Impact of a nuclear accident on drinking water

Leo Puijker, KWR
Chris Twenhöfel, RIVM
Hans de Vries, KNMI

Outline

PREPARE

- Drinking water production in The Netherlands and EU Member States
- Modelling surface contamination based on the Fukushima source term and real weather conditions for a nuclear accident in the Netherlands
- Impact of meteorological conditions (wind statistics)
- Impact on drinking water quality

40 % of drinking water in the Netherlands is produced from surface water

PREPARE

Sources of drinking water in EU member states (%)

PREPARE

Country	Surface water	Ground water	Other	Population
Austria	0.1	99.0	0	8.3
Belgium	37.65	62.35	0	10.7
Bulgaria	59.06	40.94	0	7.6
Croatia				4.4
Cyprus	37.4	19.4	32.7 (seawater) 10.5 (artificial groundwater)	0.8
Czech Republic	32	37	31 (mix)	10.5
Denmark	1	99	0	5.5
Estonia	60.05	39.95	0	1.3
Finland	45.69	41.33	12.98 (bank filtrate and artificial groundwater)	5.3
France	32.64	67.28	0.08	64.3
Germany	15.5	74.5	10 (artificial groundwater and bank filtrate)	82
Greece	50	50	0	11.2
Hungary	8	35	46 (bank filtrate) 11 Other	10

Sources of drinking water in EU Member States

PREPARE

Country	Surface water	Ground water	Other	Population
Ireland	91.8	8.2	0	4.5
Italy	No information	No information	No information	60
Latvia	22	64	14 (artificial groundwater)	2.3
Lithuania	0	100	0	3.3
Luxemburg	52	48	0	0.5
Malta	0	45	55 (saline groundwater from deep wells)	0.4
Poland	31.5	68.5	0	38.1
Portugal	68	32	0	10.6
Romania	68.38	31.62	0	21.5
Slovakia	17.8	82.2	0	5.4
Slovenia	3	97	0	2
Spain	78.09	20.9	1 (coastal water) 0.01 (rain)	45.8
Sweden	24	51	25 (artificial infiltration)	9.2
The Netherlands	38.6	61.4	0	16.4
United Kingdom	45.92	19.15	34.93 (other)	61.7

