United Arab Emirates

FANR
الهيئة الاتحادية للرقابة النووية
Federal Authority for Nuclear Regulation

Development of a Radiological and Nuclear Emergency Dose Assessment Program in a New Nuclear Nation – A Regulators Perspective

Andy Woodruffe

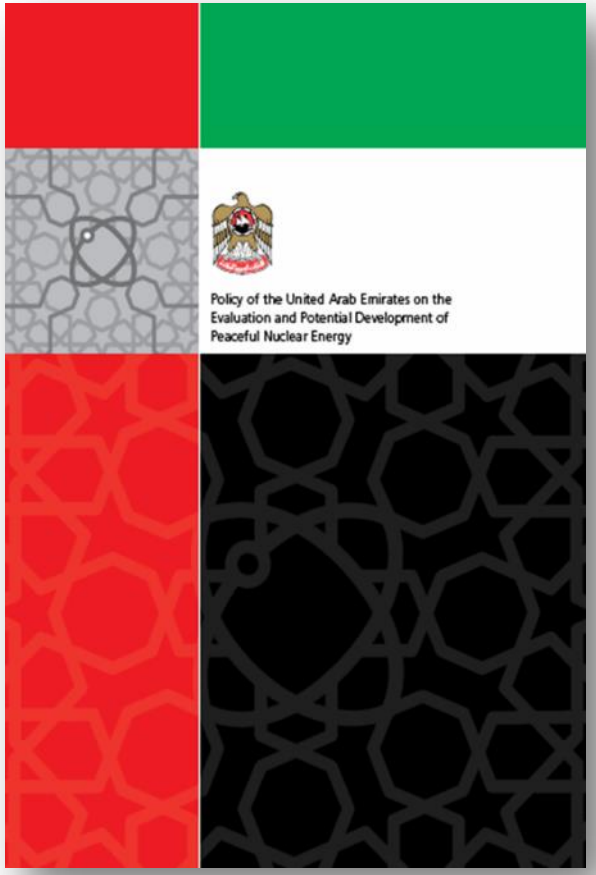
International Experts' Meeting on Assessment and Prognosis in Response to a Nuclear or Radiological Emergency
20-24 April 2015 (Vienna)

The United Arab Emirates (UAE)

- The United Arab Emirates is a constitutional federation of seven emirates, formed in 1971:
  - Abu Dhabi,
  - Dubai,
  - Sharjah,
  - Ajman,
  - Umm al-Qaiwain,
  - Ra's al-Khaimah
  - Fujairah
- UAE lies along the south-eastern tip of the Arabian peninsula. Occupying an area of about 83,600 sq. km

Federal Authority for Nuclear Regulation (FANR)

- FANR Formed in 2009 by the Nuclear Law:
  - Independent regulator with respect to nuclear safety, security, radiation protection and safeguards in the UAE
  - One of FANRs roles includes establishing frameworks for emergency preparedness and response for nuclear and radiological facilities and activities



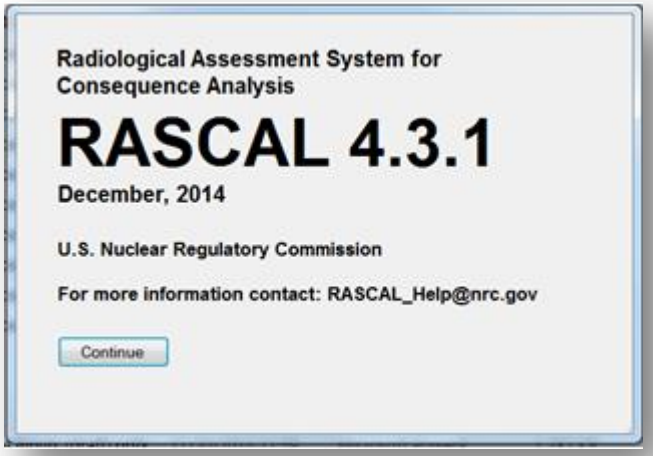
UAE Nuclear Power

- Currently 4 Korean APR1400 reactors under construction at Barakah:
  - Reference plants are Shin Kori 3 and 4 (under construction in Korea)
  - Unit 1 – commercial operation 2017
  - Remaining units, 2018, 2019, and 2020
  - When complete – 25% of UAEs electrical needs
  - FANR received the Operating License Application for Units 1 and 2 in March 2015
  - Fuel receipt - 2016

Nuclear Emergencies

Nuclear Emergencies - RASCAL

- FANR using RASCAL (version 4.3)
- US-NRC Code, developed over 25 years ago, continuously improved, includes Fukushima updates:
  - Multi-unit release
  - Increased calculation distance to 100 miles
  - Atmospheric transport
  - LTSBO
  - + others

