10^{-1}	1×10^{3}
Ac-228	1×10^{1}	1×10^{6}
Silver (47)		
Ag-105	1×10^{2}	1×10^{6}
Ag-108m (a)	1×10^{1} (b)	1×10^{6} (b)
Ag-110m (a)	1×10^{1}	1×10^{6}
Ag-111	1×10^{3}	1×10^{6}
Aluminium (13)		
Al-26	1×10^{1}	1×10^{5}
Americium (95)		
Am-241	1×10^{0}	1×10^{4}
Am-242m (a)	1×10^{0} (b)	1×10^{4} (b)

Exercises

Can the following sources be considered as Exempt material ?

- Plutonium 236
  - 1,3 kBq
  - Total mass of material to be transported is 100 g.

- Americium 241
  - 400 MBq.

Radionuclide	Activity concentration limit for exempt material (Bq/g)	Activity limit for an exempt consignment(Bq)
Am-241	1.10^0	1.10^4
Pu-236	1.10^1	1.10^4

Types of package

Graduation of dangerousness

Activity that may lead to an exposure of 50 mSv at 1m in 30 minutes	Risk	Form
A1	External exposure	Special (Not susceptible to dispersion)
A2	External and internal exposure	Non special

Any “special” source must be **certified** as to its mechanical and thermal resistance and well as its resistance to immersion.

Types of package

Graduation of dangerousness

Radionuclide (atomic number)	A_1 (TBq)	A_2 (TBq)
Actinium (89)		
Ac-225 (a)	8×10^{-1}	6×10^{-3}
Ac-227 (a)	9×10^{-1}	9×10^{-5}
Ac-228	6×10^{-1}	5×10^{-1}
Silver (47)		
Ag-105	2×10^{0}	2×10^{0}
Ag-108m (a)	7×10^{-1}	7×10^{-1}
Ag-110m (a)	4×10^{-1}	4×10^{-1}
Ag-111	2×10^{0}	6×10^{-1}
Aluminium (13)		
Al-26	1×10^{-1}	1×10^{-1}
Americium (95)		
Am-241	1×10^{1}	1×10^{-3}
Am-242m (a)	1×10^{1}	1×10^{-3}

Types of package

Step 2 : Excepted packages

When the limit is not exceeded.

Table 2.2.7.2.4.1.2: Activity limits for excepted packages

Physical state of contents	Instruments or articles		Materials
	Item limits [a]	Package limits [a]	Package limits [a]
(1)	(2)	(3)	(4)
Solids			
special form	10^{-2} A_1	A_1	10^{-3} A_1
other form	10^{-2} A_2	A_2	10^{-3} A_2
Liquids	10^{-3} A_2	10^{-1} A_2	10^{-4} A_2
Gases			
tritium	2×10^{-2} A_2	2×10^{-1} A_2	2×10^{-2} A_2
special form	10^{-3} A_1	10^{-2} A_1	10^{-3} A_1
other forms	10^{-3} A_2	10^{-2} A_2	10^{-3} A_2

Exercises

Can the following solid sources be transported as excepted packages ?

- Cesium 137
  - 1,3 MBq
  - Special form
- Americium 241
  - 400 MBq

Physical state of contents	Materials Package limits [a]
(1)	(4)
Solids	
special form	10^{-3} A_1
other form	10^{-3} A_2
Liquids	10^{-4} A_2
Gases	
tritium	2×10^{-2} A_2
special form	10^{-3} A_1
other forms	10^{-3} A_2

Radionuclide	Activity limit for an exempt consignment(Bq)	A1 (TBq)	A2 (TBq)
Am-241	1.10^4	1.10^1	1.10^{-3}
Cs-137	1.10^4	2.10^0	6.10^{-1}

Types of package

Step 3 : Type A packages

When the limit is not exceeded.

Type A packages shall not contain activities greater than either of the following:

(a) For special form radioactive material - A_1;

(b) For all other radioactive material - A_2.

Types of package

Step 4 : Type B packages

When the limits A1 or A2 are exceeded.

Air transport : Type C packages

When the activity limits for Type B packages are exceeded.

Form	Activity limits for Type B packages
Special	Smallest value between 3 000 A1 or 100 000 A2
Non special	3 000 A2

Exercise

What type of package is required to transport the following source?