Surface water intakes

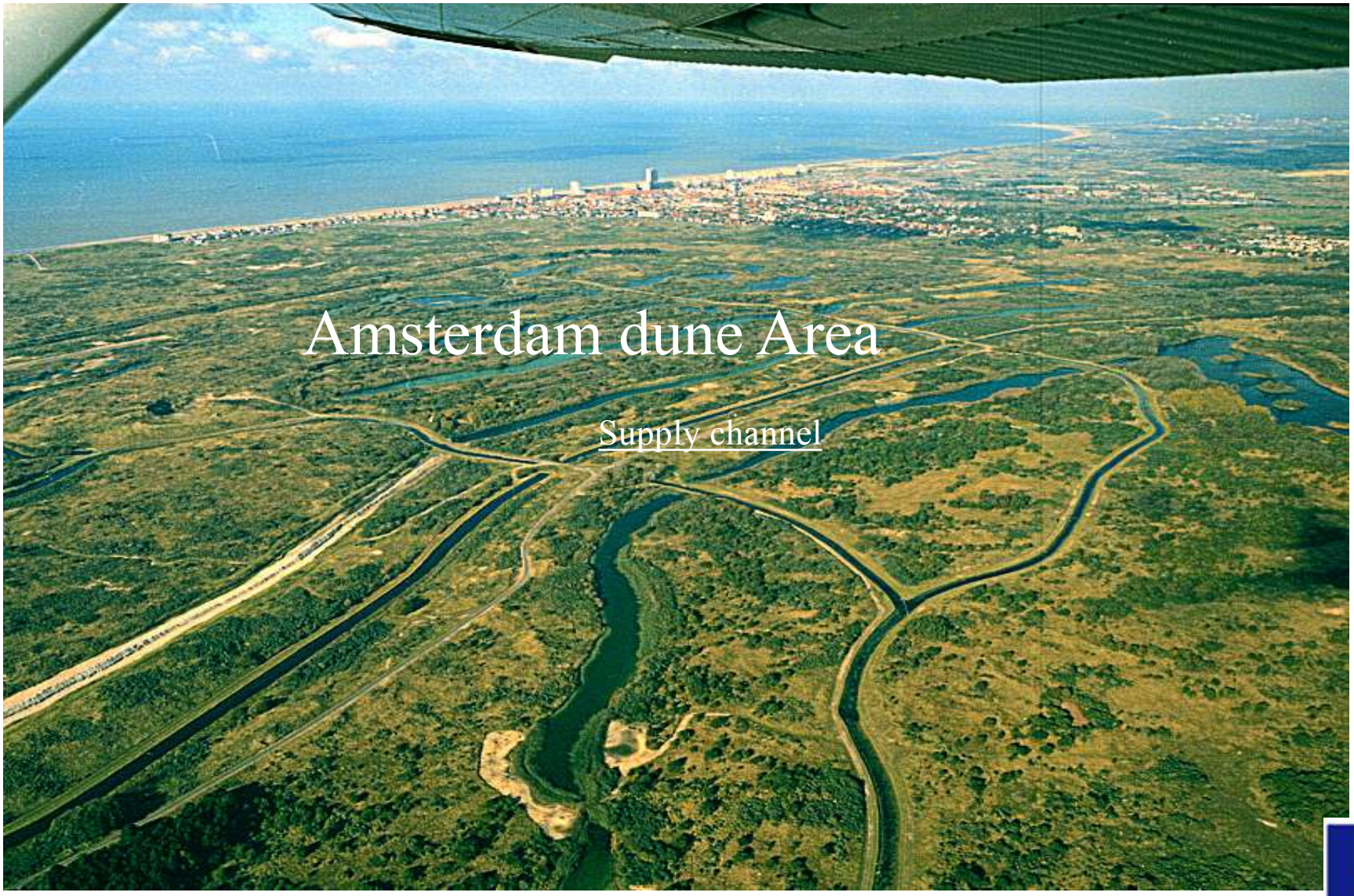
PREPARE

Surface water reservoirs

PREPARE

The Amsterdam Dune water catchment area

PREPARE



Infiltration ponds

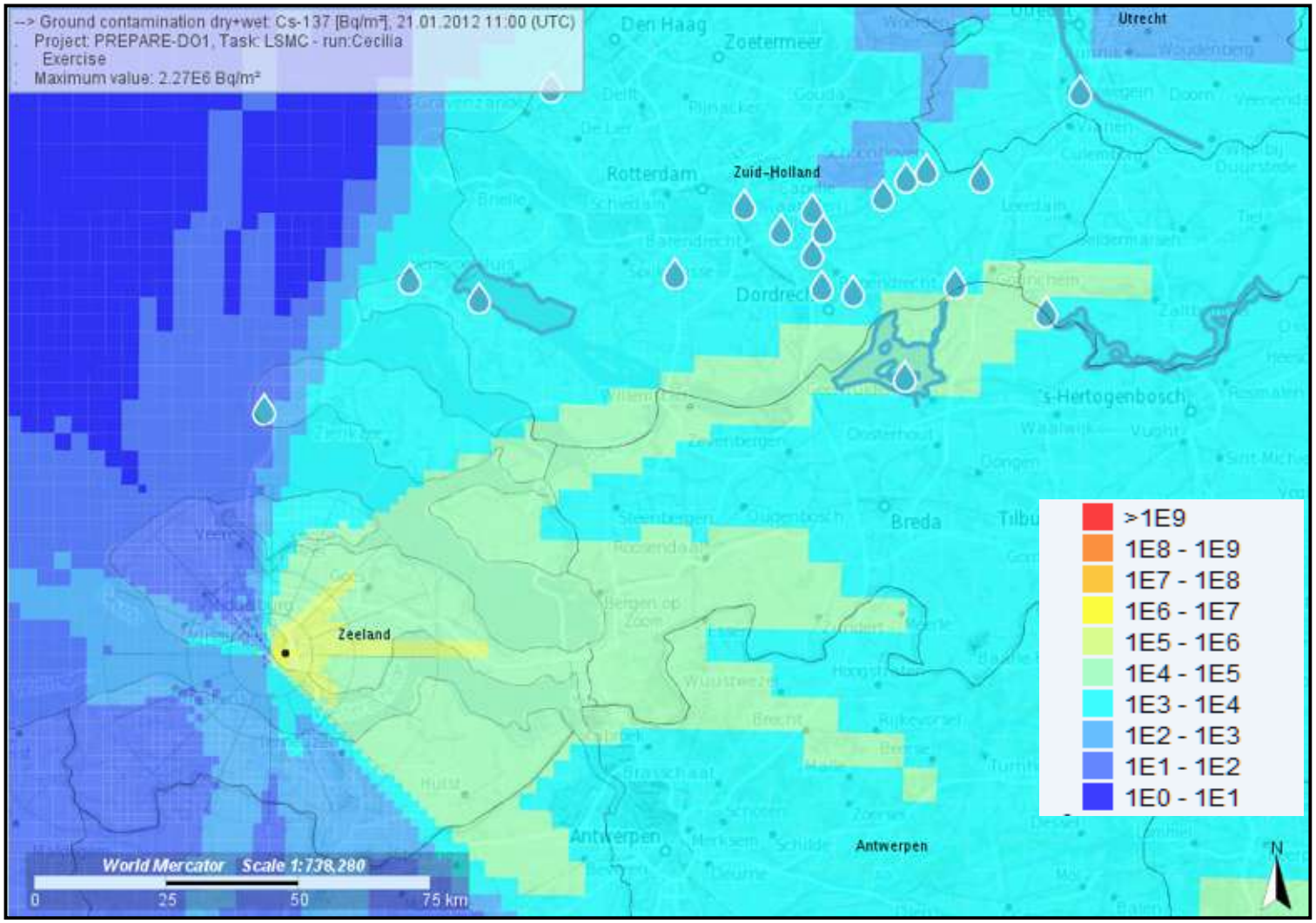
PREPARE

Modelling deposition with JRODOS

PREPARE

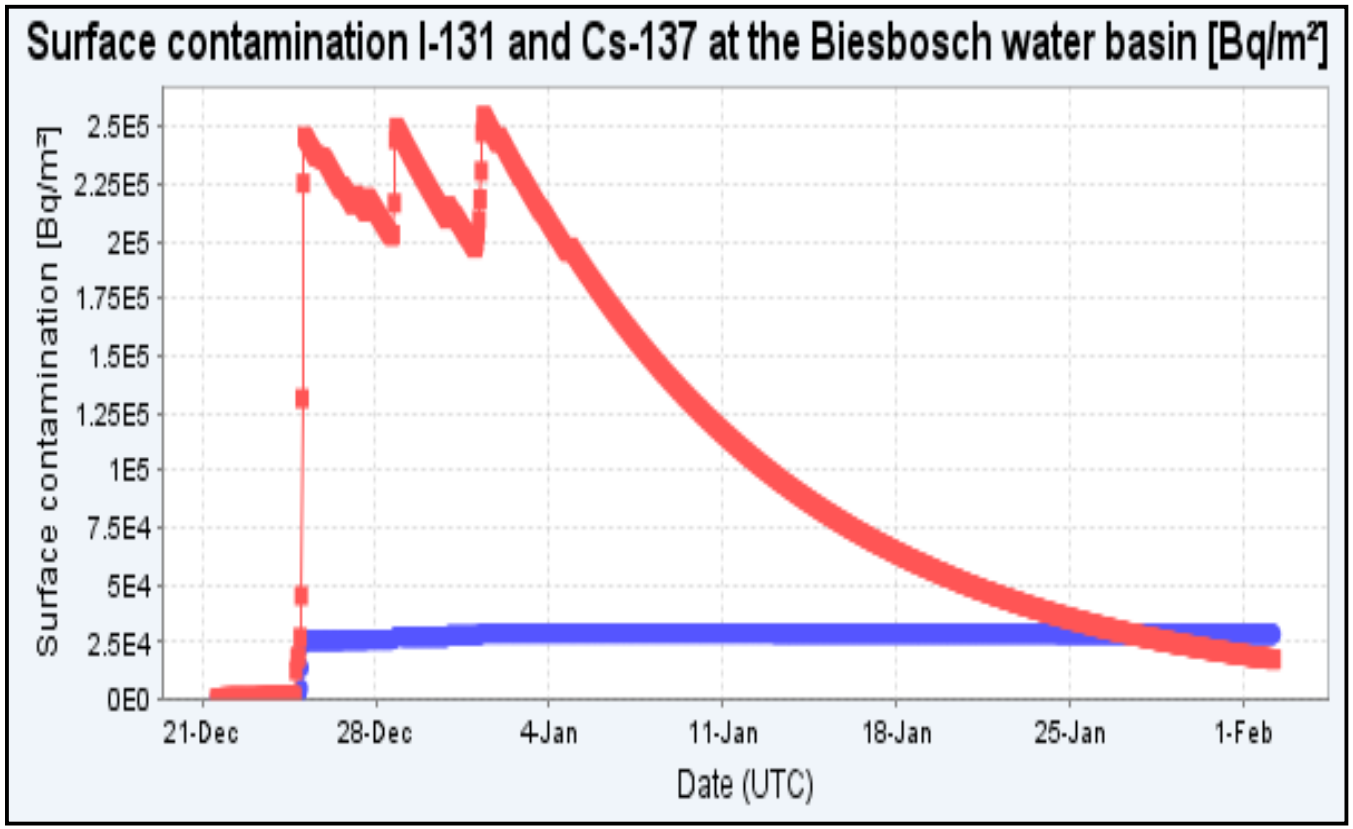
- The Fukushima source term was taken from UNSCEAR 2013 report
- The total accumulated release of ^{131}I, ^{134}Cs and ^{137}Cs to the atmosphere over all release phases amounts to 1.2 10^{17}, 9.0 10^{15} and 8.9 10^{15} Bq respectively
- The release was positioned at the location of the Borssele nuclear power plant in the province of Zeeland, in the South-West of the Netherlands
- Calculations of dispersion made by Local Scale Model and RIMPUFF with real weather conditions in December 2011 – January 2012
- The 30 release phases of the source term were reduced to the maximum of 24 release phases accessible in the JRODOS model by grouping phase 17-18, 19-20, 22-23, 25-26 and 27-30
- Total duration of all release phases adds up to 1195 hours (ca. 50 days)