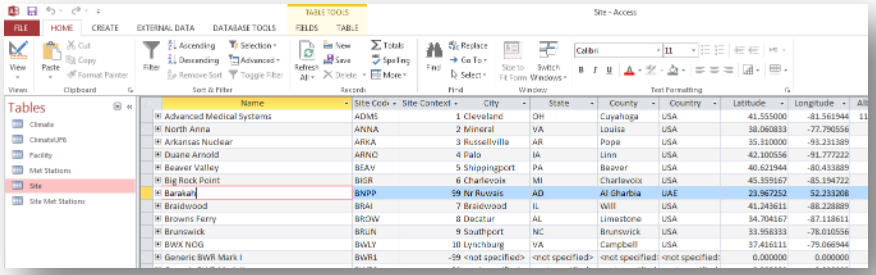


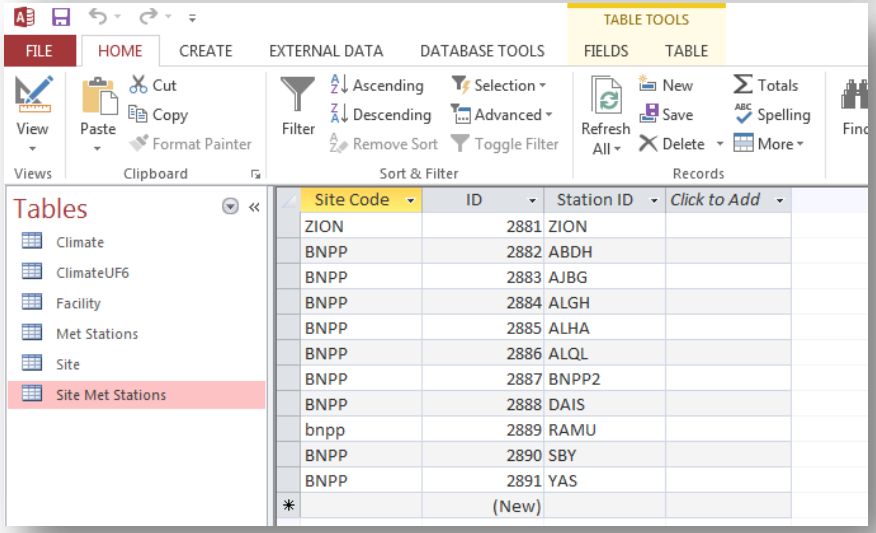
RASCAL Customization Plan

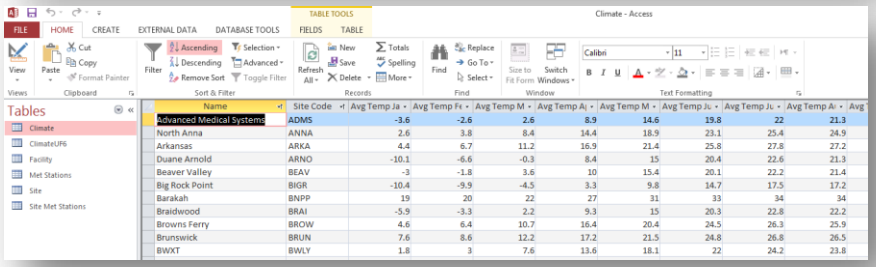
- Without customization, only includes USA NPP and facilities
- FANR needed to customize to add Barakah units:
  - Gather Inputs from license application documents:
    - PSAR
    - EIA
    - NCMS
    - RASCAL manual
    - *Verify against FSAR*
  - Prepare Basis Document
  - Update and control RASCAL
  - Add customized files to all RASCAL PCs

How to Customize RASCAL (1)

- To add new sites RASCAL needs:
  - Modified Facility_NRC-430.mdb:
    - Climate data
    - Climate UF_6 – since N/A, fill with 0's
    - Facility data
    - Met tower data
    - Site data
    - Site met stations
  - Hundreds of parameters – needs careful checking!

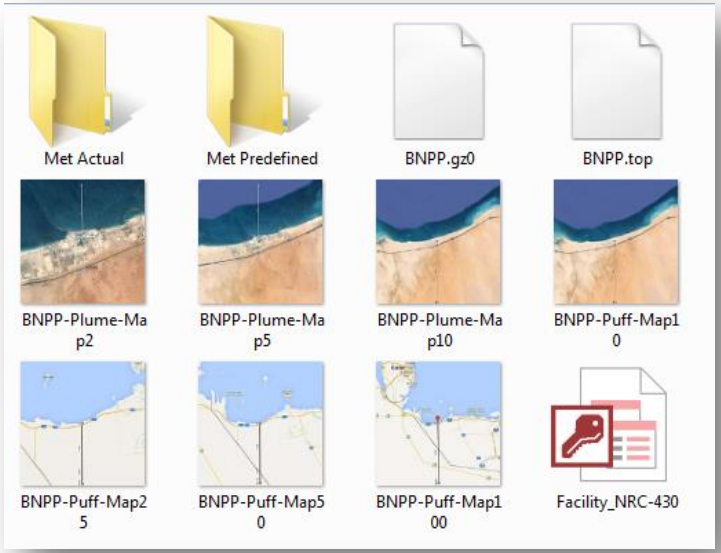


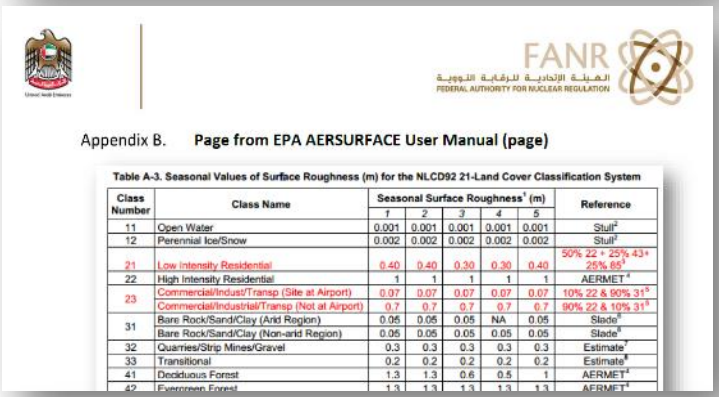




How to Customize RASCAL (2)

- Base Maps on multiple scales
  - From Google earth, and satellite
- Two empty folders which will hold met data when running RASCAL
- BNPP.gz0
  - Surface roughness file
  - 22 x 22 grid
    - 10.0, 5.0, 2.5, and 1.0 mile grid spacing
  - Roughness from satellite images and EPA AERSURFACE
- BNPP.top
  - Topography file
  - From Earth Explorer (GTOPO30)





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Appendix B. **Page from EPA AERSURFACE User Manual (page)**

Table A-3. Seasonal Values of Surface Roughness (m) for the NLCD92 21-Land Cover Classification System