- Americium 241
  - 400 MBq.

Radionuclide	A1 (TBq)	A2 (TBq)
Am-241	1.10^{1}	1.10^{-3}

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    II. Instructions in writing
    III. Equipment for personal protection
V. Safety obligations of the driver

Safety obligations of the consignor

Marking packages

UN numbers and proper shipping name

UN No.	Proper shipping name and description[a]
Excepted packages (1.7.1.5)	
UN 2908	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE - EMPTY PACKAGING
UN 2909	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE - ARTICLES MANUFACTURED FROM NATURAL URANIUM or DEPLETED URANIUM or NATURAL THORIUM
UN 2910	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE - LIMITED QUANTITY OF MATERIAL
UN 2911	RADIOACTIVE MATERIAL, EXCEPTED PACKAGE - INSTRUMENTS or ARTICLES
Type A packages (2.2.7.2.4.4)	
UN 2915	RADIOACTIVE MATERIAL, TYPE A PACKAGE, non-special form, non fissile or fissile-excepted[b]
UN 3327	RADIOACTIVE MATERIAL, TYPE A PACKAGE, FISSILE, non-special form
UN 3332	RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, non fissile or fissile-excepted[b]
UN 3333	RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, FISSILE
Type B(U) packages (2.2.7.2.4.6)	
UN 2916	RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, non fissile or fissile-excepted[b]
UN 3328	RADIOACTIVE MATERIAL, TYPE B(U) PACKAGE, FISSILE
Type B(M) packages (2.2.7.2.4.6)	
UN 2917	RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, non fissile or fissile-excepted[b]
UN 3329	RADIOACTIVE MATERIAL, TYPE B(M) PACKAGE, FISSILE
Type C packages (2.2.7.2.4.6)	
UN 3323	RADIOACTIVE MATERIAL, TYPE C PACKAGE, non fissile or fissile-excepted[b]
UN 3330	RADIOACTIVE MATERIAL, TYPE C PACKAGE, FISSILE

