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ATOMIC RADIATION

Introduction

A number of RMA SOPs contain factors for exposure to atomic radiation. Such factors specify a dose of radiation that needs to have been received by the affected organ or body site. Following the introduction of this type of factor by the RMA, SOP bulletin 42 was issued by the DSU to provide information to assist decision makers in applying those factors. This bulletin provides an update on the issue and replaces bulletin 42.

1. Atomic radiation exposure in BCOF personnel

Bulletin 42 contained background and dose information on atomic radiation exposures in Australian service personnel. In particular, it contained information on the Hiroshima atomic bomb and radiation exposure in Australians who served with the British Commonwealth Occupation Force (BCOF) in South West Japan, commencing in February 1946. That bulletin advised that independent expert opinion on exposure in BCOF personnel would be obtained. Subsequently, the Department commissioned a report from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

1.1 The ARPANSA report [1]

ARPANSA was asked to provide radiation dose estimates for a range of scenarios that covered all possible pathways of atomic radiation exposure for BCOF and related personnel. ARPANSA has provided a detailed, complex, technical and scientific report. An explanation and summary of the report is included at appendix 1 in this Bulletin for the assistance of decision makers. The report is available in electronic form (the ARPANSA report).

The dose estimates in the ARPANSA report are upper limit estimates and they are for worst case scenarios. This is further explained in appendix 1. The dose estimates provided by ARPANSA concur with those given in bulletin 42, in that they indicate that the doses that would have been received by Australian personnel in Hiroshima do not approach the minimum levels specified in the RMA SOPs.

For SOP purposes, the most useful and instructive dose estimate in the ARPANSA report is the one that combines potential exposures from external and internal sources into one total highest possible dose (appendix 2.6 in the report). This dose estimate is based on a worst case scenario whereby:

- a person spent 24 hours a day in the area with the highest level of external radiation (the high fallout zone), and
- all food consumed was sourced from areas maximally affected by radioactive contamination, and
- all drink consumed contained water contaminated by contact with soil from the maximally contaminated area, and
- the person was exposed to very high levels of maximally contaminated dust, whilst breathing at an increased rate due to exertion, for 8 hours per day.

The ARPANSA upper limit dose estimate for a person exposed as described in this scenario, every day for one year, from February 1946, is a cumulative equivalent dose to bone marrow of 0.00315 Sv (3.15 mSv).

The lowest atomic radiation dose requirement in any RMA SOP is a cumulative equivalent dose to bone marrow of 0.01 Sv (or 10 mSv), for several leukaemia RH SOPs. It follows that a person would need to be exposed to radiation as described in the above worst case scenario for more than three years to meet the lowest RMA minimum dose. For other cancers the RMA has set a lowest dose of 0.05 Sv (50 mSv) to the affected organ.

The exposures in the above scenario are far in excess of any that would have been actually experienced by Australian personnel. Approximately 75% of the 0.00315 Sv dose in the above estimate is from external radiation, from spending all day, every day in the high fallout zone. No Australian personnel were stationed in the high fallout zone. Some may have visited or worked in the area.

1.2 The NRCET report [2]

The consumption of contaminated oysters from Hiroshima bay by BCOF personnel was of particular concern to some ex-service organisation representatives. The ARPANSA report contains dose estimates for consumption of contaminated food, including seafood, but does not look specifically at the oyster consumption issue. For this reason an additional expert report was commissioned from the National Research Centre for Environmental Toxicology (NRCET), on atomic radiation exposure from consumption of seafood at Hiroshima. This report is again a detailed, complex, technical and scientific report. The report is available in hard copy from the DSU.

The NRCET report is again based on a worst-case scenario, whereby all the fallout from the Hiroshima bomb was transferred to Hiroshima bay and became available for uptake by oysters in the bay. In fact, much of the fallout went into the stratosphere and was dispersed to the west of Japan, away from Hiroshima bay. The report concludes, in essence, that the radiation dose from consumption of oysters from Hiroshima bay by BCOF personnel would be very low. An example dose of 0.00003 Sv (0.03 mSv) is given for consumption of 100 oysters in a year.