Class Number	Class Name	Seasonal Surface Roughness[1] (m)					Reference
		1	2	3	4	5	
11	Open Water	0.001	0.001	0.001	0.001	0.001	Stull[2]
12	Perennial Ice/Snow	0.002	0.002	0.002	0.002	0.002	Stull[2]
21	Low Intensity Residential	0.40	0.40	0.30	0.30	0.40	50% 22 + 25% 43+ 25% 85[3]
22	High Intensity Residential	1	1	1	1	1	AERMET[4]
23	Commercial/Indust/Transp (Site at Airport)	0.07	0.07	0.07	0.07	0.07	10% 22 & 90% 31[5]
	Commercial/Industrial/Transp (Not at Airport)	0.7	0.7	0.7	0.7	0.7	90% 22 & 10% 31[5]
31	Bare Rock/Sand/Clay (Arid Region)	0.05	0.05	0.05	NA	0.05	Slade[6]
	Bare Rock/Sand/Clay (Non-arid Region)	0.05	0.05	0.05	0.05	0.05	Slade[6]
32	Quarries/Strip Mines/Gravel	0.3	0.3	0.3	0.3	0.3	Estimate[7]
33	Transitional	0.2	0.2	0.2	0.2	0.2	Estimate[8]
41	Deciduous Forest	1.3	1.3	0.6	0.5	1	AERMET[4]
42	Evergreen Forest	1.3	1.3	1.3	1.3	1.3	AERMET[4]

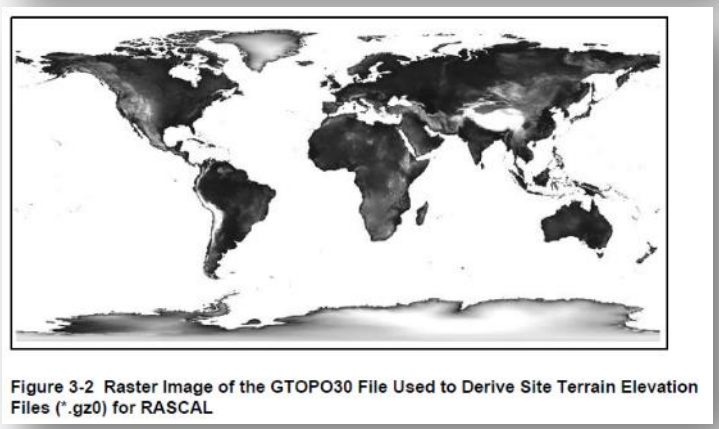
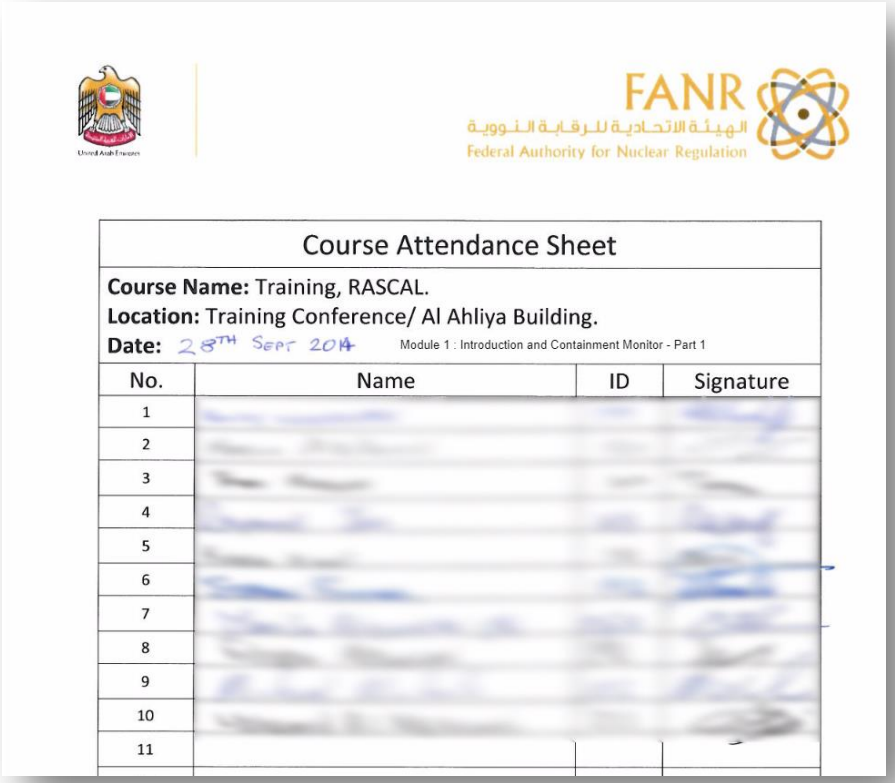


Figure 3-2 Raster Image of the GTOPO30 File Used to Derive Site Terrain Elevation Files (*.gz0) for RASCAL

RASCAL Training

- ~10 half day training modules
- Training ~10 FANR staff to use RASCAL + understanding protective actions
- Training for other departments to understand RASCAL capabilities (EMs, NSD, SRO, etc.)
- Once trained – periodic refresher training + drills
- Take part in full scale UAE exercises
- Training in other tools, such as SPADES+ and BARAM



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Course Attendance Sheet

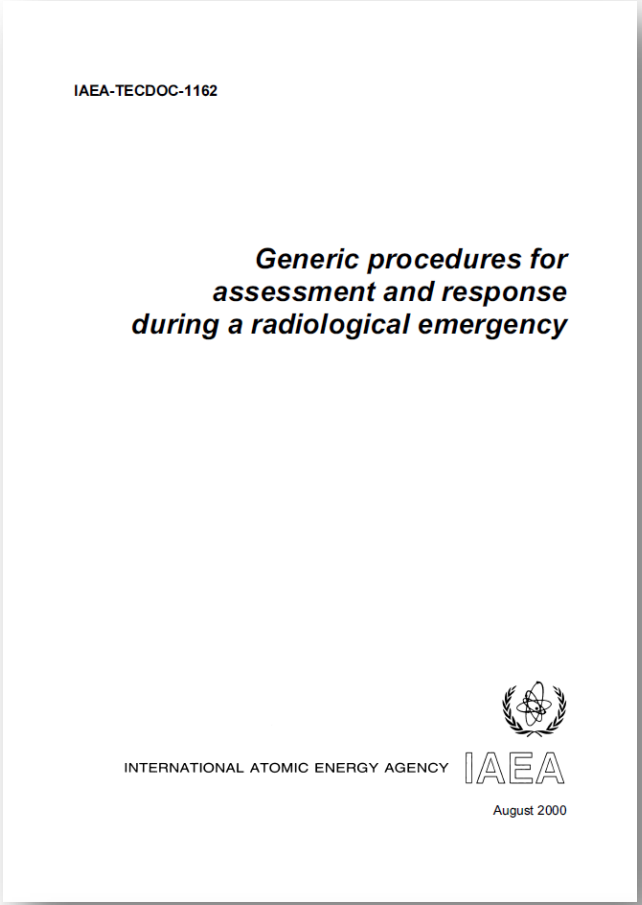
Course Name: Training, RASCAL.
Location: Training Conference/ Al Ahliya Building.
Date: 28TH SEPT 2014 Module 1 : Introduction and Containment Monitor - Part 1

