HOMESTAKE
Grants Project

Homestake Mining Company of California

Thomas Wohlford
Closure Manager

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Document Control Desk
U.S. Nuclear Regulatory Commission,
Washington, DC 20555–0001

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Mr. Ron Linton, Project Manager
Project Manager, Materials Decommissioning Branch (Mail Stop: T-8F5)
Decommissioning, Uranium Recovery & Waste Programs
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

RE: Homestake Mining Company of California – Grants Reclamation Project – Occupational Dose Assessment for Work on Evaporation Ponds

Dear Mr. Linton:

In response to a verbal request from the Nuclear Regulatory Commission (NRC), please see attached an occupational dose assessment for potential radiological exposures at the evaporation ponds on Homestake Mining Company's Grants Reclamation Project. The results from this assessment are that potential occupational exposures to radionuclides are unlikely to result in significant radiological doses.

Thank you for your time and attention on this matter. If you have any questions, please contact me via e-mail at twohlford@homestakeminingcoca.com or via phone at 505.290.2187.

Respectfully,

Thomas P. Wohlford

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TECHNICAL MEMORANDUM

To: Tom Wohlford (HMC)	**Date:** August 18, 2017
From: Randy Whicker (ERG)	**Project:** HMC Grants Reclamation Project
Direct: 970-556-1174	**Task(s):** Radiation Protection Administrator
Cc: Toby Wright (WES); Chuck Farr (ERG)	
Subject: Occupational dose assessment for potential radiological exposures at surface pond facilities	

Dear Mr. Wohlford,

Per my recent request to have salt crust samples from Evaporation Pond 1 (EP1) analyzed for U-nat, Th-230 and Ra-226, this Technical Memorandum provides conservative radiological dose assessments for workers that could potentially be occupationally exposed to radionuclides when working on or near any of the surface pond facilities at the Homestake Mining Company of California (HMC) Grants Reclamation Project. The intent of this information is to support a determination of whether occupational air monitoring or other radiation safety measures may be prudent to consider under future Radiation Work Permits (RWPs) for projects involving potential exposures to pond process water, sludge, or evaporative salts at the HMC Grants Reclamation Project site.

Please let me know if you have questions or need more information.

Thanks,

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Occupational Dose Assessment for Surface Pond Facilities

1. Introduction

This Technical Memorandum provides conservative radiation dose assessments for workers at the Homestake Mining Company of California (HMC) Grants Reclamation Project (Site) whom may be occupationally exposed to 11.e(2) byproduct material radionuclides when working on or near collection or evaporation ponds. The intent of this information is to support a determination of whether occupational air monitoring or other radiation safety measures may be prudent to consider under future Radiation Work Permits (RWPs) for projects involving potential exposures to process water, sludge, or evaporative salts at the HMC Grants Reclamation Project site.

2. Potential Exposure Scenarios

Based on observation of operational procedures involving the process water collection or evaporation ponds, HMC's Radiation Protection Administrator (RPA) has identified the following potential pathways for potential occupational exposure to radiation from 11.e(2) byproduct radionuclides:

1) Accidental ingestion of dissolved radionuclides in process water contained in the collection or evaporation ponds.
2) Inhalation of radionuclides in airborne particulates released from dried evaporative salts or exposed sludge from the ponds.
3) Inhalation of radionuclides in airborne liquid aerosols released by turbo misters.
4) Exposure to external gamma radiation from sludge contained in the collection or evaporation ponds or near-surface tailings below the liner of the small tailings pile (STP).

For the ingestion pathway, it was conservatively assumed for this dose assessment that a worker could fall into one of the ponds and accidentally ingest as much as 1 liter of water containing elevated levels of dissolved radionuclides. For the inhalation pathway, it was conservatively assumed that a worker could be intermittently exposed to airborne particulate matter from dried evaporative salts or sludge, or to aerosols of process water that are released into the air by turbo misters. Elevated levels of gamma radiation and the external exposure pathway is primarily limited to areas near the edges of Evaporation Pond 1 (EP1), and since routine dosimetry monitoring of workers over the years has not shown significant external doses in the past, this pathway is not evaluated in this Technical Memorandum.

3. Source Term

The source terms used for assessment of potential internal doses from occupational exposure scenarios 1-3 as identified in the previous Section, were based on analytical results for samples of process water, sludge and evaporative salts collected from the ponds. Specifically, the radiological data in Table 1 were compiled for this dose assessment.

Table 1: Relevant media concentration data.