1.3 Conclusion
Based on the expert reports from ARPANSA and the NRCET and what is known of the movements and activities of Australian personnel who served in or visited the Hiroshima area after World War II, it can be generally stated that atomic radiation exposure in such personnel from service in that area would have been far lower than the minimum requirement in any of the RMA SOPs. The essential reason for the low exposure is that by the time the first Australian personnel arrived in the area, more than six months after the bomb detonation, decay and dispersion of the radiation meant that there was little residual radiation remaining. Individual circumstances and facts still need to be given appropriate consideration in any decision on relevant claims.

2. Depleted uranium
Depleted uranium (DU), used in weapons and armour in the Balkans and Gulf Wars, is weakly radioactive. External exposure, from e.g. handling DU munitions, or being in close proximity to DU armour, results in negligible atomic radiation exposure.

A small number of Australian Gulf War veterans had self-reported possible DU exposure because they reported being at Camp Doha in Kuwait when a tank compound caught fire and were involved in the subsequent clean up operations, or they reported being in Kuwait, or in the areas of the battle zones after 17th January 1991 and they reported contact with destroyed enemy equipment. [3] Such personnel may have had internal exposure, through inhalation or ingestion of DU particles and residue. Potential exposure in such circumstances has been thoroughly assessed and radiation doses from such exposure have been extensively quantified. [4,5,6] The metabolism and sites of accumulation of uranium in the body following inhalation or ingestion are also well understood. [6] Exposure to DU in the above circumstances would not produce radiation doses to relevant organs or body sites that would approach the minimum levels specified in any RMA SOPs.

A piece of DU shrapnel, lodged in the body, would deliver a significant radiation dose to the immediate surrounding area (within one millimetre). In such an instance RMA SOP requirements could be satisfied, particularly for a soft tissue sarcoma arising at the site of the shrapnel. There are no Australian service personnel known to have embedded DU shrapnel.

3. Other atomic radiation exposures

3.1 POW(J)s at Nagasaki
There were 27 Australian POWs at or near Nagasaki on August 9 1945 when an atomic bomb was exploded on that city. These POWs can be assumed to have had exposure that would satisfy the 0.01 and 0.05 Sv requirements in relevant RMA SOPs.

3.2 Radium dial painters
A small group of personnel, mustered as instrument makers, who painted aircraft dials with radium during World War II, may have had atomic radiation exposure from that activity. No dosage information is available for this group. If any claimant raises a contention about radium exposure, expert advice specific to the claim will need to be sought.

3.3 Nuclear weapons testing
Service by Australian personnel involved in the British nuclear test program conducted in Australia from 1952 to 1963 is not covered under the VEA. There are no known instances of Australian

service personnel being exposed to atomic radiation from involvement in nuclear testing during a period of eligible service.

3.4 Engineers handling radioactive material

Some personnel may have handled radioactive material in the course of training in nuclear, biological and chemical warfare. This was always done in a controlled environment and no meaningful atomic radiation exposure would have ensued.

4. Additional information

Appendix 2 contains further information on RMA SOP factors, ionising radiation, the Hiroshima atomic bomb and BCOF. This information is an update of that found in bulletin 42.

Further reading / reference sources

BCOF

1 O'Brien R. Estimations of atomic radiation exposure in Australian service personnel in South West Japan 1946-52. A report to the Commonwealth Department of Veterans' Affairs by the Australian Radiation Protection and Nuclear Safety Agency, 2002. The ARPANSA report

2 Noller B, Moore M and Kleinschmidt R. An evaluation of atomic radiation exposure in Australian service personnel from consumption of seafood at Hiroshima following the bomb explosion on 6 August 1945. A report by the National Research Centre for Environmental Toxicology and Queensland Health Scientific Services for the Commonwealth Department of Veterans' Affairs, 2002. (Available in hard copy only from the DSU)

Depleted Uranium

3 Commonwealth Department of Veterans' Affairs. Australian Gulf War Veterans' Health Study, 2003. www.dva.gov.au/media/publicat/2003/gulfwarhs/html/contents.htm