No.	Name	ID	Signature
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

Radiological Emergencies

Radiological Emergencies

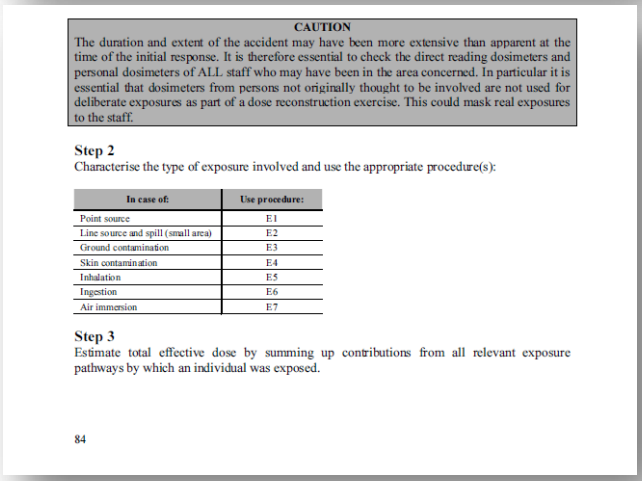
- FANR elected to use **IAEA TECDOC 1162**, *'Generic Procedures for Assessment and Response During a Radiological Emergency'*, dose assessment methodology as described in Section E:
  - Point sources
  - Line and spill sources
  - Ground contamination – Exposure (internal + external) from contaminated ground, factoring in resuspension
  - Skin contamination – Beta
  - Inhalation – Exposure to airborne radionuclides, incorporating material fire release fractions, release rate, dispersion factors, wind, stability class, etc.
  - Ingestion
  - Air immersion
- All supplemented by other codes, such as RASCAL, IMBA, MicroShield, etc.


IAEA-TECDOC-1162

Generic procedures for assessment and response during a radiological emergency

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

August 2000


CAUTION

The duration and extent of the accident may have been more extensive than apparent at the time of the initial response. It is therefore essential to check the direct reading dosimeters and personal dosimeters of ALL staff who may have been in the area concerned. In particular it is essential that dosimeters from persons not originally thought to be involved are not used for deliberate exposures as part of a dose reconstruction exercise. This could mask real exposures to the staff.

Step 2

Characterise the type of exposure involved and use the appropriate procedure(s):

In case of:	Use procedure:
Point source	E1
Line source and spill (small area)	E2
Ground contamination	E3
Skin contamination	E4
Inhalation	E5
Ingestion	E6
Air immersion	E7

Step 3

Estimate total effective dose by summing up contributions from all relevant exposure pathways by which an individual was exposed.

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Why Develop a Software Tool for 1162?

- TECDOC requires multiple unit conversions, reading values from graphs, finding values in tables, etc.
- Takes time to use in a calculation and may result in errors under stressful conditions
- Developed software – easier/faster to change based on user requests

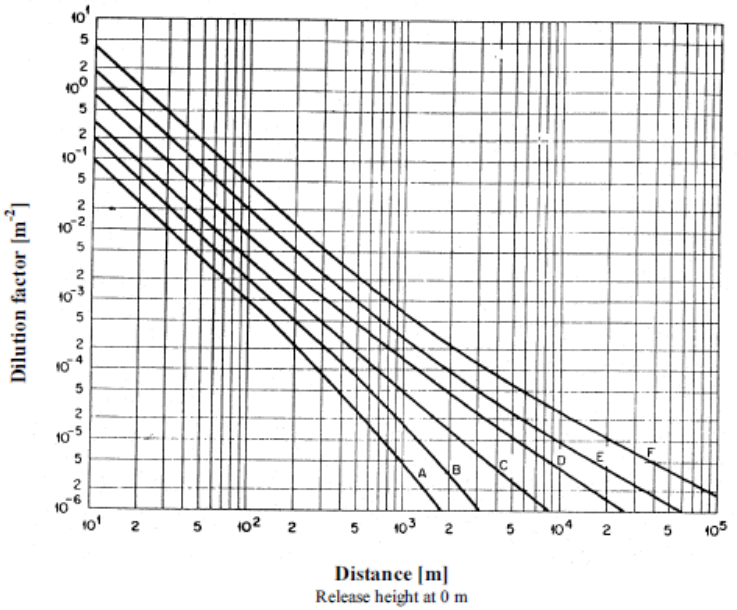


FIG. E1. Dilution factor as a function of downwind distance.

Reference: [26]

Spill

Effective dose

Estimate the effective dose (external irradiation) from a spill using the following expression:

$$E_{ext} = 2\pi \cdot CF_6 \cdot A_s \cdot T_e \cdot \ln\frac{X^2 + R^2}{X^2}$$

Where
X = Distance from the centre of the spill [m]
R = Spill radius [m]
E_{ext} = Effective dose [mSv]
CF_6 = Conversion factor from Table E1 [(mSv/h)/(kBq)]
A_s = Activity of the spill [Bq/m^2]
T_e = Time of exposure [h]

Dose rate

Calculate the dose rate at a distance X from a spill using the following expression:

$$\dot{D} = 2\pi \cdot CF_7 \cdot A_s \cdot \ln\frac{X^2 + R^2}{X^2}$$

Where
$\dot{D}$ =Dose rate [mGy/h]
CF_7 =Conversion factor from Table E1 [(mGa/h)/(kBq)]
X =Distance from the line source (pipe) [m]
R =Spill radius [m]
A_s =Activity of the spill [Bq/m^2]