Surface contamination map of ^{137}Cs 1 month after first release, maximum in the Biesbosch area is 30 kBq/m^2 of ^{137}Cs



Surface contamination at reservoir

PREPARE



Surface contamination of ^{131}I (upper line) and ^{137}Cs (lower line) in Bq/m^2 in the Biesbosch area, located 70-80 km from the Borssele nuclear power plant. Contamination maximum in the Biesbosch area is about 250 kBq/m^2 ^{131}I and 30 kBq/m^2 ^{137}Cs. Three dominant cloud passages is clearly visible.

Wind statistics

PREPARE

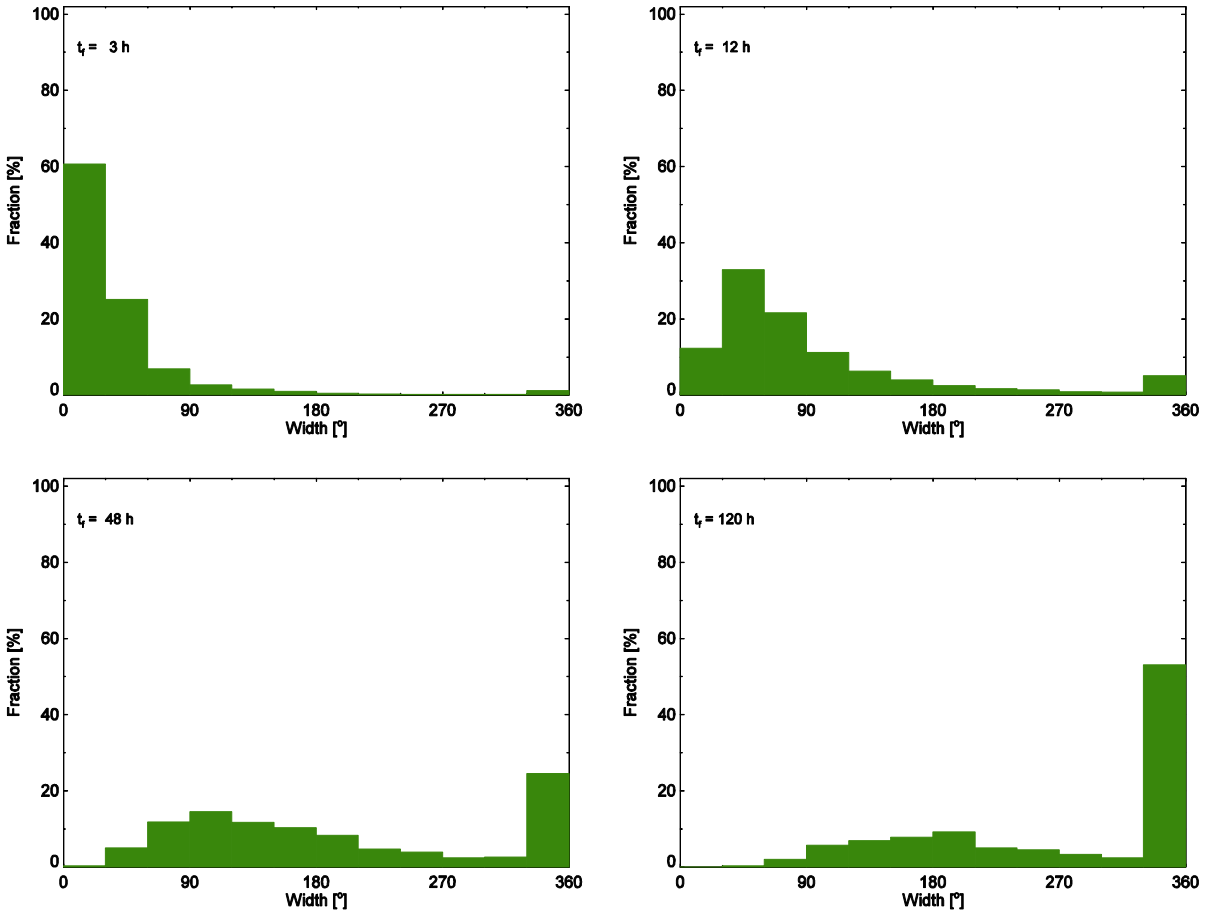
- The number of sectors in the 5 and 20 km zones around the release point where actions have to be taken, will increase when the release continues in time, depending on the changes in the wind direction.

- This has been statistically investigated with hourly observations for the wind direction in Vlissingen from 1 June 2012 – 31 May 2015. For every hour in this period, the number of sectors that are covered by the wind in the following hours up to 30 days, has been determined

Effects of weather conditions

PREPARE

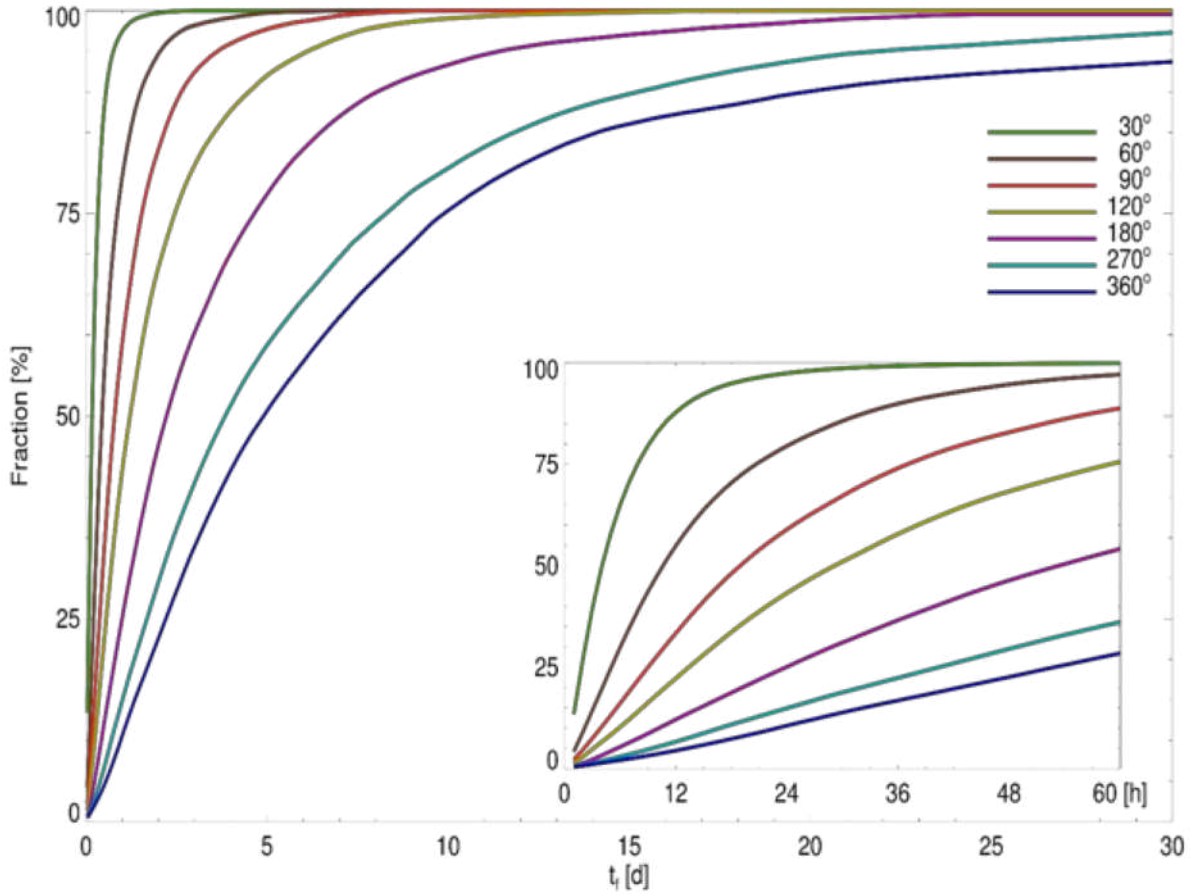
Distribution of the sector size covered in a continuous release at 3, 12, 48 and 120 h after the start of the release