4 Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses (OSAGWI), **"**Depleted Uranium in the Gulf (II)," Environmental Exposure Report, December 13, 2000. www.gulflink.osd.mil/du_ii/index.htm

5 US Army Center for Health Promotion and Preventive Medicine, "Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments (Capstone Report)," October 2004. www.deploymentlink.osd.mil/du_library/du_capstone/index.pdf

6 Institute of Medicine. Gulf War and Health: Volume 1. Depleted Uranium, Pyridostigmine Bromide, Sarin, and Vaccines, 2000, pp 89-168. http://fermat.nap.edu/books/030907178X/html/89.html

7. Bordujenko A. Military medical aspects of depleted uranium munitions. ADF health Vol 3, Sep 2002, pp 50-57. www.defence.gov.au/DPE/DHS/infocentre/publications/journals/NoIDs/adfhealth_sept02/ADFHealth_3_2_50-57.pdf

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Appendix 1: Explanation and summary of the ARPANSA report

Background

ARPANSA was commissioned by the Department to provide atomic radiation dose estimates for BCOF and related personnel who served in the Hiroshima area between February 1946 and 1952.

Potential exposure in Australian personnel was predominantly to external radiation from being in radiation-contaminated areas. Some additional exposure could have resulted from inhaling radioactive dust, ingesting contaminated food, water or dust, absorbing radioactive material through the skin, or taking radioactive material away as a souvenir. APRANSA was therefore asked to provide dose estimates for scenarios covering each of those potential exposure pathways.

Two radiation surveys of Hiroshima were undertaken in October and November 1945. These identified two areas of radiation contamination. One, from induced radiation, was centred around the bomb hypocentre (ground zero). The other, from fallout, was in an area approximately 3 km to the west. Radiation contamination was detected in 50% of the built up area of Hiroshima. Levels of greater than 0.0001 mSv/hr (at the time of the surveys) were found in < 1% of the built up area. All known locations for Australian headquarters and bases were outside the radiologically contaminated areas.

Methodology

The ARPANSA dose estimates have been derived using a range of sources, including the initial radiological surveys and subsequent measurements, calculations based on the yield of the bomb, laboratory tests on soil and building materials from Hiroshima, and computer modelling for internal exposures.

The ARPANSA dose estimates do not take account of factors that would have reduced the levels of residual radiation. Example 1: the effects of soil leaching and surface run-off that would have resulted from rainfall have been excluded. Example 2: in calculating the dose from inhalation it has been assumed that all fallout from the bomb fell in the high fallout zone – this would result in an external dose rate five times higher than was actually measured. Thus, the ARPANSA dose estimates are upper limit levels that are likely to be considerably higher than the actual levels.

The ARPANSA dose estimates are also based on worst case scenarios. Example: The dose estimate for external exposure from induced radiation is based on a person staying in one spot directly below the point of detonation (ground zero), where the radiation level was highest, all day every day for 2 years. The radiation level fell away rapidly with distance from the hypocentre and there was essentially no residual radiation beyond a distance of around 2.5 km from ground zero. The realistic external exposure for any Australian personnel, even if they were working in the area around ground zero, would be only a small fraction of the worst case scenario estimate.

Dose estimates

The dose estimates in the ARPANSA report are for the most part expressed in terms of effective dose to the person (whole body). For SOP purposes the dosage information required is the cumulative equivalent dose to a particular organ or site. Conversion of an effective whole body dose to an organ equivalent dose is straightforward for external radiation, as described in appendix

2.6 of the ARPANSA report. For internal radiation the issue is more complex, with radionuclide metabolism and distribution within the body needing to be factored in, along with the type of radiation emitted by particular radionuclides and an adjustment for an organ specific weighting factor. The dose estimates listed below are the ARPANSA dose estimates, converted where necessary to cumulative equivalent doses to relevant organs, using the ARPANSA methodology in appendix 2.6