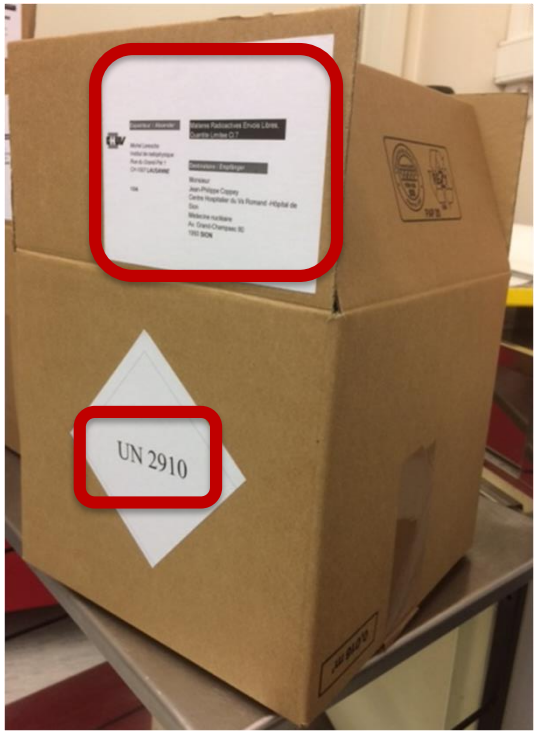
Safety obligations of the consignor

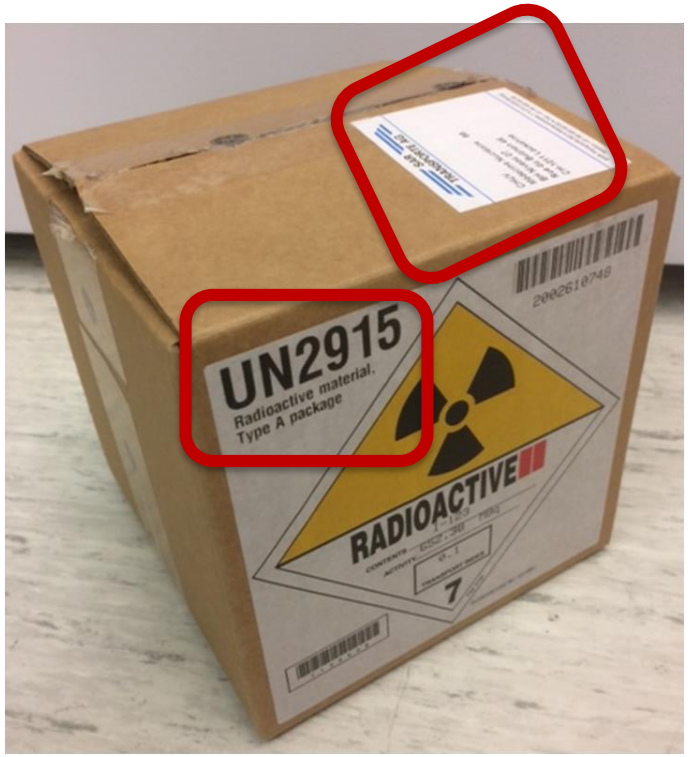
Marking packages

Excepted packages	Others types of packages	
UN number	UN number and proper shipping name	
Identification of the consignor and/or the consignee	Identification of the consignor and/or the consignee	
Mass if > 50 kg	Mass if > 50 kg	
	« TYPE A »	« TYPE B » ou « TYPE C »
	VIR Code	Serial number
	Name of the manufacturer	Trefoil symbol resistant to fire and water

