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SOP Bulletin No. 145



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ATOMIC RADIATION – UPDATE

BRITISH NUCLEAR TEST PARTICIPANTS

From 1 July 2010 former Australian Defence Force (ADF) personnel who were British Nuclear Test (BNT) participants have eligibility for compensation under the VEA for service-related injury, disease or death.

For relevant claims the Repatriation Medical Authority (RMA) reasonable hypothesis SOPs apply. There are many RMA SOPs that have atomic radiation as a causal factor. Those SOPs generally specify a minimum dose of atomic radiation that needs to have been received. This bulletin contains information on atomic radiation exposure in BNT participants that will assist decision makers to determine whether RMA SOP requirements have been met.

Information on atomic radiation exposure in other veterans can be found in previous DSU bulletins, No. 42 and No. 106. See Appendix B for links to those documents.

British Nuclear tests

The United Kingdom conducted 12 major nuclear weapons tests in Australia between 1952 and 1957. The tests occurred at the Monte Bello Islands off the northwest coast of Western Australia, and at Emu Field and Maralinga in the western desert region of South Australia.

In addition to the major tests, approximately 600 minor trials, in several series, were carried out between 1953 and 1963. Some of these minor trials did generate relatively large quantities of radioactive contamination.

Around 8,150 members of the Australian Army, RAN and RAAF, were involved directly and indirectly in various tests and trials. The ADF personnel were involved primarily in preparing test sites, monitoring and observing the tests, and cleaning up the sites. In addition to working in the test areas, some ADF personnel carried out tasks at sites remote from the tests that may have led to some atomic radiation exposure (mostly aircraft decontamination and servicing).

Most individual participants were present for only one major trial series, approximately 10% attended two series, and less than 3% attended three or more series.

Atomic radiation exposure

BNT participants had atomic radiation exposure. Levels of exposure in the participants have been carefully studied, with the results published in a report to the Department (the dosimetry study)¹ and also in a peer-reviewed scientific publication.² Dose information in this bulletin has been taken from the dosimetry study.¹

Overall exposure in ADF personnel who were included in the dosimetry study is summarised in the following table:

Table 1. Atomic radiation exposure in ADF BNT participants

Category	Exposure	No. of ADF	%
A	< 1 mSv*	5,049	71.0
B	1 to 4.9 mSv	686	9.6
C	5 to 19.9 mSv	466	6.5
D	20 to 50 mSv	237	3.3
E	> 50 mSv	18	0.3
F	Unknown	660	9.3
Total		7,116	100.0

* mSv = milliSievert

For comparison:

- Background ionising radiation results in exposure of around 1 to 2 mSv per year to all people in the general community.
- The annual permissible occupational exposure limit to ionising radiation in Australia is 20 mSv.

Note: atomic radiation is a type of ionising radiation. For SOP purposes, the RMA has defined atomic radiation to mean ionising radiation other than natural background radiation, therapeutic radiation and radiation from diagnostic procedures. So, atomic radiation includes ionising radiation

¹ Gun R, Parsons J, Ryan P, Crouch P and Hiller J. (2006) Australian participants in British nuclear tests in Australia Volume 1: Dosimetry, Department of Veterans Affairs, Canberra.

² Crouch P, Robotham F, Williams W, and Wise K. (2009) Assessment of radiation doses to Australian participants in British Nuclear Tests. Radiation Protection Dosimetry 136(3):158-167.

from nuclear bombs and tests, nuclear power plants and other industrial, commercial and military sources.

Table 1 indicates that most BNT participants had low level ionising radiation exposure. However, some had exposure that could meet the minimum dose requirements for some RMA SOPs.

Table 2. RMA SOP minimum doses for atomic radiation (RH SOP).

Disease*	Dose
Leukaemias	10 mSv
Solid cancers	50 mSv
Benign schwannoma of eye	100 mSv
Other conditions	≥ 200 mSv

* See Appendix B for a link to a full list of RMA SOPs with atomic radiation factors.

RMA SOP doses are expressed as a “cumulative equivalent dose” to the affected organ or site. The dosimetry study provides effective doses to the whole body. These are not the same.

A whole body effective dose needs to be converted to an organ or site specific equivalent dose in order to assess whether a SOP factor is satisfied. This is straightforward for external radiation, but can be complicated for internal radiation. For BNT participants the organ or site specific dose received will be lower than the whole body effective dose except in limited circumstances. This is further explained, in Appendix A.