TABLE E9. RELATIONSHIP BETWEEN STABILITY CLASS AND WEATHER CONDITIONS

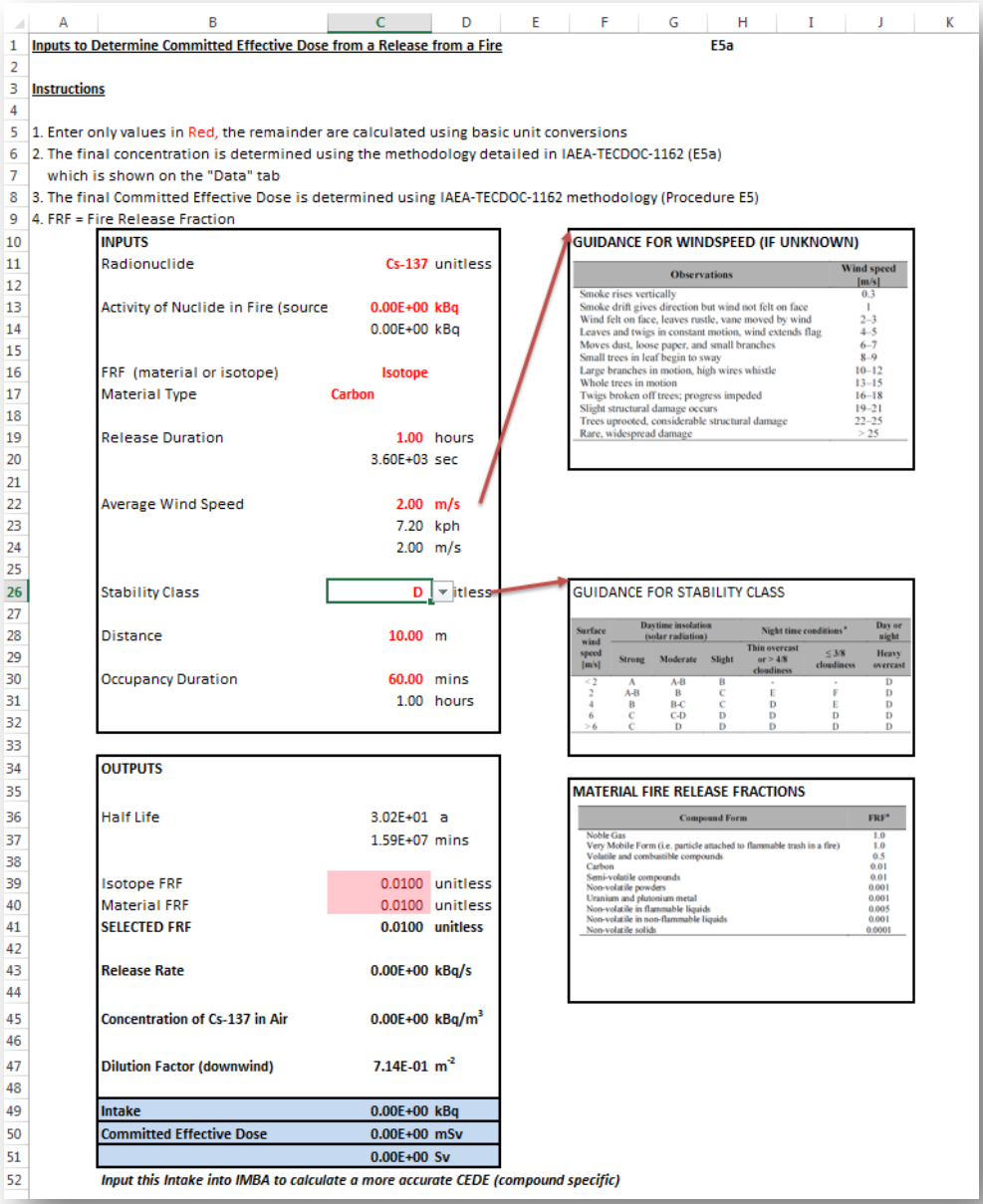
Surface wind speed [m/s]	Daytime insolation (solar radiation)			Night time conditions[a]		Day or night
	Strong	Moderate	Slight	Thin overcast or > 4/8 cloudiness	≤ 3/8 cloudiness	Heavy overcast
<2	A	A-B	B	-	-	D
2	A-B	B	C	E	F	D
4	B	B-C	C	D	E	D
6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

Reference: [24], p. 591.

[a] The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon that is covered by clouds.

Radiological Emergency Calculation Tool (RECT)

- FANR developed RECT using Macro enabled Excel spreadsheet:
  - One tab per exposure type
  - Data tab containing all tables, graphs, etc. (locked)
  - All cells locked – except inputs (in red)
  - Dropdown menus for most inputs/unit selections
  - Summary sheet summarizing inputs/outputs
  - Warning when parameters outside of expected range
- Prepared documentation to support RECT



Inputs to Determine Committed Effective Dose from a Release from a Fire E5a

Instructions

1. Enter only values in Red, the remainder are calculated using basic unit conversions
2. The final concentration is determined using the methodology detailed in IAEA-TECDOC-1162 (E5a) which is shown on the "Data" tab
3. The final Committed Effective Dose is determined using IAEA-TECDOC-1162 methodology (Procedure E5)
4. FRF = Fire Release Fraction

INPUTS

Radionuclide	Cs-137	unitless
Activity of Nuclide in Fire (source	0.00E+00	kBq
	0.00E+00	kBq
FRF (material or isotope)	Isotope	
Material Type	Carbon	
Release Duration	1.00	hours
	3.60E+03	sec
Average Wind Speed	2.00	m/s
	7.20	kph
	2.00	m/s
Stability Class	D	itless
Distance	10.00	m
Occupancy Duration	60.00	mins
	1.00	hours

