SOP Bulletin No. 42

Update

17 November 2000

NEW ATOMIC RADIATION FACTORS IN RMA SOPS
INTERIM ADVICE

This Bulletin contains interim informal advice. The Department is seeking independent expert opinion on this subject. Further information and policy advice will be provided once this is available.

Claims Assessors and Review Officers are reminded that, notwithstanding the contents of this bulletin, they must take into account and consider the evidence available in individual cases and make their decision within the law.

1. New SOP Factors

The RMA is making changes to the atomic radiation factors in SOPs. New factors have been included in the latest SOPs for Malignant Neoplasm of the Bladder and for Goitre. The same changes will progressively be made to the other 10 SOPs that include an atomic radiation factor (see Appendix 1 for a list).

The new factors will specify a dose of atomic radiation rather than the previous proxy measure:

Old factor

> "having been within four kilometres of the epicentre of the atomic bomb explosions on Hiroshima or Nagasaki within the seven days immediately following the explosion on those cities, before the clinical onset of…"

New factor for MN of the Bladder (reasonable hypothesis SOP)

> "having received a cumulative equivalent dose of 0.05 Sievert of atomic radiation to the bladder where this dose was accumulated at least five years before the clinical onset of malignant neoplasm of the bladder

The radiation unit used in the new SOP factors is the Sievert (Sv). Radiation doses in this bulletin are expressed in milliSieverts (mSv). One Sv = 1000 mSv. Using mSv gives doses expressed in whole numbers and small fractions, rather than fractions with many decimal places. To compare doses in mSv to the requirements of the SOPs, divide by 1000, or refer to the table below. For an explanation of cumulative equivalent dose, Sieverts and other radiation units, see Appendix 2.

The dose of atomic radiation and the time frame in each SOP factor will vary with the disease and the standard of proof. The RMA is expected to set cumulative doses for the different diseases as follows:

Condition	RH dose		BOP dose	
Solid cancers & myeloma	0.05 Sv	(50 mSv)	0.5 Sv	(500 mSv)
Leukaemias	0.01 Sv	(10 mSv)	0.1 Sv	(100 mSv)
Goitre	0.2 Sv	(200 mSv)	1.0 Sv	(1000 mSv)
Cataract	0.5 Sv	(500 mSv)	1.0 Sv	(1000 mSv)

To apply the new SOP factors, decision makers will require an understanding of the cumulative doses in Australian service personnel who had atomic radiation exposure.

2. Atomic Radiation exposure in Australian Service Personnel

Australian service personnel with known atomic radiation exposure are:

i. POW(J)s who were in the Nagasaki area on 9 August 1945.
ii. Personnel who served in or visited Hiroshima in connection with the occupation of Japan by the British Commonwealth Occupation Force from February 1946.

Apart from the atomic bombs exploded on Hiroshima and Nagasaki in August 1945, other potential sources of atomic radiation exposure have been:

- Atmospheric nuclear tests.
- Nuclear reactors – particularly radiation leaks (e.g. Chernobyl, Three mile island, nuclear submarine accidents).
- Stored nuclear waste products.

Apart from i. and ii. above, there are no other groups of Australian service personnel with eligible VEA service who have known service-related atomic radiation exposure. There may be individual service personnel who contend exposure from other than the Japanese atomic bombs. Such claims should be investigated on their merits.

3. Other sources of ionising radiation

Atomic radiation excludes: natural background radiation, therapeutic radiation and radiation from diagnostic procedures (see SOP definition).

All individuals are exposed to naturally occurring background radiation, everywhere, all the time. The main sources are cosmic rays and naturally occurring radioisotopes. The dose varies with location but typically amounts to around 1 mSv/year.