Sample	Location	Sample Date	U-nat (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Ra-228 (pCi/g)
Salt Crust	EP1	6/14/2017	161	16.6	20.1	-
Sludge	W Coll Pond	9/24/2015	2566	0.5	-	-
Sludge	EP1	9/24/2015	-	-	32.5	-

Sample	Location	Sample Date	U-nat (mg/L)	Th-230 (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)
Water	E Coll Pond	8/5/2015	14.4	3.8	10	3.7
Water	EP1	8/17/2010	538	792	138	4.7
Water	EP2	8/17/2010	68	45	76	1.6
Water	EP3A	8/16/2011	362	893	84	11.9
Water	EP3B	8/7/2012	575	826	82	73.9
Water	W Coll Pond	8/4/2014	20	0.09	1.4	0.8

For water samples, additional data are available, but samples with among the highest reported concentrations were selectively included in the table above. The concentration values actually used as the source term for the dose assessment were the maximum values in the above table for each type of media (water, sludge and salt crust), and these values are shown in Table 2.

Table 2: Assumed source term concentrations.

Media	Conc. Units	U-nat	Th-230	Ra-226	Ra-228
Evaporative Salts	pCi/g	161	16.6	20.1	-
Pond Sludge	pCi/g	2566	0.5	32.5	-
Process Water	mg/L	575	-	-	-
Process Water	pCi/L	-	893	138	73.9

4. Intakes

INGESTION

For the process water ingestion pathway, the activity intake for the ith radionuclide (in μCi) from accidental ingestion of 1 liter of process water was calculated as follows:

U-nat:

$$Ingestion\ Intake\ (\mu Ci) = \left(Conc_i \frac{mg}{L}\right)\left(SA \frac{\mu Ci}{mg}\right)(1\ L)$$

Where:

Conc$_i$ = source term concentration of U-nat (from Table 2)

SA = specific activity of U-nat [0.000691 μCi/mg (ORISE, 2017)]

Th-230, Ra-226 and Ra-228:

$$Ingestion\ Intake\ (\mu Ci) = \left(Conc_i \frac{pCi}{L}\right)\left(\frac{\mu Ci}{1 \times 10^6\ pCi}\right)(1\ L)$$

Where:

*Conc*ᵢ = source term concentration of Th-230, Ra-226 or Ra-228 (from Table 2)

The resulting intake for each radionuclide is shown in Table 3.

Table 3: Assumed intake of each radionuclide from ingestion of 1 liter of process water.

U-nat			Th-230		Ra-226		Ra-228	
Process Water (mg/L)	Spec. Activity (µCi/mg)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)
575	6.91E-04	0.397	893	8.9E-04	138	1.4E-04	73.9	7.4E-05

INHALATION

For the inhalation pathway, mass-based and activity-based source term concentrations from Table 2 were converted into airborne activity concentrations using the applicable equation below. The assumed source-to-air mass loading for inhalation was 0.0001 g/m³ for releases of dry sludge to air [this is the default value for releases from soil to air as given in the RESRAD-OFFSITE computer code (ANL, 2013)]. For releases of evaporative salts to air, or process water to airborne aerosols via the turbo mister, the mass loading was assumed to be an order of magnitude higher (0.001 g/m³) based on opacity criteria described in Table 4.

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{mg}{kg}\right)\left(\frac{kg}{1000\ g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{g}{1000\ mg}\right)\left(SA \frac{\mu Ci}{g}\right)\left(\frac{m^3}{10^6\ mL}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{pCi}{g}\right)\left(\frac{\mu Ci}{10^6\ pCi}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{mg}{L}\right)\left(\frac{L}{1000\ cm^3}\right)\left(\rho \frac{cm^3}{g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)\left(SA \frac{\mu Ci}{mg}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{pCi}{L}\right)\left(\frac{L}{1000\ cm^3}\right)\left(\rho \frac{cm^3}{g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)\left(\frac{\mu Ci}{10^6\ pCi}\right)$$

Where:

*Conc*ᵢ = source term concentration (from Table 2)
ML = mass loading (g/m³)
SA = specific activity of U-nat [0.691 µCi/g (ORISE, 2017)]

Table 4: Mass loading assumption criteria.

Airborne mass loading (g/m^3)	Visibility (miles)	Comment
0.00001	50	Very clear
0.00002	25	NM Average
0.0001	5	Hazy; RESRAD default
0.00015	3	24-hr PM-10 standard
0.001	0.5	Smoke from nearby fire

The resulting activity concentrations in air were assumed as shown in Table 5. Intakes via inhalation were based on a breathing rate of 20 L/minute and an exposure occupancy time of 200 hours per year (10% occupational occupancy) as shown in the dose calculations presented in Section 5.