A number of BNT participants could meet the 10 mSv dose (to bone marrow) requirements for the leukaemia SOPs and a small number could meet the 50 mSv requirement in the solid cancer SOPs. No ADF BNT participants are thought to have received organ or site specific doses of ≥ 200 mSv.

Each claim from a BNT participant where an atomic radiation exposure contention is raised will need to be assessed on its merits.

From the information in the dosimetry study it is possible to identify certain groups with potential exposure that could satisfy RMA dose requirements for atomic radiation exposure. Details of those groups are provided in tables 3 to 5, below.³ Not being in one of the groups in Tables 3 to 5 does not exclude the possibility of someone meeting a dose requirement, but does make it unlikely. Some participants were present at more than one operation and so may have multiple exposures that cumulatively satisfy SOP dose requirements.

Table 3 lists groups with atomic radiation exposure that could satisfy the requirements in one of the RMA solid cancer SOPs of having a cumulative equivalent dose to the relevant organ or site of 50 mSv.

³ This information comes particularly from chapter 7 in the dosimetry study. Table 7.26 on page 141/2 of the study provides a summary of main exposure outcomes.

Table 3. ADF personnel with potential exposure to 50 mSv of atomic radiation to an organ or site

Operation, site and date	Personnel
Operation Hurricane Monte Bello Islands Nov/Dec 1952	Two members of the Joint Services Training Unit who took part in training exercises and sample collection on Trimouille island had film badge records that indicated exposures of over 50 mSv.
Operation Mosaic Monte Bello Islands May/June 1956	RAAF aircrew flew RAF Canberra bombers to undertake cloud sampling following two above ground tests. RAF crews recorded external radiation doses up to 58 mSv. The same level of exposure may have been experienced by RAAF crew undertaking similar work.
Operation Buffalo Maralinga Sept/Oct 1956	RAAF aircrew flew RAF Canberra bombers for cloud sampling for each of three above ground tests. Crew who participated in those tests received an external radiation dose that probably exceeded 50 mSv.
Operation Antler Maralinga Sept/Oct 1957	An RAAF aircrew flew a RAF Canberra bomber for cloud sampling for each of three above ground tests. Crew who participated in those tests received an external radiation dose that probably exceeded 50 mSv.

Having an external dose of ≥ 50 mSv does not necessarily mean that an RMA dose requirement of 50 mSv to an organ or site will be satisfied. An external dose of 50 mSv would equate to a dose to an internal organ or site of approximately 30 - 35 mSv. See Appendix A for further details.

External doses also do not include any internal radiation dose (mostly from inhalation), which need to be added to the total. The whole body internal radiation dose varies with the circumstances. For aircrews involved with cloud sampling the internal whole body effective dose was approximately $\frac{1}{4}$ of the external dose. In most other circumstances the internal whole body dose was less than 10% of the external dose. The internal dose to the lungs, liver and bone could be higher than the internal effective whole body dose and may have added significantly to the total dose to one of those sites. This is because of the way radioactive particles are metabolised and localised within the body. See Appendix A for further details.

Tables 4 and 5 list groups with atomic radiation exposure that could satisfy the requirements in the RMA leukaemia SOPs of having a cumulative equivalent dose to bone marrow of 10 mSv.

Table 4. ADF personnel with probable exposure to > 10 mSv of atomic radiation to bone marrow

Operation, site and date	Personnel
Operation Hurricane Monte Bello Islands Oct/Dec 1952	One further member of the Joint Services Training Unit who took part in training exercises and sample collection on Trimouille island had a film badge record indicating category D (20 -50 mSv) exposure. Divers from HMAS Koala involved in recovering a sunken landing craft.
Operation Totem Emu field Oct 1953	Radiation Hazards Group members who undertook radiological surveys near ground zero.

Operation Buffalo Maralinga Sept/Oct 1956	Peace officers who patrolled and guarded the test area long term from after the tests.
Operation Antler Maralinga Sept/Oct 1957	Maralinga Range Support Unit (MARSU) Engineering and scientific teams who worked at more than one round of testing or were involved in more than one task. Peace Officers who patrolled and guarded the test area long term from after operation Buffalo.
Post Antler / Minor trials After 1957	Personnel from the Australian health physics team who assisted with the decontamination of the DC12 facility in March 1961 – in particular personnel from the training unit and decontamination team. Peace Officers who patrolled and guarded the test area long term from after operation Buffalo.