Therapeutic radiation, particularly for the treatment of types of cancer, may entail very large organ doses of radiation. Cumulative doses to organs of the order of 50 Sv (50,000 mSv) and more may be given over a period of time. [1]

Approximate bone marrow radiation doses from various diagnostic procedures are: [2]

- Chest Xray 0.1 mSv
- CT head scan 0.2 mSv
- Lumbosacral spine Xray series 2.4 mSv

All individuals are also exposed to low level atomic radiation from atmospheric nuclear test fallout. Estimates of exposure for United States residents are around 0.05 mSv/year. [3]

4. Atomic radiation from the Hiroshima bomb [4 5 6]

An atomic (uranium) bomb was released over Hiroshima on 6 August 1945. It exploded at a height of 580 metres above the centre of the city. The blast, heat and fires caused by the explosion produced major damage within a radius of approximately 5 km from the hypocentre (the point on the ground directly below the explosion), with complete devastation of the area within 2 km of the hypocentre.

The atomic radiation that resulted from the Hiroshima bomb can be divided into two categories:

A. Initial radiation.
B. Residual radiation.

A. INITIAL RADIATION

About 3% of the energy from the Hiroshima bomb was released as atomic radiation (alpha particles, beta-rays, gamma-rays and neutrons). Of these, alpha particles and beta-rays travel only short distances. Only gamma-rays and neutrons reached the ground. Gamma-rays reached over a radius of around 3 km from the hypocentre and neutrons reached over a radius of about 2.5km.

Initial radiation was received only by persons present within a 3 km radius of the hypocentre at the time of the explosion.

B. RESIDUAL RADIATION

Residual radiation is that radiation persisting after the initial explosion. Residual radiation comes from (i) external exposure, mainly to gamma-rays from outside the body, and (ii) internal exposure to beta-rays and gamma-rays from radioactive substances taken into the body.

(i) External radiation

There were two sources of external radiation in Hiroshima:

a. Induced radiation.
b. Radioactive fallout.

a. Induced radiation

The neutrons released by the bomb interacted with elements in the soil and structural materials to form radioisotopes. These isotopes were formed only in the area within a 2.5 km radius from the hypocentre. These isotopes gave off radiation as they decayed. The major isotopes that were produced were short lived, having half-lives of minutes to hours. Much smaller quantities of longer-lived isotopes were produced. As a result the levels of induced radiation were high immediately after the bomb but decreased rapidly.

The levels of induced radiation were also highest at the hypocentre, falling away rapidly with distance. At a distance of 500 metres levels were around 10% of those at the hypocentre and at one kilometre, 1%.

b. Fallout

Fallout in Hiroshima comprised many different radioisotopes that were the fission products of uranium and residual material from the bomb that had been made radioactive by neutrons. These minute particles were mostly released into the atmosphere, but a proportion fell in the form of black rain, from about 30 minutes after the explosion, over an area extending from the hypocentre to the west and to the north. The fallout was concentrated over a confined zone, centred approximately 3 km to the west of the hypocentre in the Koi-Takasu area. Like the induced radiation, much of the radioactive fallout was short-lived and the intensity of radioactivity in the fallout affected areas fell rapidly.

(ii) Internal radiation

Radioactive isotopes from either the induced radiation or the fallout could potentially enter the body by inhalation, through ingestion (contaminated food and drinking water) or via absorption through the skin (particularly damaged skin).

5. Atomic radiation doses in Australian Personnel

A. POW(J)s

In August 1945 there were Australian POWs at camps in the Nagasaki area. These POWs were exposed to atomic radiation either directly from the explosion or as a result of radioactive fallout. It can be presumed that any POW who was in the Nagasaki area on 9 August 1945 had cumulative equivalent exposure that would satisfy the requirements of all the RMA SOPs that contain atomic radiation factors. The names of the Australian POWs known to have been in Nagasaki on 9 August 1945 are held by the DSU.

There were no prisoner of war camps at Hiroshima and no Australian POWs were acutely exposed to atomic radiation in that city.