Safety obligations of the consignor

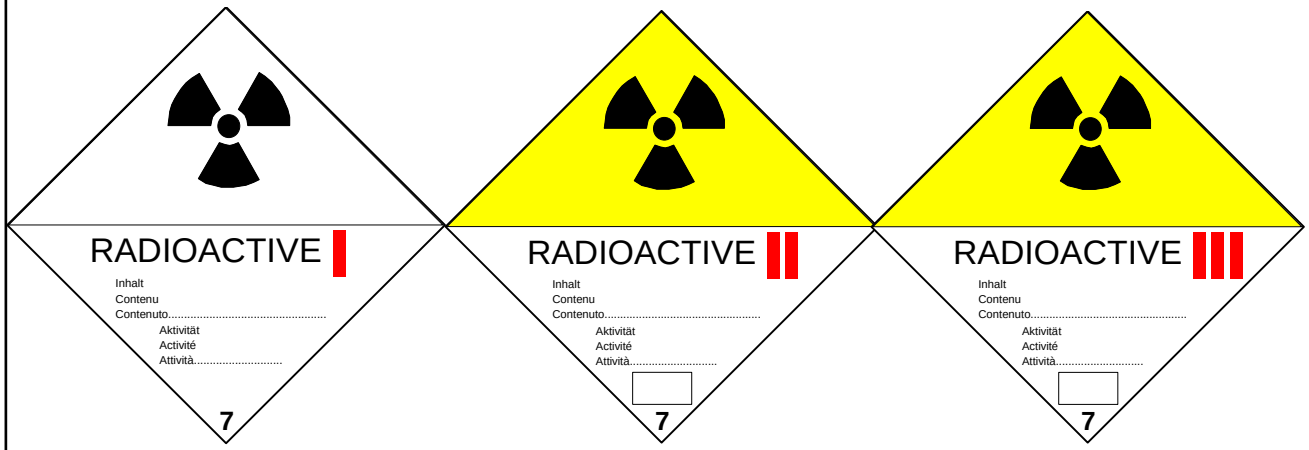
Marking packages





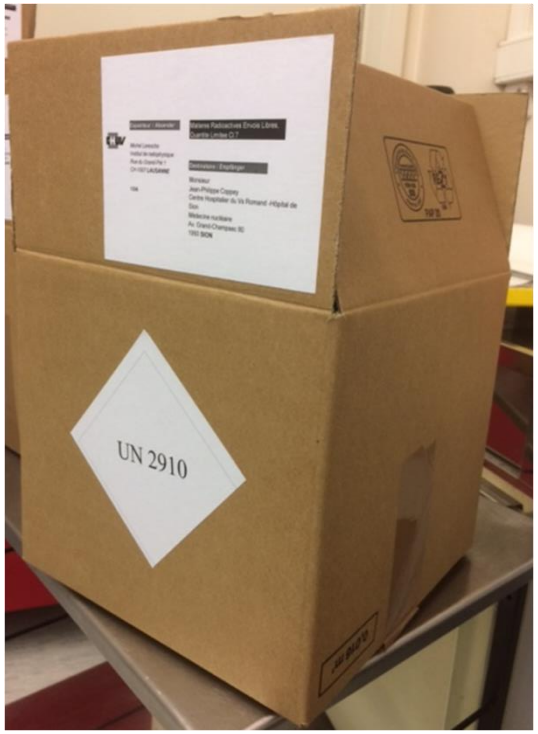
Safety obligations of the consignor

Labelling packages

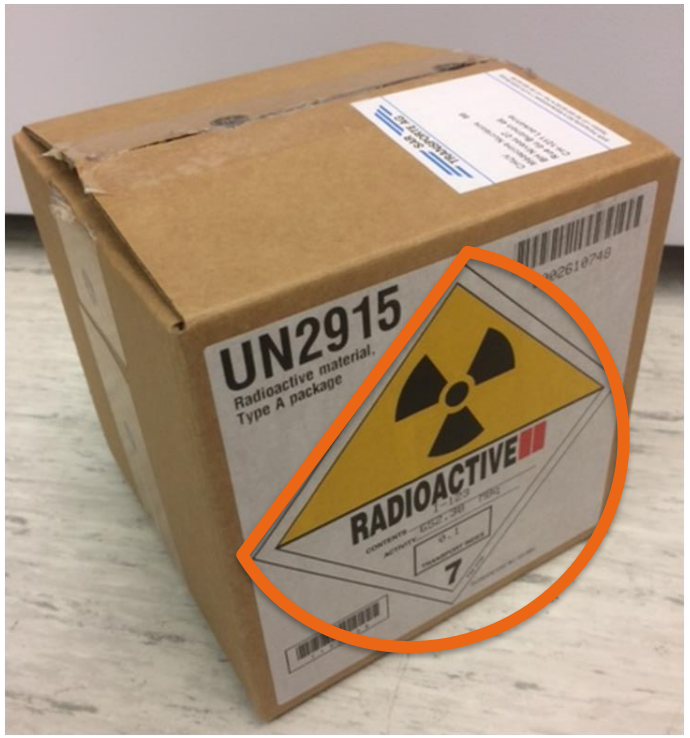
Excepted packages	Others types of packages
-	On two opposite sides of the package 

