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DEPARTMENT OF PREMIER AND CABINET  SafeWork SA

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BHP BILLITON OLYMPIC DAM  Head of HSE Olympic Dam

Head of Health and Hygiene A&I, Minerals Australia

General Manager Mine

General Manager Surface

Manager Radiation, Health and Hygiene Improvement

Superintendent Environment, Radiation and Hygiene Business Partner

Supervisor Radiation and Occupational Hygiene
This Report has been reviewed by:

Head of HSE Olympic Dam
Martin Smith

Manager Radiation, Health & Hygiene Analysis and Improvement
Neil Camillo

Supervisor Radiation and Occupational Hygiene Business Partner
James Gardner

Specialist Radiation and Regulatory Affairs A&I
Matthew Roberts
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1 Introduction

This document is the annual report on radiation protection for BHP Billiton Olympic Dam Corporation Pty Ltd (ODC).

In fulfilment of clauses 2.10.1, 3.8.1 and 3.10.1 of the Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Processing 2005, employee dose assessments, dose calculation methodologies, dose parameters and dose conversion factors for the period 1 July 2017 to 30 June 2018 (FY2018) are presented.

The overall average full-time worker dose was 1.8 mSv for underground workers and 1.7 mSv for surface workers.

2 Employee Dose Assessment Method

2.1 Exposure Calculation Underground

The main exposure pathways for Mine workers are inhalation of Radon Decay Products (RDP), irradiation by gamma radiation and inhalation of Long Lived Radioactive Dust (Dust). Assessment of exposure from dust and RDP are based on employee time sheet information and measurements from the approved monitoring program.

Medgate™ is the data and dose management system, which is used to assess and record individual radiation exposures. The site security database (CARDAX) is used to determine the daily hours for employees working on site. The information in CARDAX is categorised into 3 major areas: surface, underground safe zone and underground blasting zone. Medgate™ records employee name, employee number, occupation, date, work location and hours in location information.

Locations at the Mine End are separated into three main zones: Surface, Safe, and Blast. Surface includes all above ground locations, including the quarry and backfill areas. The Safe Zone includes the 420 Platform and adjacent offices and workshops and is considered a fresh air base. The Blast Zone includes all other underground areas. The RDP concentrations are determined for each zone for each week using measurements from the approved monitoring program, which monitor the most active work areas. Where no samples were taken for the week an overall average of all samples from that zone is used to determine the RDP concentration for that week. This average is calculated from all readings for that particular zone over the quarter.

RDP exposure for all key underground workgroups is assessed through the use of Personal Alpha Dosimeters (PADs). In previous years PADs had only been allocated to select high risk workgroups, but in FY18 the program was expanded to all underground workgroups.

Employee exposure to radioactive dust is calculated using quarterly occupational-based averages. The averages are obtained from monitoring performed under the approved monitoring program.

The occupation-based dust concentration information and location-based RDP concentration information is then combined with the employee time card information to derive individual exposure data. Dust concentration is measured in units of Becquerel-hours per cubic metre (Bq.hr/m³) and RDP concentration is measured in units of micro Joule-hours per cubic metre (µJ.hr/m³). Exposure details are combined to give quarterly personal exposures.

The system is designed such that the Radiation Safety Officer is required to perform checks in each step of the process. This is in addition to a built-in auditing system within the program, as set out in section 8.10 of Olympic Dam’s Radiation Management Plan.

Respiratory protection in the form of airstream helmets is available for high-risk workers. They are typically worn by some workgroups such as Ore Handling Beltrunners and Services Ventilation Crew. Airstream helmets or P2 dust masks are also mandatory for specific tasks or in certain conditions. No respiratory protection factors are used in exposure calculations, and therefore actual individual exposures could be lower than reported.
Exposure to gamma radiation is assessed using Optically Stimulated Luminescence Dosimeters (OSLD) badges from the Landauer Personal Radiation Monitoring Service. OSLD badges are worn for a period of three months; non-badge wearers are allocated an occupation-based average exposure.

2.2 Exposure Calculation on the Surface

The main exposure pathways for Metallurgical Plant workers are inhalation of long lived radioactive dust (LLRD) and fumes, and irradiation by gamma radiation. Assessment of exposure from dust and fumes is based on employee time information and measurements from the approved monitoring program. Dust exposure in the Metallurgical Plant may involve exposure to different types of dust. The dust can differ in particle size and radionuclide composition, which results in different dust Dose Conversion Factors (DCFs). Appendix A provides a table of DCFs used in FY2018.