Table 5: Calculated airborne concentrations for the inhalation dose pathway.

Media	Mass Loading (g/m3)	U-nat (µCi/mL)	Th-230 (µCi/mL)	Ra-226 (µCi/mL)	Ra-228 (µCi/mL)
Evaporative Salts	0.001	1.6E-13	1.7E-14	2.0E-14	-
Pond Sludge	0.0001	2.6E-13	5.0E-17	3.3E-15	-
Water	0.001	4.0E-13	8.9E-16	1.4E-16	7.4E-17

5. Radiological Dose

The calculated dose for each source term radionuclide and occupational exposure pathway scenario were based on the Annual Limit on Intake (ALI) values or Derived Air Concentration (DAC) for each radionuclide as given in 10 CFR 20 Appendix B (Table 6). Both non-stochastic ALIs (NALI) for the committed dose equivalent (CDE) to organs or tissues, and stochastic ALIs (SALI) for the effective committed dose equivalent (CEDE) to the whole body, were considered. DAC values for the radionuclides considered are given in 10 CFR 20 Appendix B in terms of the CEDE only.

Table 6: Relevant occupational intake limits from 10 CFR 20 Appendix B.

	U-nat (µCi)	Th-230 (µCi)	Ra-226 (µCi)	Ra-228 (µCi)
$NALI_{ingest\,(d)}$	10	4	2	2
$SALI_{ingest\,(d)}$	20	9	5	4
$NALI_{inhal\,(d)}$	1	0.006	-	-
$SALI_{inhal\,(d)}$	2	0.02	0.6	1
	U-nat (µCi/mL)	**Th-230 (µCi/mL)**	**Ra-226 (µCi/mL)**	**Ra-228 (µCi/mL)**
DAC (day)	5E-10	-	-	-
DAC (week)	3E-10	3E-12	3E-10	5E-10
DAC (year)	2E-11	6E-12	-	-

INGESTION PATHWAY

The applicable occupational dose limits for CDE to organs/tissues and CEDE for the whole body are 50 rem/yr and 5 rem/yr respectively (10 CFR 20.1201). The ALI and DAC values given in Table 6 equate to these annual dose limits. For the ingestion pathway, the CDE (critical organ = bone) and CEDE values for each radionuclide based on the calculated intake assumptions (Table 3) and ALI values (Table 6), were individually calculated and summed to estimate total internal dose from ingestion as follows:

$$CDE = \sum_{n=1}^{i}(Intake_i\ \mu Ci)\left(NALI_i \frac{rem}{\mu Ci}\right)\left(\frac{1000\ mrem}{rem}\right)$$

$$CEDE = \sum_{n=1}^{i}(Intake_i\ \mu Ci)\left(SALI_i \frac{rem}{\mu Ci}\right)\left(\frac{1000\ mrem}{rem}\right)$$

Where:
$Intake_i$ = intake (in µCi) of the i^{th} radionuclide (from Table 3)
$NALI_i$ = Non-stochastic ALI for i^{th} radionuclide (from Table 6)
$SALI_i$ = Stochastic ALI for i^{th} radionuclide (from Table 6)

The resulting individual and total internal doses by radionuclide and dose quantity are given in Table 7.

Table 7: Estimated internal occupational dose from accidental ingestion of 1 L of process water.

Internal Dose Quantity	U-nat Dose (mrem)	Th-230 Dose (mrem)	Ra-226 Dose (mrem)	Ra-228 Dose (mrem)	Total Dose (mrem)
CDE (bone)	1987	11	3	2	2003
CEDE	99	0	0	0	100

The conservatively estimated internal doses expected from accidental ingestion of 1 liter of process water are a small fraction of the annual non-stochastic CDE limit (50,000 mrem) or stochastic CEDE limit (5,000 mrem/yr) for workers as specified in 10 CFR 20.1201. These doses are unlikely to ever occur as even if a worker fell into a pond, it is unlikely that the worker would ingest a full liter of process water. These results can be scaled according to actual intake, if known, though the source term may differ from the maximal values used for this assessment. For example, if only 1 mL of process water with concentrations equivalent to those assumed in this assessment were accidentally ingested, the resulting CDE and CEDE values would be on the order of 2 mrem and 0.1 mrem respectively.