Safety obligations of the consignor

Labelling packages

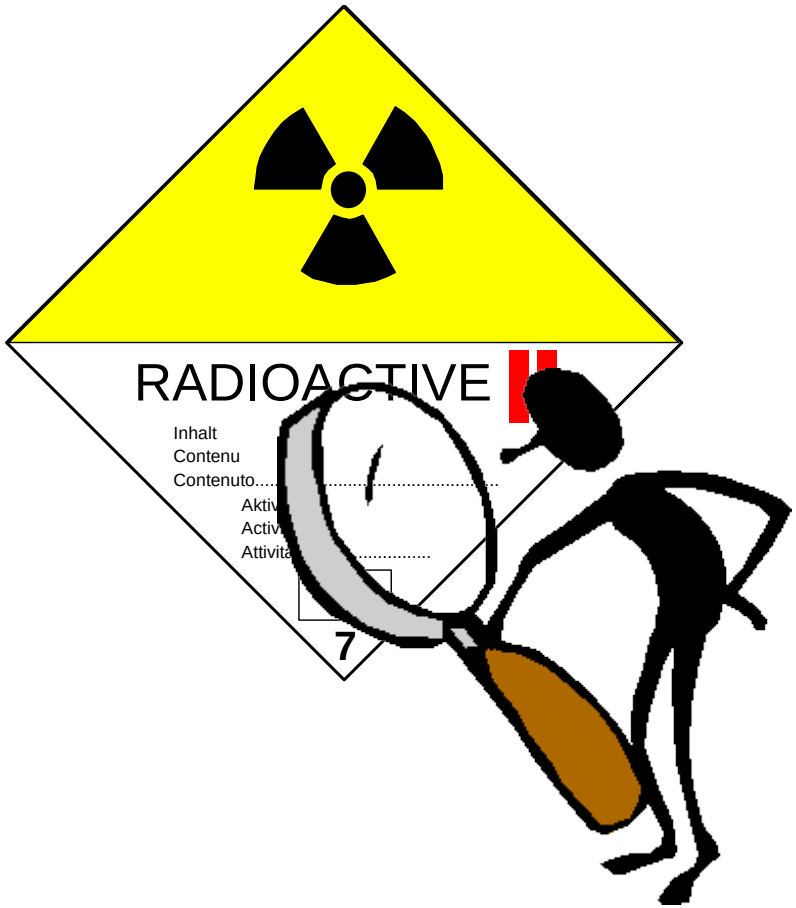


No labelling



Safety obligations of the consignor

Labelling packages



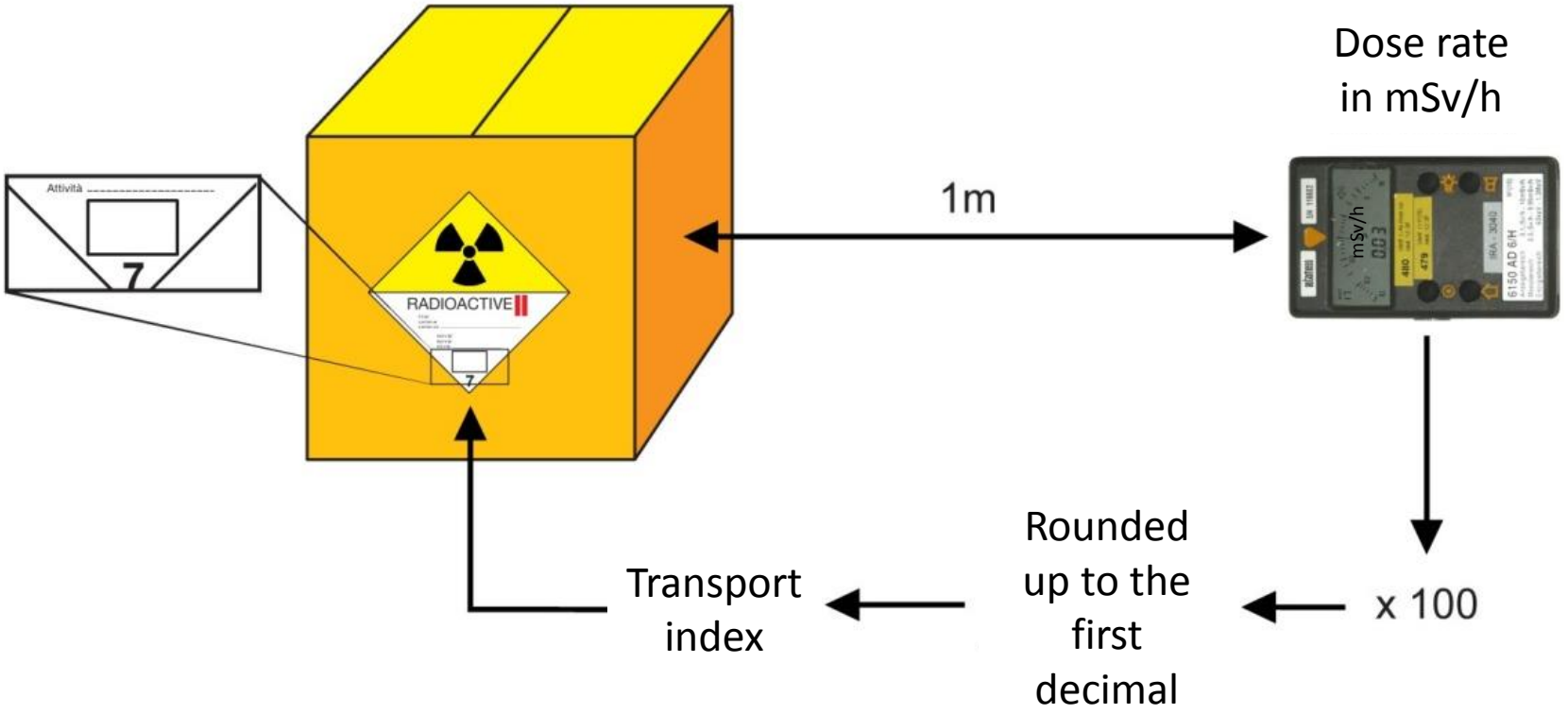
- Content
- Activity
- Transport index
- Class 7

