FILENOTE

OFFICIAL

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Subject	Safety and Security Consequence Analysis for the Bounding Case Release from NMMF

	Name	Position	Signature	Date
Prepared	[redacted]			
Reviewed				

1. BACKGROUND

A new Nuclear Medicine Manufacturing Facility (NMMF) has been proposed to be built at ANSTO Lucas Heights campus to replace the existing ageing facility Building 23. The NMMF will be designed to three mainstream production processes including:

- the production of Technetium-99m generators;
- the production of Iodine-131 and niche products; and
- the production of Lutetium-177.

The NMMF will be a two-storey building with a footprint of approximately 6,700 m^2 and can easily extend to an additional 1,400 m^2 in the future for additional production space if required. The total square meterage of the building is currently designed to be 13,000 m^2 (ANSTO NMMF, 2023a).

This filenote documents the analysis of the potential radiological impacts for the airborne release of radioactive material outside the facility as a result of a bounding case accident (fire event) in the NMMF.

PC-Cosyma was used to assess the radiological hazard for identifying potential consequences of the release outside the facility. The analysis was performed reflecting day and night conditions for projected effective doses and thyroid doses for exposure of adults, children and infants at various distances from NMMF.

This assessment was performed to support preparedness and planning for a nuclear or radiological emergency at ANSTO.

2. BOUNDING CASE ACCIDENT

Three potential bounding case accidents were considered:

- Building Fire
- Seismic event
- Security event

It is assessed that a large-scale building fire which has the potential to result in the airborne release of all the available radioactive materials stored in the facility represents the bounding case accident with respect to releases to the environment.

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These assumptions should be revisited when the facility design is more mature, to provide a more realistic assessment of consequences.

As the airborne release fraction from a powder spill is $2x10^{-3}$ (USNRC, 1998) and the airborne release fraction for a fire is $6x10^{-3}$ (USNRC 1998), the building fire has been identified as bounding relative to a seismic event. A seismic event has the potential to release the inventory of liquid waste in addition to the potential airborne release of aerosols, however the dose consequence outside the facility would be very much less than the airborne releases. Therefore, this will not impact the emergency planning category for the facility. For completeness, an assessment of the consequences of the liquid releases due to a seismic event should be performed during the detailed design phase of the project.

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3. METHODOLOGY

A summary of the analysis methodology and the assumptions used is given below.

3.1 Generic Assumptions

The computer package PC-Cosyma (Version 2) has been used to estimate doses due to accidental airborne releases. For a full description of this model, please see relevant item provided in the reference list (Jones et al, 1996). For this analysis three calculations were performed: one reflecting average day conditions, normally associated with the most significant on-site consequences; and two reflecting night conditions, normally associated with the worst consequences to off-site receptors.

The calculations performed were deterministic, with the end point for the short-term (7 days) and long-term (50-year integrated) dose to an individual adult. For the fire event, dose in 1 year (365 days) was also calculated. The pathways considered for this calculation were cloud-shine, ground-shine, inhalation, re-suspension, and direct skin contamination (ingestion was not included in this assessment).

The weather conditions assessed were “D” stability category with a wind speed of 3 m/s (to reflect average daytime conditions) and “E” and “F” categories with a wind speed of 1 m/s (to reflect the conservative night-time conditions).

The measurement height of the wind speed was set at 10 m (PC-Cosyma automatically adjusts the actual wind speed to account for differences with height). Default values were used for all plume shape parameters.

The surface roughness used (as per PC-Cosyma’s options) was “rough”, which is the best estimate of the local conditions around the LHSTC site. Deposition velocities used were set at 10^{-2}m/s for elemental iodine, 10^{-3}m/s for other particulates, and 10^{-5}m/s for organically bound iodine.