OUTPUTS

Half Life	3.02E+01	a
	1.59E+07	mins
Isotope FRF	0.0100	unitless
Material FRF	0.0100	unitless
SELECTED FRF	0.0100	unitless
Release Rate	0.00E+00	kBq/s
Concentration of Cs-137 in Air	0.00E+00	kBq/m^3
Dilution Factor (downwind)	7.14E-01	m^{-2}
Intake	0.00E+00	kBq
Committed Effective Dose	0.00E+00	mSv
	0.00E+00	Sv

Input this Intake into IMBA to calculate a more accurate CEDE (compound specific)

GUIDANCE FOR WINDSPEED (IF UNKNOWN)

Observations	Wind speed [m/s]
Smoke rises vertically	0.3
Smoke drift gives direction but wind not felt on face	1
Wind felt on face, leaves rustle, vane moved by wind	2–3
Leaves and twigs in constant motion, wind extends flag	4–5
Moves dust, loose paper, and small branches	6–7
Small trees in leaf begin to sway	8–9
Large branches in motion, high wires whistle	10–12
Whole trees in motion	13–15
Twigs broken off trees; progress impeded	16–18
Slight structural damage occurs	19–21
Trees uprooted, considerable structural damage	22–25
Rare, widespread damage	> 25

GUIDANCE FOR STABILITY CLASS

Surface wind speed [m/s]	Daytime insolation (solar radiation)			Night time conditions*		Day or night
	Strong	Moderate	Slight	Thin overcast or > 4/8 cloudiness	≤ 3/8 cloudiness	Heavy overcast
< 2	A	A-B	B	-	-	D
2	A-B	B	C	E	F	D
4	B	B-C	C	D	E	D
6	C	C-D	D	D	D	D
> 6	C	D	D	D	D	D

MATERIAL FIRE RELEASE FRACTIONS

Compound Form	FRF*
Noble Gas	1.0
Very Mobile Form (i.e. particle attached to flammable trash in a fire)	1.0
Volatile and combustible compounds	0.5
Carbon	0.01
Semi-volatile compounds	0.01
Non-volatile powders	0.001
Uranium and plutonium metal	0.001
Non-volatile in flammable liquids	0.005
Non-volatile in non-flammable liquids	0.001
Non-volatile solids	0.0001

Radiological Emergency Calculation Tool (RECT)

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Radiological Emergency Calculation Tool (RECT) **Rev 1**

Print All Pathways with Exposure

Summary Page

Exposure Types	Effective Dose (mSv)
E1 - Point Source	-
E2 - Line Source	-
E2 - Spill	-
E3 - Ground Contamination	-
E4 - Skin Dose	-
E5 - Dispersion + CED (Internal)	-
E5a - Fire Dispersion and CED	-
E6 - Ingestion	-
E7 - Air Immersion	-
TOTAL	- mSv

For inputs used to calculate doses, see individual sheets

Report Information

Calculation completed: _____ date/time

Calculation By: _____

Input Information Source:

- ☐ Written data/message (attach)
- ☐ Phone call/conversation

When _____

Party _____

Data Applicability Information

Date of Exposure: _____

Start Time of Exposure: _____

End Time of Exposure: _____

Total Exposure Time: _____

Location of Exposure: _____

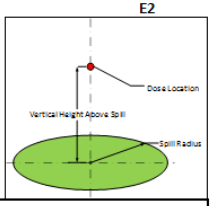
Names of Exposed Individuals/Groups: _____

Notes: _____

Inputs to Determine External Dose from a Line Source and Spill E2

Instructions

1. Enter only values in Red, the remainder are calculated using basic unit conversions
2. The final dose is determined using the methodology detailed in IAEA-TECDOC-1162 (E2) which is shown on the "Data" tab



INPUTS (Line Source)		
Radionuclide	Co-60	unitless
Source Activity	0.00E+00	kBq/m
	0.00E+00	kBq/m
	0.00E+00	µCi/cm
	0.00E+00	Ci/m
Distance from Source	0.50	m
	1.64	ft
Exposure Duration	1.00	hours
	60.00	mins

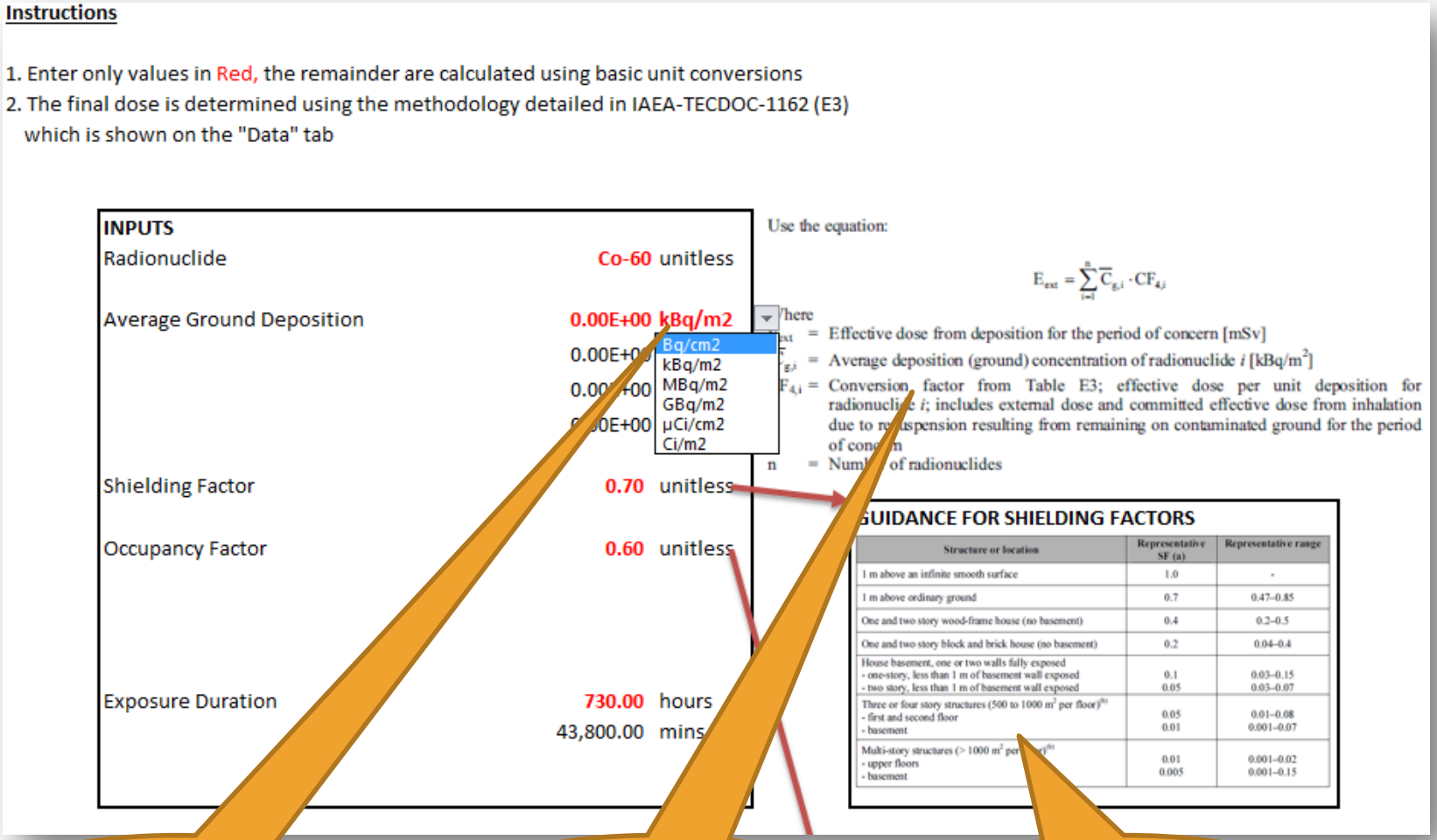
INPUTS (Spill Source)		
Radionuclide	Cs-137	unitless
Source Activity	0.00E+00	kBq/m2
	0.00E+00	kBq/m^2
	0.00E+00	µCi/cm^2
	0.00E+00	Ci/m^2
Vertical Distance from Center of Spill	100.00	m
	328.08	ft
Spill Radius	1.00	m
	3.28	ft
Exposure Duration	1.00	hours
	60.00	mins