Safety obligations of the consignor

Labelling packages

Choosing the label

Step 1 : Transport index



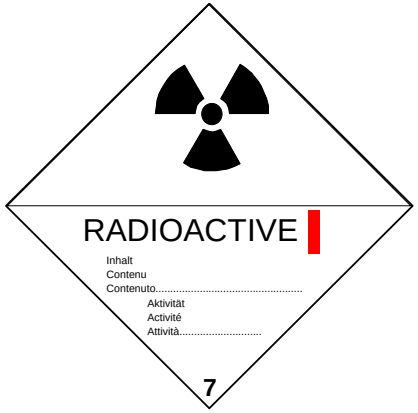
Safety obligations of the consignor

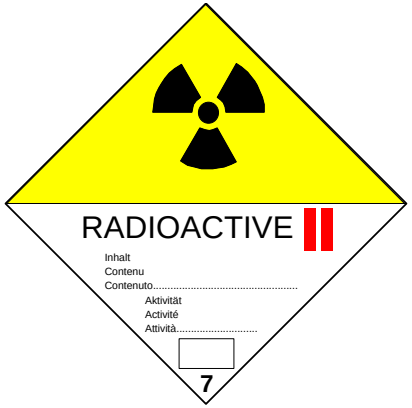
Labelling packages

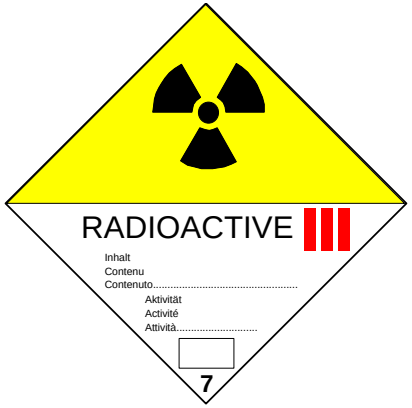
Choosing the label

Step 2 : Categories

Transport index	Maximum dose rate on the surface	Categories
0	D < 5 µSv/h	I - White
0 < TI ≤ 1	5 µSv/h < D ≤ 0,5 mSv/h	II - Yellow
1 < TI ≤ 10	0,5 mSv/h < D ≤ 2 mSv/h	III - Yellow
10 < TI	2 mSv/h < D ≤ 10 mSv/h	III - Yellow







Exercices

Which label should be placed on a package with a dose rate on the surface of 0.67 mSv/h and a dose rate at 1 m of 1.4 µSv/h ?

Transport index	Maximum dose rate on the surface	Categories
0	D < 5 µSv/h	I - White
0 < TI ≤ 1	5 µSv/h < D ≤ 0,5 mSv/h	II - Yellow
1 < TI ≤ 10	0,5 mSv/h < D ≤ 2 mSv/h	III - Yellow
10 < TI	2 mSv/h < D ≤ 10 mSv/h	III - Yellow

Safety obligations of the consignor

Transport document

Excepted packages	Other types of packages
- UN number preceded by letters “UN” - Name and address of the consignor - Name and address of the consignee	- UN number preceded by letters “UN” - Name and address of the consignor - Name and address of the consignee
-	- Proper shipping name - Class number “7” - Number and description of the packages - Total quantity of each item - Name or symbol of each radionuclide - Physical and chemical form of the material - Maximum activity of the radioactive contents during carriage (in Bq) - Category of the package - Transport index

Safety obligations of the consignor

Transport document

CHUV Institut de radiophysique	Page 1 / 1
Document de transport de matières radioactives	**IRA/64.01/08.01/01**

Colis exceptés[1] et colis de type A	Nom et adresse de l'expéditeur :	CHUV - Institut de radiophysique Rue du Grand-Pré 1, CH-1007 Lausanne Tél. +41 21 314 8068 - Fax +41 21 314 8299
	Nom et adresse du destinataire :	Nom : Adresse : Tél :
	Description de la marchandise dangereuse :	Choisissez un élément.
Colis de type A uniquement	Radionucléides :	
	Etat physique (forme chimique) :	
	Activité de l'envoi :	
	Catégorie de l'envoi :	
	Indice de transport de l'envoi :	
	Nombre et description des colis :	
	Quantité totale de marchandise (exprimée en volume ou masse) :	
	Prescription supplémentaires[2] :	
	Restrictions [3] :	
	Dispositions à prendre en cas d'urgence :	Se référer au document IRA/64.01/07.01 joint.