For the day release scenario, it was considered that there should be no account taken for any shielding (the person would be standing outside in the open for the duration of the scenario). For the night release, it was considered appropriate to take into consideration the much greater likelihood of people being indoors. The shielding values chosen are the same as those quoted in the assessment of releases from HIFAR (Hambley, 1997) for normal activity, and are listed below:

Table 1 - Shielding Factors

Pathway	Shielding factor
Cloudshine	0.43
Groundshine	0.33
Inhalation	0.81
Resuspension	0.81
Skin contamination	0.81

3.2 Release Mechanisms

3.2.1 Building Fire event

In an event of building fire, plume model is used to analyse the release. Fire loading density assumptions are provided in (Lees 1996-16/292) for a variety of building types. Conservatively this calculation assumes the lowest quoted value of $25 lb/ft^2$, or $122 kg/m^2$. Using the calorific value for wood from the same reference, this is equivalent to 2135MJ/m2. The active area of the NMMF is assumed to be the footprint area of 6700 m^2. The fraction of convective heat versus the total heat released is assumed to be 0.44, equivalent to wood, according to NUREG/CR-6410 (NRC, 1998). Lees also provides a correlation between fire load and duration, in this case, a combustible content of $122 kg/m^2$ of wood equivalent yields a duration of approximately 2.5 hours.

The plume heat is then given by:

$$Heat = \frac{D \times A \times CF}{T}$$

Where:

D = fire load density ($2135 MJ/m^2$)
A = area (6700 m^2)
CF = convective fraction (0.44, dimensionless)
T = fire duration (2.5 hour, 9000 s)

The convective heat released by burning the entire fire load of the NMMF is therefore 636MW. For the purpose of this calculation, only 1% of this is assumed to burn, giving a thermal plume of 6.36MW.

For conservatism, it was assumed that the entire expected inventory of the NMMF would be in powder form and available for release in the first hour of the fire event. Iodine would be expected to release entirely in a fire with a Release Fraction of 1. For the other nuclides, based upon guidance in NUREG/CR-6410 (NRC, 1998), an Airborne Release Fraction (ARF) of $6{\times}10^{-3}$ as for the bounding case thermal release for a powder was used.

3.2.2 Security event

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3.3 Child and Infant Dose

For releases to the environment, it is considered credible that infants (1 year) and children (10 years) could be affected by the release and therefore the effective and thyroid doses to these age groups were also assessed for both the short term (7 days, 365days for fire event) and long term (50 years).

As PC-Cosyma does not include child or infant doses, the results for these age groups are scaled from the adult doses, using the age-related dose conversion factors weighted by nuclide contribution. To enable this adjustment, a spreadsheet based upon that previously used for this purpose (Turner, 2013) was developed and used to appropriately scale the results of the PC-Cosyma modelling at 2km for the fire event and 500 m for the security event. This spreadsheet uses the age-dependent dose coefficients in ICRP 119 (ICRP, 2012) for effective dose calculation. The age-dependent dose coefficients for thyroid are from ICRP 71 (ICRP, 1995) and 119 (ICRP, 2012) if the nuclides that are not available in ICRP 71. The age-dependant breathing rates are taken from ICRP 89 (ICRP, 2003) to scale the estimated inhalation dose obtained using PC-Cosyma.

3.4 Inventory

3.4.1 Building Fire Event

The analysis was carried out for the maximum inventory for the NMMF that is provided by the NMMF team (ANSTO NMMF, 2024).

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Isotope I-123 is not presented in the data base of PC-Cosyma. Given its low activity compared with the activity of I-131, the dose contribution is negligible and hence is not included in the assessment. Isotopes of Au-198, Ir-192, Lu-177 and Ho-166 are not present in the database of PC-Cosyma. To ensure completeness of the assessment, the International Nuclear Event Scale (INES, 2008) methodology for calculating a radiological equivalence has been used. Ir-192 and Ho-166 have been modelled as an equivalent activity of Co-56 and Y-90, respectively. Au-198 and Lu-177 have been modelled as equivalent activity of Mo-99.

Based upon this methodology the dose from a release can be estimated using the following equation:

$$D_{tot} = Q \times X \times (DC_{inh} \times BR + DC_{grnd} \times V_g)$$

Where:

D_{tot} = Total dose (Sv) resulting from an activity release

Q = Activity released (Bq)

X = Time-integrated, ground-level airborne radionuclide concentration ($Bq.s/m^3$)

DC_{inh} = Dose Coefficient Inhalation $Sv.Bq^{-1}$

BR = Breathing Rate (3.3×10^{-4} $m^3.s^{-1}$)

DC_{grnd} = Dose Coefficient Ground deposition Sv per $Bq.m^{-2}$

V_g = Resuspension Rate ($m.s^{-1}$)