B. BCOF AND ASSOCIATED PERSONNEL

BCOF background [7 8 9]

Australian personnel first arrived in south west Japan as part of the British Commonwealth Occupation Force (BCOF) in February 1946, approximately 6 months after the bombing of Hiroshima. Most arrived via ship at Kure, approximately 20 km southeast of Hiroshima. BCOF headquarters and the 130 Australian General Hospital were established on Etajima, an island off Kure. The 34 Australian infantry brigade was based initially at Kaitaichi, approximately 7 km east of Hiroshima. It then established headquarters at Hiro, approximately 8 km to the east of Kure. Other Australian bases were established in a number of centres extending approximately 80 km to the east of Kure. Part of the 67 Australian Infantry battalion was stationed at Kaitaichi. C company, 67 Australian infantry battalion was stationed in Hiroshima itself, with responsibility for repatriating Japanese soldiers though the port at Ujina, (located about 4 km to the south of the bomb hypocentre). RAAF squadrons were based at Bofu and Iwakuni (approximately 80 km and 30 km to the west of Kure, respectively). The bulk of BCOF personnel served for 2 years or less in Japan.

The majority of Australian BCOF personnel were stationed outside Hiroshima. Some visited the city on only one occasion during their service in Japan. Many made frequent trips to the city and others, as above, were stationed in the city. Some naval personnel on ships arriving at Kure harbour also made day trips to Hiroshima.

Personnel in the Hiroshima area supplemented rations with locally produced food. Drinking water and beer were sourced from within the city. Sporting events for troops were also held within the city.

Nagasaki was located outside the BCOF controlled area, on a separate island 250 km away and was not accessible to Australian personnel.

Australian personnel serving in or visiting Hiroshima had potential exposure to induced radiation, fallout and internal radiation.

Based on the extensive available scientific evidence, including records of radiation levels from soon after the bombing and various dose estimates and reconstructions, it is possible to calculate reasonably accurate approximations of the doses that would have been received by Australian personnel. Individual doses are dependent on the timing of visits to the area, the amount of time spent in the area, and the precise areas visited.

External radiation (whole body doses) [4 6 10 11]

a. Induced radiation

An individual visiting the hypocentre area during February 1946 would have received a maximum radiation dose of approximately 0.00046 mSv/hour.[*] This hourly dose would roughly halve over each subsequent 6 month period.

[*] Calculations based on: measurement on day 87 after the explosion of 70 microrads/hr of gamma rays; measurements of decay at the hypocentre on day 71 and 193 giving an effective half life of 180 days; and estimated of decrease in induced radioactivity with distance from hypocentre. References 4 and 6.

A hypothetical person standing at the hypocentre from February 1946 for 12 hours/day every day for 2 years would have received a total atomic radiation dose of approximately 2.5 mSv.[*]

For a person standing 1 km from the hypocentre the equivalent dose would be approximately 0.025 mSv (i.e. about 1% of the dose at the hypocentre).[*]

b. Fallout

An individual visiting the high fallout zone during February 1946 would have received a maximum whole body radiation dose of about 0.00017 mSv/hour.[†]

A hypothetical person located in the high fallout zone from February 1946 for 24 hours/day every day for 2 years would have received a total atomic radiation dose of approximately 1.0 mSv.[†]

c. Souvenired radioactive items

Some BCOF personnel have described souveniring potentially radioactive objects such as molten glass or metal. The radioactivity of such an object would depend on its place of origin, size and composition. Available evidence suggests that the cumulative radiation dose from such a souvenir would be well below the levels required by the SOPs. Expert advice on this subject is being sought.

d. Organ dose

The radiation dose to a particular organ of the body would be approximately 60% of the whole body dose.

Internal Radiation [10 12 13]

The radiation dose to a particular organ from internal radiation depends on:

- The amount of radioactive material internalised,
- The type of radiation it emits (gamma-rays or beta-rays),
- The metabolism of the material by the body, particularly the biological half-life of the material (which differs from the half-life in the environment).

Dosage calculations for Hiroshima are not available. Calculations are available for residents of the high fallout zone in Nagasaki (the Nishiyama district), where the radiation from fallout was a number of times higher than in the high fallout zone in Hiroshima. These calculations only relate to Cesium 137 (^{137}Cs), a gamma-ray emitting radioisotope with a 30 year half-life (100 day biological half-life) that was the most prevalent of the long-lived radioisotopes in both the Nagasaki and Hiroshima fallout zones.