Je déclare que le contenu de ce chargement est décrit ci-dessus de façon complète et exacte par la désignation officelle de transport et qu'il est convenablement classé, emballé, étiqueté, placardé et à tous les égards, bien conditionné pour être transporté conformément aux règlementations internationales et nationales.	Nom et date :
Transport effectué par :	Date :
Document transmis au responsable de la radioprotection[4]	Date :
Document transmis au conseiller à la sécurité[4]	Date :

Outline

I. Legislation
II. Types of package
III. Safety obligations of the consignor
    I. Marking packages
    II. Labelling packages
    III. Transport document
IV. Safety obligations of the carrier
    I. Placarding of the vehicle
    II. Instructions in writing
    III. Equipment for personal protection
V. Safety obligations of the driver

Safety obligations of the carrier

Placarding of the vehicle

Excepted packages	Other types of packages	
-		Both sides and at the rear
		At the front and at the rear

Safety obligations of the carrier

Placarding of the vehicle

Safety obligations of the carrier

Instructions in writing

Excepted packages	Other types of packages
-	Instructions in writing to be carried out the transport unit

INSTRUCTIONS IN WRITING ACCORDING TO ADR

Actions in the event of an accident or emergency

In the event of an accident or emergency that may occur or arise during carriage, the members of the vehicle crew shall take the following actions where safe and practicable to do so:

- Apply the braking system, stop the engine and isolate the battery by activating the master switch where available;
- Avoid sources of ignition, in particular, do not smoke, use electronic cigarettes or similar devices or switch on any electrical equipment;
- Inform the appropriate emergency services, giving as much information about the incident or accident and substances involved as possible;
- Put on the warning vest and place the self-standing warning signs as appropriate;
- Keep the transport documents readily available for responders on arrival;
- Do not walk into or touch spilled substances and avoid inhalation of fumes, smoke, dusts and vapours by staying up wind;
- Where appropriate and safe to do so, use the fire extinguishers to put out small/initial fires in tyres, brakes and engine compartments;
- Fires in load compartments shall not be tackled by members of the vehicle crew;
- Where appropriate and safe to do so, use on-board equipment to prevent leakages into the aquatic environment or the sewage system and to contain spillages;
- Move away from the vicinity of the accident or emergency, advise other persons to move away and follow the advice of the emergency services;
- Remove any contaminated clothing and used contaminated protective equipment and dispose of it safely.

Safety obligations of the carrier

Equipment for personal protection

Excepted packages	Other types of packages
One portable fire extinguisher with a minimum capacity of 2 kg dry powder	2 portable fire extinguishers with a minimum capacity of 2 kg each
-	For the vehicle : - A wheel chock - 2 self-standing warning signs - Eye rinsing liquid
	For each member of the vehicle crew : -A warning vest - Portable lighting apparatus - A pair of protective gloves - Eye protection (e.g. protective goggles)