Scenario	Exposure	Cumulative equivalent dose to organ/site
1	To external radiation from being at ground zero 24 hrs/ day, every day for 2 years	0.00035 Sv (0.35 mSv) for bone marrow, lung, stomach or other organs
2	To external radiation from being in high fallout zone 24 hrs/day, every day for 2 years	0.0047 Sv (4.7 mSv) for bone marrow, lung, stomach or other organ
3	From souvenired radioactive object	Negligible
4	Internal radiation from consuming only food and water from fallout contaminated sources for 2 years	0.00065 Sv (0.65 mSv) To bone marrow [#]
5	Internal radiation from inhaling high levels of contaminated dust in high fallout zone 8 hrs/day every day for 2 years	0.00094 Sv (0.94 mSv) To bone marrow [#]
6	Internal radiation from absorption of contaminated soil via open skin wound	Negligible
7	Combined maximum external and internal exposure over 2 years	0.0063 Sv (6.3 mSv) To bone marrow [#]

[#] Cumulative equivalent dose calculation available for bone marrow only. Main component of internal dose is from Strontium 90 which is mostly deposited to bone and is a beta emitter. This radiation would reach the bone marrow but not other organs. Doses to other organs/sites would be lower.

As previously stated these are upper limit doses for worst case scenarios. Taking all relevant factors into consideration, the real total doses of atomic radiation to Australians from service in the Hiroshima area are highly likely to have been well below 0.001 Sv (1 mSv). Individual circumstances and facts still need to be given appropriate consideration in any decision on relevant claims.

Appendix 2 – Other relevant information

1. RMA SOPs with atomic radiation factors (as at July 2006)

Condition	RH dose	BOP dose
Leukaemias		
Acute lymphoid leukaemia	0.01 Sv (10 mSv)	0.1 Sv (100 mSv)
Chronic myeloid leukaemia	"	"
Solid cancers & myeloma	0.05 Sv (50 mSv)	0.5 Sv (500 mSv)
Malignant neoplasm of bladder	"	"
Malignant neoplasm of brain	"	"
Malignant neoplasm of breast	"	"
Malignant neoplasm of colorectum	"	"
Malignant neoplasm of lung	"	"
Malignant neoplasm of salivary gland	"	"
Malignant neoplasm of stomach	"	"
Non-melanotic malignant neoplasm of the skin	"	"
Malignant neoplasm of thyroid gland	"	" or 0.1 Sv at age < 20
Myeloma	"	No BOP factor
Soft tissue sarcoma	"	" *
Malignant neoplasm of unknown primary site	0.2 Sv (to body)	0.5 Sv (to body)
Benign conditions		
Cataract	0.5 Sv	1.0 Sv
Goitre	0.2 Sv	1.0 Sv

* Soft tissue sarcoma BOP SOP includes a factor for ionising radiation (0.5 Sv) from internal deposition of an alpha particle emitter. This covers atomic radiation from e.g. depleted uranium.

The dose must be the cumulative equivalent dose to the affected organ / site and must have been accumulated at least X years before clinical onset. X = 2, 5 or 10 years, depending on the SOP.

2. Atomic and other ionising radiation – general information

Atomic radiation is a form of ionising radiation. Atomic radiation is defined by the RMA to mean ionising radiation other than natural background radiation, therapeutic radiation and radiation from diagnostic procedures.

All individuals are exposed to naturally occurring background ionising 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.

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.

Approximate bone marrow radiation doses from various diagnostic procedures are:

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

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.

3. Further background information on the Hiroshima atomic bomb

An atomic (uranium) bomb was released over Hiroshima on 6 August 1945. It exploded at a height of 510 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 mostly beta-rays and gamma-rays from radioactive substances taken into the body.

<u>(i) External radiation</u>

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 from the hypocentre.

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.

<u>(ii) Internal radiation</u>

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).

4. Further background information on BCOF [1 2 3]

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, including seafood (oysters) from Hiroshima bay. Drinking water and beer were sourced from within the city. Sporting events for troops were also held within the city.

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

BCOF history references

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

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3 Lacey L. *BCOF – An unofficial history.* McMahon Graphics, Glen Innes. 1995.