Based on measurements using a whole body counter, the internal dose to residents from ^{137}Cs over a 40 year period from 1945 was estimated to be 0.1 mSv. This exposure was largely from ongoing dietary intake of contaminated agricultural products.

The ^{137}Cs internal dose to Australian personnel, who were in the radiation affected area for a comparatively short time and who would have consumed far less contaminated food and water,

[†] Calculations based on: formula in reference 11, using upper limit of estimated maximum absorbed doses in Koi-Takasu area of 20 mSv.

would be at most a small fraction of that in the Nishiyama residents. However, any individual circumstances about ingestion of local foods must be considered before making a decision on a claim.

For any other radioisotope to contribute meaningfully to internal radiation dose it would need to be present in significant quantities, have a long half-life and be soluble in body fluids. The other radioisotope that along with ^{137}Cs contributes the major portion of the dose from internally deposited fallout from atmospheric nuclear weapons is Strontium 90 (^{90}Sr). ^{90}Sr has been hypothesised to be of relevance in non-SOP cases at the AAT level. The ^{90}Sr hypothesis is now likely to be raised in relation to the new dose factors.

The Strontium hypothesis [14] [15] [16] [17]

^{90}Sr is a beta emitting radioisotope that was a constituent of the fallout in Hiroshima. It has a half-life of 28 years and a biological half-life of around 15 years. It is metabolised in the body like calcium, and is deposited almost entirely in bones. The beta-rays emitted by ^{90}Sr penetrate only a few millimetres in soft tissue. Internal radiation from ^{90}Sr is therefore only a consideration in relation to diseases of the bone and bone marrow. In SOP terms this means only:

- Acute lymphoid leukemia
- Acute myeloid leukemia
- Chronic myeloid leukemia
- Myeloma.

Reconstructing the potential internal dose of ^{90}Sr is very difficult. There were no actual measurements of ^{90}Sr concentrations in the soil and no measurements of ^{90}Sr in persons exposed to residual radiation. The Department is seeking independent expert advice on potential doses from internal radiation in general and ^{90}Sr in particular.

Available evidence indicates that little if any ^{90}Sr was induced by neutrons around the hypocentre at Hiroshima. Some internal exposure to ^{90}Sr could have resulted from:

i. Being in the fallout zone and inhaling or absorbing through the skin dust or other matter containing ^{90}Sr,
ii. Drinking water contaminated with ^{90}Sr, or
iii. Eating food from an area affected by the fallout.

As previously indicated, low level fallout affected a wide area extending north and west from the hypocentre. Much higher level fallout affected a small zone about 3 km west of the hypocentre.

Drinking water appears to have come from the river system to the north of the city, although this has not been confirmed. The municipal filtration plant was located about 3 km NNE of the hypocentre, alongside the Ota river. The river catchment included areas affected by low level fallout (but not the high fallout area). The amount of radiation contamination in the river water in February 1946 would have been very low, because of the initial low radiation levels in the low fallout zone, the six month decay period and the 900 mm of rain that fell in the area in the three months after the bombing.

Likewise, food from the area affected by low level fallout would have contained very low quantities of radioactive material. There seems little prospect of Australian service personnel having eaten food grown in the high fallout area, because of the small size and apparent land use of this area. However, individual circumstances about ingestion of food need to be considered.

The ^{90}Sr internal dose to bone could be expected to be no higher than the general ^{137}Cs dose in the Nishiyama residents, discussed above. The amount of ^{90}Sr internalised by Australian service personnel would be considerably lower than the ^{137}Cs internalised by the Nishiyama residents who were present from immediately after the bombing and subject to much higher levels of fallout.

Countering the lower intake, the cumulative dose from ^{90}Sr would be higher than that from an equivalent amount of ^{137}Cs due to its longer biological half-life, which is 15 years versus the effective 7.4 year half-life in the Nishiyama residents.[‡]

Additional evidence comes from the measurement of internal ^{90}Sr in US military personnel exposed to radiation from atmospheric nuclear weapons tests. The subjects came from a large cohort with an average external radiation exposure of 4.6 mSv. The subjects had either above average exposure or opportunity for inhalation or ingestion of weapon debris. The ^{90}Sr levels in these subjects were found not to be elevated (all people have very low levels of ^{90}Sr due to global fallout from nuclear weapons – approx 0.015 mSv/year).