As inhalation is dominant in this scenario, the effective dose to the public from ground deposition of radionuclides ($DC_{inh} \times V_g$) is excluded from the assessment. The total dose equation has been simplified as:

$$D_{tot} = Q \times X \times DC_{inh} \times BR$$

For each radionuclide, the relative radiological equivalence can then be estimated as:

$$Q_{equivalent} = \frac{Q_{original} \times X_{original} \times DC_{inh.original} \times BR_{original}}{X_{equivalent} \times DC_{inh.equivalent} \times BR_{equivalent}}$$

Due to the short duration of the scenario, it is assumed that the time-integrated ground level concentration (X) (ie radioactive half-life differences are not significant) and the breathing rate (BR) are the same for each nuclide. The equivalence can be calculated based on the ratio of the inhalation dose coefficients as follows:

$$Q_{equivalent} = \frac{Q_{original} \times DC_{inh.original}}{DC_{equivalent}}$$

The dose coefficients to public were taken from Annex G in ICRP 119 (ICRP, 2012). The type of nuclides was determined based upon guidance in Annex E. All the other nuclides are considered to be unspecified compounds or all compounds.

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Note that this inventory is automatically modified by PC-Cosyma to include ingrowth of daughter products, and in this assessment has been set to exclude nuclides that do not contribute more than 0.1% of the dose from any pathway.

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4. RESULTS

4.1 Building Fire Event

4.1.1 Effective Dose

The effective dose at distances for adult from a release from a building fire event in NMMF are calculated by the PC-Cosyma analysis. The effective dose for child (10 years) and infant (1 year) based on assessment of the effective dose for adult are calculated using a spreadsheet discussed in Section 3.3.

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5. DOSE AT SPECIFIC RECEPTOR POINTS

The effective dose and thyroid dose within a year at specific receptor points from the building fire are presented below.

5.1 Annual Effective Dose from Building Fire

Table 18: Building Fire Resulting Annual Effective Doses at Specific Receptor Points

Receptor Point	D3 met. Conditions			E1 met. Conditions			F1 met. Conditions		
	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)
0.2 km (*New Illawarra Road)*	4.9	6.6	7.5	0	0	0	0	0	0
0.3 km (*Peak Dose, D Condition*)	**8.2**	**11**	**13**	0	0	0	0	0	0
1km (*KU ANSTO*)	3.0	4.0	4.6	0.012	0.037	0.045	1.7E-03	2.9E-03	3.5E-03
1.6 km (*Buffer Zone*)	1.5	2	2.2	0.06	0.21	0.25	4.5E-03	0.013	0.016
1.7 km (*Engadine*)	1.3	1.8	2.0	0.069	0.24	0.29	5.5E-03	0.017	0.02
3.3km (*Peak Dose, E Condition*)	0.45	0.6	0.69	**0.13**	**0.44**	**0.53**	0.028	0.095	0.11
6km (*Peak Dose, F Condition*)	-[3]	-	-	-	-	-	**0.091**	**0.14**	**0.17**

5.2 Annual Thyroid Dose from Building Fire

Table 19: Building Fire Resulting Annual Thyroid Doses at Specific Receptor Points

Receptor Point	D3 met. Conditions			E1 met. Conditions			F1 met. Conditions		
	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)	Adult (mSv)	Child 10ys (mSv)	Infant 1y (mSv)
0.2 km (*New Illawarra Road)*	40	70	88	0	0	0	0	0	0
0.3 km (*Peak Dose, D Condition*)	**67**	**120**	**150**	0	0	0	0	0	0
1km (*KU ANSTO*)	24	43	54	0.28	0.5	0.63	6.5E-03	0.012	0.015
1.6 km (*Buffer Zone*)	12	21	26	1.6	3.0	3.8	0.097	0.18	0.22
1.7 km (*Engadine*)	11	19	24	1.9	3.4	4.3	0.13	0.23	0.29
3.3km (*Peak Dose, E Condition*)	3.6	6.5	8.1	**3.5**	**6.4**	**8.0**	0.75	1.4	1.7
6km (*Peak Dose, F Condition*)	-	-	-	-	-	-	**1.1**	**2.0**	**2.6**

[3] Dose at the distance was not modelled.

6. REFERENCES

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