Persons in the above table are listed as having exposure in category D (20 to 50 mSv whole body effective dose) in the dosimetry study. Someone with that level of exposure would comfortably meet an RMA leukaemia SOP requirement of a cumulative equivalent dose to the bone marrow of 10 mSv.

Table 5. ADF personnel with possible exposure to ≥ 10 mSv of atomic radiation to bone marrow

Operation, site and date	Personnel
Operation Hurricane Monte Bello Islands Oct/Dec 1952	Other members of the Joint Services Training Unit who took part in training exercises and sample collection on Trimouille island. Crews from HMAS Hawkesbury and HMAS Koala.
Operation Totem Emu field Oct 1953	Drivers and passengers who travelled in contaminated vehicles/ over contaminated ground following the tests, for > 400 hrs. Peace officers who patrolled and guarded the test area long term. RAAF aircrew involved in cloud sampling.
Operation Buffalo Maralinga Sept/Oct 1956	Maralinga Range Support Unit (MARSU) engineering and scientific teams. Drivers and passengers who travelled in contaminated vehicles/ over contaminated ground following the tests, for > 400 hrs. Peace officers who patrolled and guarded the test area long term from after the tests.
Operation Antler Maralinga Sept/Oct 1957	Maralinga Range Support Unit (MARSU) engineering and scientific teams who worked at more than one round of testing or were involved in more than one task.
Post Antler / Minor trials	Australian Health Physics Group personnel who were: <ul style="list-style-type: none"> radiation surveyors

After 1957	<ul style="list-style-type: none"> • involved in Cobalt 60 pellet collection at Tadge. • involved in the decontamination of the DC12 facility in March 1961 – in particular, personnel from the training unit and decontamination team.
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Persons in the above table are listed as having exposure in category C (5 to 20 mSv whole body effective dose) in the dosimetry study. Further detail in the dosimetry study identifies some groups as being in category C, but having exposure of < 10 mSv. Those groups have not been included in the above table. Someone with category C exposure could meet an RMA leukaemia SOP requirement of a cumulative equivalent dose to the bone marrow of 10 mSv, but cases will need to be individually assessed on their merits.

For a limited number of participants, film badge records of external radiation exposure are also available. Film badges were personal radiation monitoring devices worn by individuals to measure the amount of external radiation they were exposed to. See Appendix B.

Summary and conclusions

Most ADF BNT participants had exposure to atomic radiation that was insufficient to satisfy the dose requirements in relevant RMA SOPs. Claims for relevant diseases are more likely to succeed via other SOP factors than via an atomic radiation exposure pathway.

For claims for atomic radiation-related disease that involve a BNT participant who is on one of the above lists or where there is other evidence of a significant radiation dose, it will be necessary to attempt to quantify the atomic radiation dose to the relevant organ or site. This will be the cumulative exposure from all relevant sources of external and internal radiation.

For most claims it should be reasonably straightforward to establish whether an RMA atomic radiation factor has been satisfied, based on the activities of the BNT participant and the disease under consideration. For more complex cases the DSU may be able to provide assistance. In some instances, expert advice may need to be sought.

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APPENDIX A – SOURCES AND DOSES OF RADIATION EXPOSURE IN BNT PARTICIPANTS

Sources of exposure

1. Direct exposure to the initial gamma/neutron radiation burst from a nuclear explosion
 - Nearly all BNT participants were too far away at the time of the explosions to receive any radiation dose from this source.
 - Around 30 Australians who were members of the Indoctrinee Force at Operation Buffalo were located at 1800 m or 3000 m from the “Marcoo” test (Oct 1956). The resulting prompt external radiation dose has been calculated at < 1.0 mSv.
2. External radiation from radioactive fallout and induced radiation
 - Most of the radiation exposure received by BNT participants was from these sources. The dose to internal organs was almost entirely from gamma radiation. The surface of the body (the skin and external eye in particular) could have received additional dose from beta particles (which cannot penetrate far into the body).
3. Internal radiation
 - Internal radiation resulted mostly from inhalation of radioactive airborne particles but also from ingestion of such particles, and from contamination of open wounds. For most people the main source of internal radiation was breathing in raised dust when in a contaminated area. The dosimetry study calculates that for most types of exposure the internal dose was < 10% of the external dose. The notable exceptions were for:
 - aircrew conducting cloud sampling soon after the explosions, where the dose was calculated to be around ¼ of the external dose; and
 - people significantly exposed to areas highly contaminated by plutonium-239 (²³⁹Pu), where the dose could amount to around ½ of the total whole body dose and the organ specific dose could be higher than the whole body dose (further information below).