The available evidence indicates that significant radiation doses would not have resulted in Australian personnel from internal exposure to ^{90}Sr. Expert advice on this issue is needed.

[‡] The effective half-life of 7.4 years was a combination of the natural half-life, the biological half-life and the ongoing exposure over years to contaminated soil and food. The effective half-life of ^{90}Sr in any exposed Australian service personnel would be the same as the biological half-life, as there was no ongoing intake after leaving the area.

6. Summary

i. There are 12 RMA SOPs that have atomic radiation factors.

ii. The RMA is changing the factors to specify a minimum dose of atomic radiation instead of the previous proxy measure. The dose will vary with the disease and the standard of proof.

iii. The new factors are of relevance to:
- POW(J)s who were in Nagasaki in August 1945,
- BCOF and associated personnel who served in or visited Hiroshima.

iv. The above group of POW(J)s can be presumed to have had atomic radiation exposure that would meet the new SOP factors.

v. Available scientific evidence indicates that BCOF and associated personnel had low atomic radiation exposure from service in Hiroshima. Preliminary advice is that the amount of radiation received, even for worst case exposure scenarios, would not have approached the minimum levels that will be specified in the updated RMA SOPs. Individual circumstances and facts still need to be given appropriate consideration in any decisions on relevant claims.

vi. There are no other Australian personnel with VEA eligible service who are known to have had service-related atomic radiation exposure that would meet the requirements of the new SOP factors.

vii. The Department is seeking independent expert advice on this subject. Further information will be distributed once that expert advice is available.

Contact Officers for this bulletin:

Dr Jon Kelley 07 3223 8412

This bulletin is available on the *DSU Intranet site*.

References

[1] Dische S and Saunders MI. Clinical fractionation studies. *In Oxford Textbook of Oncology*. Peckham M, Pinedo H and Veronesi U [Eds]. Oxford University Press, Oxford 1995; Chapter 4.29:796-811.

[2] Handbook of Health Physics and Radiological Health. 3rd Edition. Shleien B, Slaback LA, Birky BK [Eds] Baltimore: Williams & Wilkins, 1998: Table 1.5.

[3] Iturralde, MP. *Dictionary and Handbook of Nuclear Medicine and Clinical Imaging* 1990. CRC Press, Boca Raton. 1990; 439.

[4] The committee for the compilation of material on damage caused by the atomic bombs in Hiroshima and Nagasaki. *Hiroshima and Nagasaki: The Physical, Medical and Social Effects of the Atomic Bombings.* Ishikaw E Swain DL [translators] Iwanami Shoten, Tokyo. 1981; Chapter 5:68-79.

[5] The committee for the compilation of material on damage caused by the atomic bombs in Hiroshima and Nagasaki. *Hiroshima and Nagasaki: The Physical, Medical and Social Effects of the Atomic Bombings.* Ishikaw E Swain DL [translators] Iwanami Shoten, Tokyo. 1981; Chapters 1-4:21-66.

[6] Schull WJ. Exposure and Dose. In *Effects of Atomic Radiation: A half-century of studies from Hiroshima and Nagasaki*. Wiley-Liss New York 1995; Chapter 5:102-26.

[7] Bates P. *Japan and The British Commonwealth Occupation Force 1946-52*. Brassey's, London. 1993.

[8] John AW. *Uneasy Lies the Head That Wears a Crown. A History of the British Commonwealth Occupation Force Japan*. The Gen Publishers, Cheltenham. 1987.

[9] Lacey L. *BCOF – An unofficial history.* McMahon Graphics, Glen Innes. 1995.

[10] Okajima S and Fujita S. Radiation doses from residual radioactivity. In *US – Japan Joint Reassessment of Atomic Bomb Radiation Dosimetry in Hiroshima and Nagasaki*. Roesch WC [Ed] 1987; Chapter 6: 205-26.