From an As Low As Reasonably Achievable (ALARA) perspective, analysis of routine samples of process water in each pond should include U-nat, Th-230, Ra-226 and Ra-228 on at least a semiannual basis in order to have recent radiological concentration data available should a worker accidentally ingest any of this water at the Site. In the event of an accidental ingestion of process water, a urine bioassay sample should be collected about 36 hours after the intake and analyzed for uranium. The analytical result should be evaluated relative to the 10 mg/week limit to protect against toxicity effects for soluble uranium as indicated in 10 CFR 20.1201(e). Where possible, any additional protocols that would minimize the potential for workers to fall into a pond would be consistent with ALARA principles, and should be included in the relevant standard operating procedures (SOP) or radiation work permit (RWP) for any work to be performed on or near the collection or evaporation ponds.

INHALATION PATHWAY

It would be unrealistic to assume that any worker could be continuously exposed to the calculated airborne radionuclide concentrations assumed in Table 5 (Section 4) while working near the collection or evaporation ponds. It was instead conservatively assumed that on an annual basis, a worker is exposed to these airborne concentrations 10% of the time (200 hours out of a total of 2,000 work hours per year). Based on this assumption, the annual CEDE from inhalation of soluble and insoluble forms of these radionuclides (where applicable) based on the calculated airborne concentration assumptions (Table 5) and DAC values (Table 6), were individually calculated and summed to estimate total internal dose from inhalation as follows:

$$CEDE = \sum_{n=1}^{i} \left(AC_i \frac{\mu Ci}{mL}\right)\left(\frac{DAC_i}{\mu Ci/_{mL}}\right)(200\ hrs)\left(\frac{2.5\ mrem}{DAC - hr}\right)$$

Where:
AC_i = Airborne concentration for the i^{th} radionuclide (from Table 4)
DAC_i = Derived air concentration for i^{th} radionuclide (from Table 6)

The resulting individual and total internal doses by radionuclide source and solubility class are given in Table 8.

Table 8: Estimated internal occupational dose from inhalation of airborne radionuclides from the ponds.

SOLUBLE INHALATION DOSE

Media	CEDE U-nat (mrem)	CEDE Th-230 (mrem)	CEDE Ra-226 (mrem)	CEDE Ra-228 (mrem)	CEDE Total (mrem)
Evaporative Salts	0.3	2.8	0.03	-	3.1
Pond Sludge	0.4	0.01	0.01	-	0.4
Water	0.7	0.1	0.0002	0.0001	0.8

INSOLUBLE INHALATION DOSE

Media	CEDE U-nat (mrem)	CEDE Th-230 (mrem)	CEDE Ra-226 (mrem)	CEDE Ra-228 (mrem)	CEDE Total (mrem)
Evaporative Salts	4.0	1.4	-	-	5.4
Pond Sludge	6.4	0.004	-	-	6.4
Water	9.9	0.1	-	-	10.0

The conservatively estimated internal doses from incidental inhalation of airborne radionuclides by solubility class from each potential source (evaporative salts, sludge and liquid aerosols from the turbo misters) and are a very small fraction of the stochastic CEDE limit (5,000 mrem/yr) for workers as specified in 10 CFR 20.1201. These dose estimates are conservative (erring in favor of higher doses) as it is unlikely that workers would consistently be exposed to such airborne concentrations for 200 hours per year.

From an ALARA perspective, analysis of routine samples of process water in each pond should include U-nat, Th-230, Ra-226 and Ra-228 on at least a semiannual basis in order to have recent radiological concentration data available for use in future dose assessments in the event that conditions change. Although these estimated doses are low and do not warrant routine air monitoring, non-routine air monitoring could be warranted under a RWP for non-routine activities at the discretion of the Radiation Safety Officer (RSO) (e.g. replacing a pond liner, cleaning out dried sludge from collection ponds, etc.).

6. Conclusions

The results of this dose assessment indicate that potential occupational exposures to radionuclides from working on or near the collection or evaporation ponds are unlikely to result in significant radiological doses from accidental ingestion or inhalation exposure pathways. The conservatively calculated dose estimate for each exposure scenario is well below 10% of applicable regulatory dose limits. The concentrations of U-nat, Th-230, Ra-226 and Ra-228 in process water should be analyzed on a semiannual basis to maintain recent data for future dose assessments as needed to ensure that exposures and doses will be kept ALARA. While routine air monitoring for work performed near collection or evaporation ponds is not warranted based on this dose assessment, non-routine work activities involving potential for ingestion or inhalation intakes of evaporative salts, sludge or process water may be warranted under a RWP at the discretion of the RSO.

7. References

Oak Ridge Institute for Science and Education (ORISE). 2017. Radiological and Chemical Properties of Uranium. USNRC ADAMS Accession No. ML11227A233.
URL: https://www.nrc.gov/docs/ML1122/ML11227A233.pdf (accessed 8-6-17).