OUTPUTS (Line Source)	
(mGy/h)/(kBq)	3.60E-07
(mSv/h)/(kBq)	2.50E-07
Effective Dose	**0.00E+00 mSv**
Dose Rate	**0.00E+00 mGy/h**

OUTPUTS (Spill Source)	
(mGy/h)/(kBq)	9.50E-08
(mSv/h)/(kBq)	6.20E-08
Effective Dose	**0.00E+00 mSv**
Dose Rate	**0.00E+00 mGy/h**

Summary | E1-Point Source | E2-Line Source and Spill | E3-Ground Contamination | E4-Skin Dose | E5-Dispersion + CED (Internal) | E5-Fire Dispersion and CED | E6-Ingestion | E7-Air Immersion | Data

Radiological Emergency Calculation Tool (RECT)



Instructions

1. Enter only values in Red, the remainder are calculated using basic unit conversions
2. The final dose is determined using the methodology detailed in IAEA-TECDOC-1162 (E3) which is shown on the "Data" tab

INPUTS

Radionuclide	Co-60	unitless
Average Ground Deposition	0.00E+00	kBq/m2
	0.00E+0	
	0.00 +00	
	0E+00	
Shielding Factor	0.70	unitless
Occupancy Factor	0.60	unitless
Exposure Duration	730.00	hours
	43,800.00	mins

Bq/cm2
kBq/m2
MBq/m2
GBq/m2
µCi/cm2
Ci/m2

Use the equation:

$$E_{ext} = \sum_{i=1}^{n} \overline{C}_{g,i} \cdot CF_{4,i}$$

Where

E_{ext} = Effective dose from deposition for the period of concern [mSv]

$\overline{C}_{g,i}$ = Average deposition (ground) concentration of radionuclide *i* [kBq/m^2]

$F_{4,i}$ = Conversion factor from Table E3; effective dose per unit deposition for radionuclide *i*; includes external dose and committed effective dose from inhalation due to resuspension resulting from remaining on contaminated ground for the period of concern

n = Number of radionuclides

GUIDANCE FOR SHIELDING FACTORS

Structure or location	Representative SF (a)	Representative range
1 m above an infinite smooth surface	1.0	-
1 m above ordinary ground	0.7	0.47–0.85
One and two story wood-frame house (no basement)	0.4	0.2–0.5
One and two story block and brick house (no basement)	0.2	0.04–0.4
House basement, one or two walls fully exposed - one-story, less than 1 m of basement wall exposed - two story, less than 1 m of basement wall exposed	0.1 0.05	0.03–0.15 0.03–0.07
Three or four story structures (500 to 1000 m^2 per floor)[b] - first and second floor - basement	0.05 0.01	0.01–0.08 0.001–0.07
Multi-story structures (> 1000 m^2 per [illegible])[b] - upper floors - basement	0.01 0.005	0.001–0.02 0.001–0.15