Effects of weather conditions

PREPARE

Cumulative coverage in time for a series of sectors. The inset gives the first 2.5 days (60 h) of the total figure (30 d) in more detail



Impact on surface water quality

PREPARE

Maximum deposition in surface water reservoir at 70 - 80 km distance:

Maximum deposition ^{131}I : 250 kBq/m^2

Maximum deposition ^{137}Cs : 30 kBq/m^2

Maximum activities at a dilution factor of 10 (depth reservoir 10 m):

Maximum activity ^{131}I : 25 Bq/L

Maximum activity ^{137}Cs : 3 Bq/L

These levels can be increased by rainfall

WHO guideline for drinking water for both nuclides: 10 Bq/L

Effects of drinking water treatment

PREPARE

Effect of different water treatment steps on the removal efficiency for Cs-137 and I-131, based on data from Haberer (1989) and Kwakman and Versteegh (2010)[a]

Element	Floccula-tion/ coagu-lation [d]	Sand filtration (fast/ slow)	Activa-ted carbon	Softe-ning [b]	Clay zeolites	Ionen-ex-change[c]	Aeration	RO
Iodine	-	-	+	- -	-	+	++	++
Cesium	-	-	- -	-	+	+		++

a) The removal efficiency is based on the assumption that the nucleotides are not adsorbed to other particles. (- -: 0-10%, - : 10-40%, + : 40-70%, ++: >70%).

b) In case of a lack of data, it is assumed that the softening step does not have an effect.

c) Cation and anion exchanger are included.

d) Depending on turbidity of the water [2].

Conclusions

PREPARE

In case of a nuclear accident surface water can be contaminated by high levels of radionuclides and is not suitable for drinking water production

Common water treatment processes as aeration and filtration do not effectively remove ^{131}I and ^{137}Cs

Advanced treatment processes as ion-exchange and reversed osmosis do remove radionuclides effectively, but these are not common practice

Soil passage (dune infiltration, river bank filtration, groundwater) are a safe barrier for ^{131}I and ^{137}Cs nuclides

If surface water is the main direct source for drinking water production emergency plans for drinking water supply are needed

Drinking water utilities in the European countries are required by the EU Drinking Water Directive to provide emergency drinking water in case of a major accident, including nuclear accidents

Wind statistics show that the probability that the complete circle will be covered during a longer-lasting release, is not negligible

Knowledge of the meteorological conditions at the initial moment of the release facilitates a more targeted response

Finally

PREPARE

- Thanks for your attention!
- Any questions?

The research leading to these results has received funding from the European Atomic Energy Community Seventh Framework Programme [FP7/2007-2011] [FP7/2012-2013] under grant agreement n° [323287].