[11] Fujita S. Estimating Doses to Servicemen Stationed near Hiroshima. *RERF Update* 1994;6(2):11. Accessed via the Internet at www.rerf.or.jp/eigo/rerfupda/dosphysi/soldiers.htm.

[12] Toohey RE, Rundo J, Essling MA, Sha JY, Oldham RD, Sedlet J and Robinson JJ. Radioactivity measurements of former military personnel exposed to weapon debris. *Science.* 1981 Aug 14;213(4509):767-8.

[13] NRCP. *Report No. 65 - Management of Persons Accidentally Contaminated with Radionuclides.* National Council on Radiation Protection and Measurements. Washington D.C. 1980.

[14] Iturralde, MP. Dictionary and handbook of nuclear medicine and clinical imaging 1990. CRC Press, Boca Raton. 1990; 320.

[15] UNSCEAR, 1982 report. Ionising radiation: sources and biological effects. United Nations, New York.

[16] The committee for the compilation of material on damage caused by the atomic bombs in Hiroshima and Nagasaki. *Hiroshima and Nagasaki: The Physical, Medical and Social Effects of the Atomic Bombings.* Ishikaw E Swain DL [translators] Iwanami Shoten, Tokyo. 1981; Figure 1:8-10.

[17] Handbook of Health Physics and Radiological Health 3rd Edition Shleien B, Slaback LA, Birky BK [Eds] Baltimore: Williams & Wilkins, 1998: Table 1.11.

Appendices

Appendix 1

SOPs with an Atomic Radiation Factor
Acquired cataract
Acute lymphoid leukemia
Acute myeloid leukemia
Chronic myeloid leukemia
Goitre
Malignant neoplasm of bladder
Malignant neoplasm of breast
Malignant neoplasm of lung
Malignant neoplasm of salivary gland
Malignant neoplasm of stomach
Malignant neoplasm of thyroid gland
Myeloma

Appendix 2 – Cumulative equivalent dose and radiation units

The new RMA SOP factors refer to the cumulative equivalent dose of atomic radiation, measured in Sieverts. The SOP definition is:

> **"cumulative equivalent dose"** means the total equivalent dose of atomic radiation from all types of radiation (eg alpha, gamma). It accounts for the differences in biological effectiveness of various types of radiation and allows doses from different radiations to be combined. Each component is calculated by multiplying the absorbed dose in a particular tissue or organ for a given type of radiation by the radiation weighting factor for that radiation. The unit of equivalent dose is the Sievert (Sv).

There are 4 basic types of atomic radiation: alpha particles, beta-rays, gamma-rays and neutrons. These types of radiation have different biological effects. In order to compare or combine absorbed doses from different types of radiation it is necessary to give each type a weighting. The absorbed dose is expressed in Grays or rads.

Weighting factors:		
Beta-rays, gamma-rays (and Xrays)		1
Neutrons	slow	5
	fast	10
Alpha particles		20

1 Gray of gamma-rays or beta-rays = 1 Sievert
1 Gray of Alpha particles = 20 Sieverts

Atomic radiation of relevance to SOPs is essentially all in the form of gamma-rays. There may also have been some internal exposure to beta-rays. Generally, relevant doses can be directly combined together and doses in Grays can be directly converted to Sieverts.

The radiation dose absorbed by a particular organ or tissue will differ from the whole body dose. For external atomic radiation from gamma rays the organ dose will be approximately 60% of the whole body dose (except for the thyroid where it will be approximately 70%).

Radiation units - definitions

Unit	Abbreviation	Description
Radiation absorbed dose	**Rad**	One rad corresponds to an energy transfer of 100 ergs per gram of any absorbing material, including tissue.
Gray	**Gy**	Unit of absorbed radiation equivalent to 100 rads.
Roentgen equivalent man	**Rem**	The quantity of any ionising radiation which has the same biological effect as 1 rad of x-rays.
Sievert	**Sv**	The SI unit of radiation absorbed dose equivalent; defined as that producing the same biological effect in a specified tissue as 1 Gray of high-energy x-rays. One Sievert equals 100 rem.