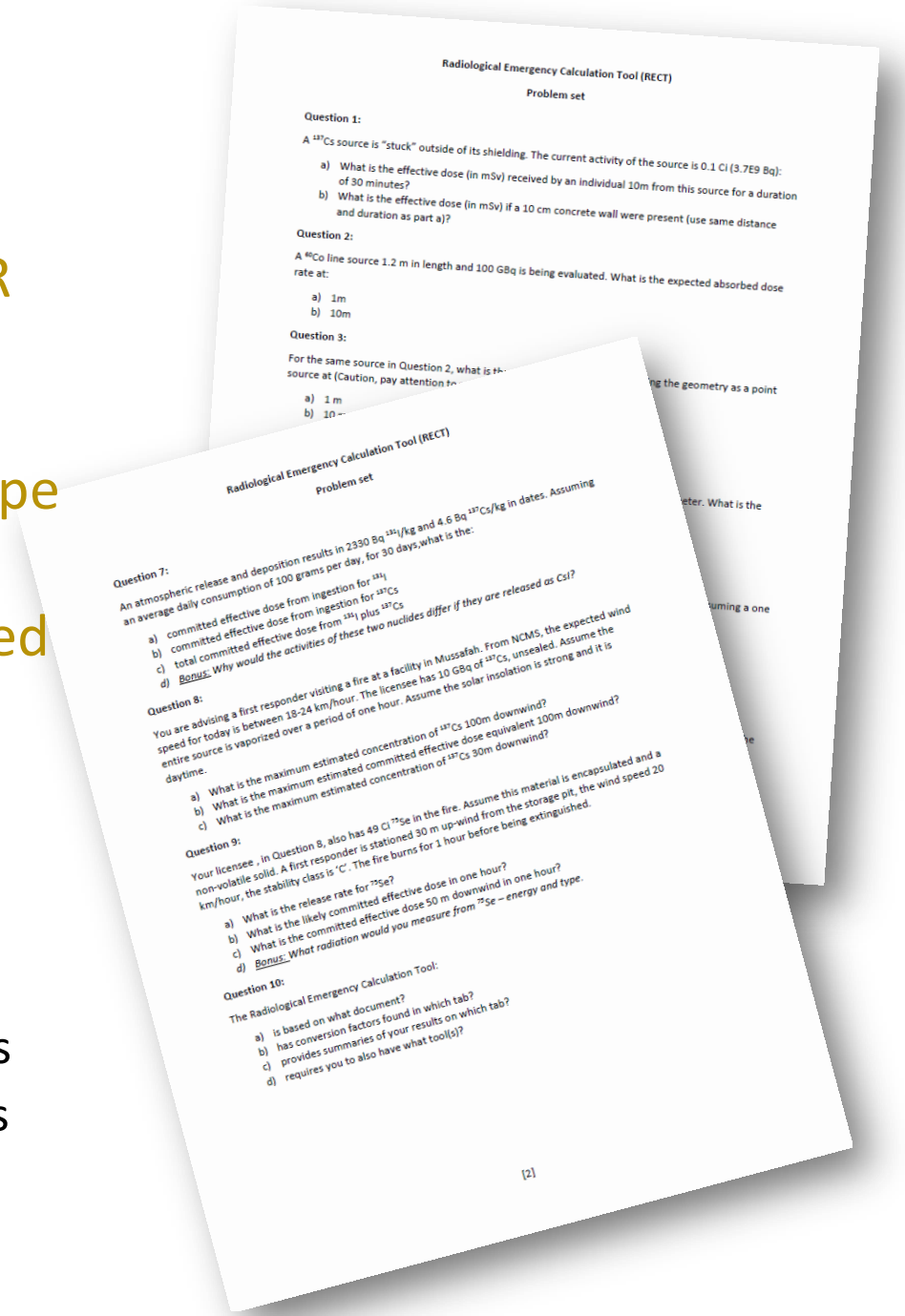
Dropdown menu for easy selection

Equations showing basis of RECT

Guidance for parameter selection

RECT Training

- Training provided for each exposure type for selected FANR staff
- Quiz completed by each trainee after training – based on UAE type sources/scenarios
- Review class after quiz completed
- ***Resulted in several changes to RECT based on user feedback:***
  - Unit conversions
  - Warnings if parameters outside of 'likely' range
  - Pictures explaining geometry types
  - Clearer wording for inputs/outputs
- Refresher training in future



Radiological Emergency Calculation Tool (RECT)

Problem set

Question 1:

A ^{137}Cs source is "stuck" outside of its shielding. The current activity of the source is 0.1 Ci (3.7E9 Bq):

a) What is the effective dose (in mSv) received by an individual 10m from this source for a duration of 30 minutes?
b) What is the effective dose (in mSv) if a 10 cm concrete wall were present (use same distance and duration as part a)?

Question 2:

A ^{60}Co line source 1.2 m in length and 100 GBq is being evaluated. What is the expected absorbed dose rate at:

a) 1m
b) 10m

Question 3:

For the same source in Question 2, what is the...
source at (Caution, pay attention to...

a) 1 m
b) 10 ...

...g the geometry as a point

Radiological Emergency Calculation Tool (RECT)

Problem set

Question 7:

An atmospheric release and deposition results in 2330 Bq ^{131}I/kg and 4.6 Bq ^{137}Cs/kg in dates. Assuming an average daily consumption of 100 grams per day, for 30 days,what is the:

a) committed effective dose from ingestion for ^{131}I
b) committed effective dose from ingestion for ^{137}Cs
c) total committed effective dose from ^{131}I plus ^{137}Cs
d) Bonus: Why would the activities of these two nuclides differ if they are released as CsI?

...eter. What is the

...uming a one

Question 8:

You are advising a first responder visiting a fire at a facility in Mussafah. From NCMS, the expected wind speed for today is between 18-24 km/hour. The licensee has 10 GBq of ^{137}Cs, unsealed. Assume the entire source is vaporized over a period of one hour. Assume the solar insolation is strong and it is daytime.

a) What is the maximum estimated concentration of ^{137}Cs 100m downwind?
b) What is the maximum estimated committed effective dose equivalent 100m downwind?
c) What is the maximum estimated concentration of ^{137}Cs 30m downwind?

Question 9:

Your licensee , in Question 8, also has 49 Ci ^{75}Se in the fire. Assume this material is encapsulated and a non-volatile solid. A first responder is stationed 30 m up-wind from the storage pit, the wind speed 20 km/hour, the stability class is 'C'. The fire burns for 1 hour before being extinguished.

a) What is the release rate for ^{75}Se?
b) What is the likely committed effective dose in one hour?
c) What is the committed effective dose 50 m downwind in one hour?
d) Bonus: What radiation would you measure from ^{75}Se – energy and type.

Question 10:

The Radiological Emergency Calculation Tool:

a) is based on what document?
b) has conversion factors found in which tab?
c) provides summaries of your results on which tab?
d) requires you to also have what tool(s)?

[2]

Future…..

- Drills/exercises
- Refresher training
- Nuclear exercises:
  - Prior to fuel receipt
  - Prior to fuel load

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Thank you