Information from employee and contractor time cards or employee activity sheets is captured by the radiation management software, Medgate™, which contains daily time sheet/card information. Medgate™ contains an up-to-date list of all locations and occupations on-site. Occupations and Locations which have similar exposure characteristics are grouped into similar exposure groups (SEGs). A quarterly mean of dust radioactivity concentration is determined for each of the exposure groups based on the results of the monitoring program.

Dust concentration averages are calculated for each SEG on a quarterly basis. These averages are then combined with the previously captured time and location information to produce a dust exposure for each employee.

Exposure to gamma radiation is assessed using OSLD badges provided by Landauer. OSLD badges are worn for a period of three months. They are issued to a randomly selected subset of workers from each SEG. Workers who do not receive an OSLD have a dose calculated based on the average OSLD dose rate for their corresponding SEG and their time sheet/card information.

Although the exposure to RDP within the Metallurgical Plant is much less than other pathways, it is assessed in the same way as for Mine workers. The same time information used for calculation of dust exposure is used for calculating RDP exposure. All surface locations/occupations are grouped into one surface airway. This surface airway has its RDP concentration calculated on the basis of a grab sampling method.
3 Changes Impacting Employee Doses

3.1 Dose Conversion Factor Changes

In January 2018 the International Commission on Radiological Protection (ICRP) published “ICRP Publication 137: Occupational Intakes of Radionuclides: Part 3”. The key impact of this publication is the updating of the default RDP dose conversion factor from 1.41 to 3.0 mSv.m³/mJ.hr. As RDP exposure previously accounted for approximately 50% of dose the new dose conversion factor means that reported doses are now approximately 56% higher.

ODC has decided to adopt the new dose conversion factor beginning in the FY19 reporting period. Thus doses in this report still use the old dose conversion factor of 1.41 mSv.m³/mJ.hr but also give an indication of what future average underground doses will be using the new conversion factor.

ICRP 137 also includes changes to dose conversion factors for other radionuclides present at Olympic Dam, however the full data set required to revise current conversion factors has not yet being published. ODC is continuing to monitor releases by the ICRP so that the impact of any altered factors can be assessed and responded as they are released.

3.2 PAD Expansion and use for assessing LLRD

Starting 1st July 2017, PAD coverage was extended to the following underground workgroups:

- 420 Plat Workers
- CC Machine Operators
- Fitters/Maintenance
- UG Part Time
- UG Services
- UG Supervisor

In addition to extending PAD coverage, underground LLRD dosimetry also switched from personal dumps to PADs. The extended coverage has led to a reduction in reported dose for most SEGs most notably Closed Cabin (CC) Machine Operators who spend almost their entire time in filtered cabin vehicles. LLRD continues to be a minor component of underground dose. As most historical readings have been very close to the minimum detectable concentration (MDC), the smaller MDC afforded by the PAD system has led to reduction for many SEGs. A notable exception is the Beltrunning SEG, which reported a slight increase.

3.3 Smelter

Smelter doses decreased slightly from previous years, this is largely due to halting of production during SCM17. A number of improvements to the hygiene ventilation were also made during this time including modification of the electric furnace slag taphole fume hoods. Doses are expected to be low in FY19 as the recent shutdown of the acid plant has led to another prolonged period with no production in the smelter.

3.4 SCM17

Approximately 1600 additional fulltime workers came on to site for SCM17. During the October to December quarter the average reported dose was approximately 2 mSv. This has had the notable impact of increasing the average surface dose to 1.7 mSv from 0.73 mSv in FY17. These doses have had a visible effect on the dose distribution shown in Figure 3. A number of workers who remained on site following SCM accumulated doses in the 3-4 mSv range skewing the distribution when compared with previous years. A more detailed analysis of doses in SCM17 is presented in the FY18 Q2 quarterly dose report.
Appendix A

Dose Conversion Factors FY2018

A summary of the airborne dust dose conversion factors for specific work areas can be viewed in the following table.