Radiation doses

RMA SOP factors are expressed as a cumulative equivalent dose to the affected organ or site, e.g.:

“having received a cumulative equivalent dose of 0.05 Sievert of atomic radiation to the lung, where this dose was accumulated at least five years before the clinical onset of malignant neoplasm of the lung” (0.05 Sievert = 50 mSv).

The cumulative equivalent dose to an organ or site will be the total of the dose to the organ or site from both external and internal radiation.

The external radiation dose to an organ will generally be around 60% to 70% of the whole body external gamma radiation dose. This is due to attenuation of the radiation as it passes through the body’s tissues. The total external dose is received at the time of exposure.

The internal dose depends on the organ and on the type/s of radionuclide taken in. Some radionuclides have very long half-lives and may be eliminated from the body only very slowly, so can continue to emit radiation in the body over many years or decades. Dose calculations for

internal radiation are based on the dose that would accumulate over a 50 year period (the committed dose).

For the British nuclear tests the most important radionuclide was plutonium (^{239}Pu). Inhaled ^{239}Pu is retained in the lung, liver and bone and is a potential risk factor for cancer at those sites.

High level plutonium contamination occurred at Maralinga at the Taranaki site as a result of the Vixen B series of minor trials from 1960 to 1963. Plutonium contamination was also significant following the TM100/101 minor trials at the Naya site (1960/1), and the Wewak minor trials (1959). If any personnel spent extended periods (many days) in those contaminated areas they may have had internal deposition of significant quantities of ^{239}Pu from inhaled dust. The whole body effective dose from such exposure may be quite small but the organ specific equivalent dose, may be multi-fold higher.

The malignant neoplasm of the lung SOP has the typical RMA 50 mSv factor. The malignant neoplasm of the liver SOP currently has no atomic radiation factor. This SOP is under review by the RMA and an atomic radiation factor may be added in the coming months. The malignant neoplasm of the bone and articular cartilage SOP has no standard format atomic radiation factor, but does have a factor for inhaling Plutonium-239, with the dose expressed as “a body burden of at least 1.5 kiloBecquerel”. This is a different type of radiation measure than the Sievert, but effectively this is a much higher dose requirement than 50 mSv to bone (of the order of 10 fold higher). It is highly unlikely that this level of exposure would have resulted from being a BNT participant. This SOP is also under review by the RMA.

If a claim relating to a BNT participant concerns a relevant disease and the available information indicates that significant plutonium inhalation may have occurred, then expert advice may be required to attempt to quantify the exposure.

APPENDIX B - FURTHER RESOURCES

[The dosimetry study](#)

This link is to a downloadable copy of the 2006 dosimetry report on “Australian Participants in British Nuclear Tests in Australia”, from the DVA Internet site.

Film badge records for some BNT participants



UK MOD table
-Australians at BNT.P

This link is to a document from the UK Ministry of Defence that contains details of some of the Australian participants, both military and civilian, at the British nuclear tests. Film badge records for some participants are available. These records consist of the gamma radiation (column 8 – “G”) and aggregate radiation doses (column 9 – “AGG”) in millirem. These are external radiation doses only and do not include any internal radiation exposure.

Aggregate records are gamma radiation plus beta particle doses. The aggregate records should be disregarded, except in the case of non-melanotic malignant neoplasm of the skin and benign neoplasm of the eye. This is because external radiation from beta particles cannot penetrate far enough into the body to irradiate internal organs.

100 Millirem = 1 milliSievert. Therefore, divide the listed dose by 100 to obtain the dose in mSv. (The rem (Roentgen Equivalent Man) is an older biological radiation unit which has been replaced by the Sievert).

Note that there are multiple entries for some individuals. In such cases doses should be summated.

Previous DSU atomic radiation bulletins



2000-10, Bulletin
42(a), Atomic radiatic

This link is to DSU bulletin 42, issued in November 2000. It contained interim advice on atomic radiation exposure in BCOF personnel who served near Hiroshima after WW2. It also contains background information on different types of radiation exposure following a nuclear explosion.



2006-07, Bulletin
106, Atomic radiation

This link is to DSU bulletin 106, issued in July 2006. It contains information on the ARPANSA and NRCET reports concerning atomic radiation exposure in BCOF veterans. It also contains information on other Australian service personnel who may have been exposed to atomic radiation.

List of current RMA SOPs with atomic radiation factors



RMA SOPs with
atomic radiation factc