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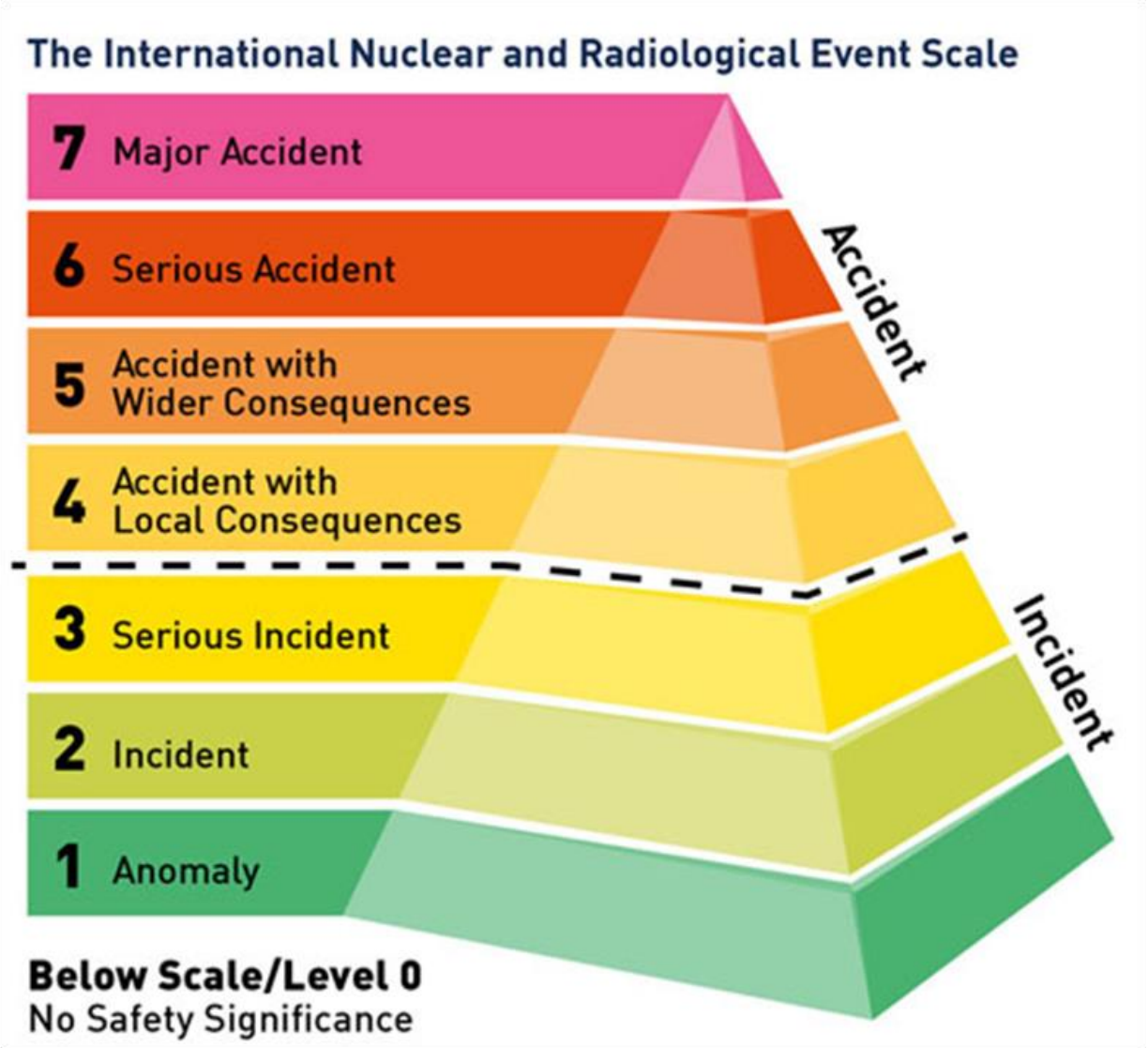
Safety obligations of the driver

Excepted packages	Other types of packages
-	Means of identification, which include a photograph, for each member of the vehicle crew
	Driver's training certificate
	Apart from members of the vehicle crew, no passengers may be carried in transport units carrying dangerous goods

Third part

ACCIDENT MANAGEMENT

INES Scale


The International Nuclear and Radiological Event Scale
7 Major Accident
6 Serious Accident
5 Accident with Wider Consequences
4 Accident with Local Consequences
3 Serious Incident
2 Incident
1 Anomaly
Accident
Incident
Below Scale/Level 0
No Safety Significance

Examples

https://www-news.iaea.org

Date	Location	INES rating	Event
07.17	USA	2	A pharmacy technician received an elevated whole body dose in April 2017. The licensee requested the expedited processing of the May 2017 whole body dosimeter and a dose of 110 mSv was reported. The isotopes involved are believed to be Mo-99/Tc-99m, Tc-99m, and Ga-68.
01.17	United Kingdom	2	Sampling of radioactive material was taking place on a reprocessing facility. Upon leaving the building and using the building exit hand and frisking monitors, the Shift Team Leader found himself to be contaminated. Contamination was found on one finger of his right hand and removed using the standard procedure. The estimated dose of just over 1 Sv exceeds the statutory equivalent annual dose limit for the hand of 500 mSv.
11.16	South Africa	2	A parcel containing an industrial radiography sealed source was transported from Kenya to South Africa. The package was labelled as empty (UN2908) and was handled as a general luggage during transportation in a South African Airways passenger flight. On arrival at the final destination the dose rate on the outside surface of the package was measured by the consignee to be 6mSv/h.