<table>
<thead>
<tr>
<th>Location</th>
<th>DCF (µSv.m^3/Bq.hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smelter</td>
<td>7.5</td>
</tr>
<tr>
<td>Refinery / STP</td>
<td>5.4</td>
</tr>
<tr>
<td>SX / Precipitation / Calciners</td>
<td>4.5</td>
</tr>
<tr>
<td>Other*</td>
<td>4.1</td>
</tr>
</tbody>
</table>

*All other areas of Mine, Concentrator, Slag Concentrator, Hydromet and Services (Laboratories and Metallurgical Workshop)

The default RDP dose conversion factor used was 1.41 mSv.m^3/mJ.hr

Appendix B

Dose Trend Charts

Legend:
- Average long lived radioactive dust dose
- Average radon decay product dose
- Average gamma dose
- Maximum of all dose pathways combined
- Average dose computed with the new RDP DCF
Figure 1: Mine Summary

Average dose for each pathway and adjusted for the new radon decay product DCF, to be adopted for FY19 reporting. Maximum dose also shown.
Figure 2: Surface Summary

Average dose for each pathway and maximum total dose

- Smelter Shutdown: Avg(LLRD) 3.6, Avg(RDP) 3.1, Avg(OSLD) 3.2
- Slag Handling: Avg(LLRD) 2.4, Avg(RDP) 2.2
- Smelting: Avg(LLRD) 1.6, Avg(RDP) 1.9, Avg(OSLD) 1.7
- Hydro Maintenance: Avg(LLRD) 1.4, Avg(RDP) 1.4, Avg(OSLD) 1.1
- Slag Pot Welding: Avg(LLRD) 1.4, Avg(RDP) 1.2, Avg(OSLD) 0.9
- SX Production: Avg(LLRD) 0.7, Avg(RDP) 0.7, Avg(OSLD) 0.8
- Casting: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Feed Prep: Avg(LLRD) 0.7, Avg(RDP) 0.6, Avg(OSLD) 0.8
- Concentrator Maintenance: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Concentrator Production: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Acid Plant: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Hydro Production: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Electrowinning: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Plant Offices: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Electrorefining: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Plant Maintenance: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- SX Maintenance: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- TRS Operations: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8
- Goldroom: Avg(LLRD) 0.7, Avg(RDP) 0.8, Avg(OSLD) 0.8

Series by:

- Avg(LLRD)
- Avg(RDP)
- Avg(OSLD)

Max(Total Dose)
Figure 3: Dose Distribution

Surface Distribution

Mine Distribution

Annual Dose (mSv)
Figure 4: Mine Dose 1

Average dose for each pathway and maximum total dose

<table>
<thead>
<tr>
<th></th>
<th>Corefarm</th>
<th>Mine 420 Plat Workers</th>
<th>Mine Backfill Operations</th>
<th>Mine Beltrunners</th>
<th>Mine CC Machine Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg(LLRD)</td>
<td></td>
<td></td>
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<tr>
<td>Avg(OSLD)</td>
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<tr>
<td>Avg(RDP)</td>
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<td></td>
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<tr>
<td>Max(Total Dose)</td>
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</table>

Averages and maximum total doses are shown for various mine operation pathways, with specific categories including Mine Development, Mine Diamond Drilling, Mine Electrical, Mine Maintenance, and Mine Offices.
Figure 5: Mine Dose 2

Average dose for each pathway and maximum total dose

- Mine Production Charging
- Mine Production Drilling
- Mine Raise Drill
- Mine Surface Worker

- Avg(LLRD)
- Avg(OSLD)
- Avg(RDP)
- Max(Total Dose)
Figure 6: Process Dose

Average dose for each pathway and maximum total dose

<table>
<thead>
<tr>
<th>Acid Plant</th>
<th>Concentrator Maintenance</th>
<th>Concentrator Production</th>
<th>Hydro Maintenance</th>
<th>Hydro Production</th>
</tr>
</thead>
</table>

- Avg(LLRD)
- Avg(OSLD)
- Avg(RDP)
- Max(Total Dose)
Figure 7: Smelter/Refinery Dose

Average dose for each pathway and maximum total dose

- Casting
- Electrosulfing
- Electrowinning
- Feed Prep
- Refinery Maintenance

Series by:
- Avg(LLRD)
- Avg(OSLD)
- Avg(RDP)
- Max(Total Dose)