NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Uranium Open Pit Mining and Milling, Operations

Reference Flow: 1 kg of Uranium Yellowcake (U_3O_8)

Brief Description: This process includes open pit mining, ore removal, and milling operations at the Ranger Mine in Australia and currently operating mines in Saskatchewan, Canada.

Section I: Meta Data

Geographical Coverage: Australia, Canada **Region:** NA

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

Process Scope: Cradle-to-Gate Process (CG)

Allocation Applied: No

Completeness: All Relevant Flows Captured

Flows Aggregated in Data Set:

☑ Process ☑ Energy Use ☑ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☑ Greenhouse Gases	☑ Criteria Air	☑ Other
Releases to Water:	☑ Inorganic	☑ Organic Emissions	☐ Other
Water Usage:	☑ Water Consumption	☑ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Electric_in	*[MWh] Electricity used in operation of the open pit mine and mill.*
PM	*[kg] PM emissions from excavation activities*
E_w_radioactive	*[MWh] Electricity used in operation of the open pit mine and mill.*
E_w_Al	*[kg] Emission output to freshwater*

E_w_Ammonia	*[kg] Emission output to freshwater*
E_w_Arsenic	*[kg] Emission output to freshwater*
E_w_Cadmium	*[kg] Emission output to freshwater*
E_w_Chromium	*[kg] Emission output to freshwater*
E_w_Copper	*[kg] Emission output to freshwater*
E_w_Mercury	*[kg] Emission output to freshwater*
E_w_Iron	*[kg] Emission output to freshwater*
E_w_Lead	*[kg] Emission output to freshwater*
E_w_Nickel	*[kg] Emission output to freshwater*
E_w_Selenium	*[kg] Emission output to freshwater*
E_w_Silver	*[kg] Emission output to freshwater*
E_w_Zinc	*[kg] Emission output to freshwater*
E_w_Uranium	*[kg] Emission output to freshwater*

Tracked Input Flows:

Diesel [Crude oil products]	*[Technosphere] Diesel used in process*
Sulfuric Acid	*[Technosphere] Sulfuric Acid used in milling*
Sodium Chlorate	*[Technosphere] Sodium Chlorate used in milling*
Ammonia	*[Technosphere] Ammonia used in milling*
Lime	*[Technosphere] Lime used in milling*
Ammonium Nitrate	*[Technosphere] Ammonium Nitrate used in explosives*
Fuel Oil	*[Technosphere] Fuel Oil used in explosives*
Thermal Energy from Diesel Combusted in Construction Vehicle	*[Technosphere] Thermal Energy from construction vehicles*
Thermal Energy from Diesel Combusted in Industrial Boiler	*[Technosphere] Thermal Energy from industrial boiler*
Power [Electric power]	*[Technosphere] electricity needed for operations*

Tracked Output Flows:

Uranium Yellowcake (U3O8) [Energy Carrier]	*Reference Flow*
Uranium Tailings [Solid Waste]	*Tailings (low level waste) from mining and milling of uranium*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_Open_Pit_Uranium_Mine_2010.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this process covers the production of uranium yellowcake during operation of an open pit uranium mine, from resource extraction to the transportation from the mill to the conversion facility. The process is based on the reference flow of 1 kg of uranium yellowcake, as described below, and in **Figure 1.** Considered are the consumption of electricity, consumption of diesel, chemicals needed during extraction, water usage, and natural gas consumption.

Boundary and Description

Operations for the open pit uranium mine are based primarily upon the operation of the Ranger Mine in Australia. The Ranger Mine produces twelve percent of the world's uranium with an annual production of 5.91 gigagrams of yellowcake in 2005 (Leeuwen 2007). Energy inputs for the Ranger Mine were reported by Storm van Leeuwen (2007) as electric and thermal energy demands for mining and milling activities.

Water emissions were not publically available for the Ranger Mine, thus, water quality data was taken from the Saskatchewan Surface Water Quality Objectives. These emissions targets must be met by the four operating uranium mines (SSWQO 2004). According to a planning description of Cluff Lake uranium mine, water emissions from the mine are very near SSWQO targets (Accott 2004).

With the exception of ore removal emissions, PM Emissions from operation of open pit uranium mines are approximated by the activities of surface coal mines. The substitution overcomes a data limitation with a surrogate data set considered largely similar to open pit uranium mine operation. It is noted, however, that uranium is extracted from hard rock and thus is expected to require considerably more blasting energy, generating more PM, than surface coal mining. Therefore the "number of blasts per week is doubled from the 5 blasts per week averaged for a coal mine. Considerations for the blasting, overburden bulldozing, and dragline removal of overburden were considered in the calculation.

Radioactive emissions to the soil and water were calculated from a technical radiological mining emissions report from the United States EPA. The document focused on mining impacts and how to reclaim the land after the mining activities are completed. Emissions to soil include arsenic, iron, lead, mercury, selenium, thallium, and vanadium.

Water use for the facility is modeled as 0 withdrawal and discharge. This is because the Ranger facility is located in a tropical location with a large amount of rainfall. The facility water demands are met by recycling process water and using stored rainwater. All water is stored in on-site ponds so any water that evaporates has essentially returned to the source. Water is also discharged to nearby sites when there are excessive levels of rain. This water is treated, but the facility has essentially only acted as a waypoint for rainfall, so is not given credit for the water discharges (ERA, 2013).

Figure 1 provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, upstream emissions associated with the production and delivery of secondary inputs (raw materials, energy inputs) are accounted for outside of the boundary of this unit process.

Figure 1: Unit Process Scope and Boundary

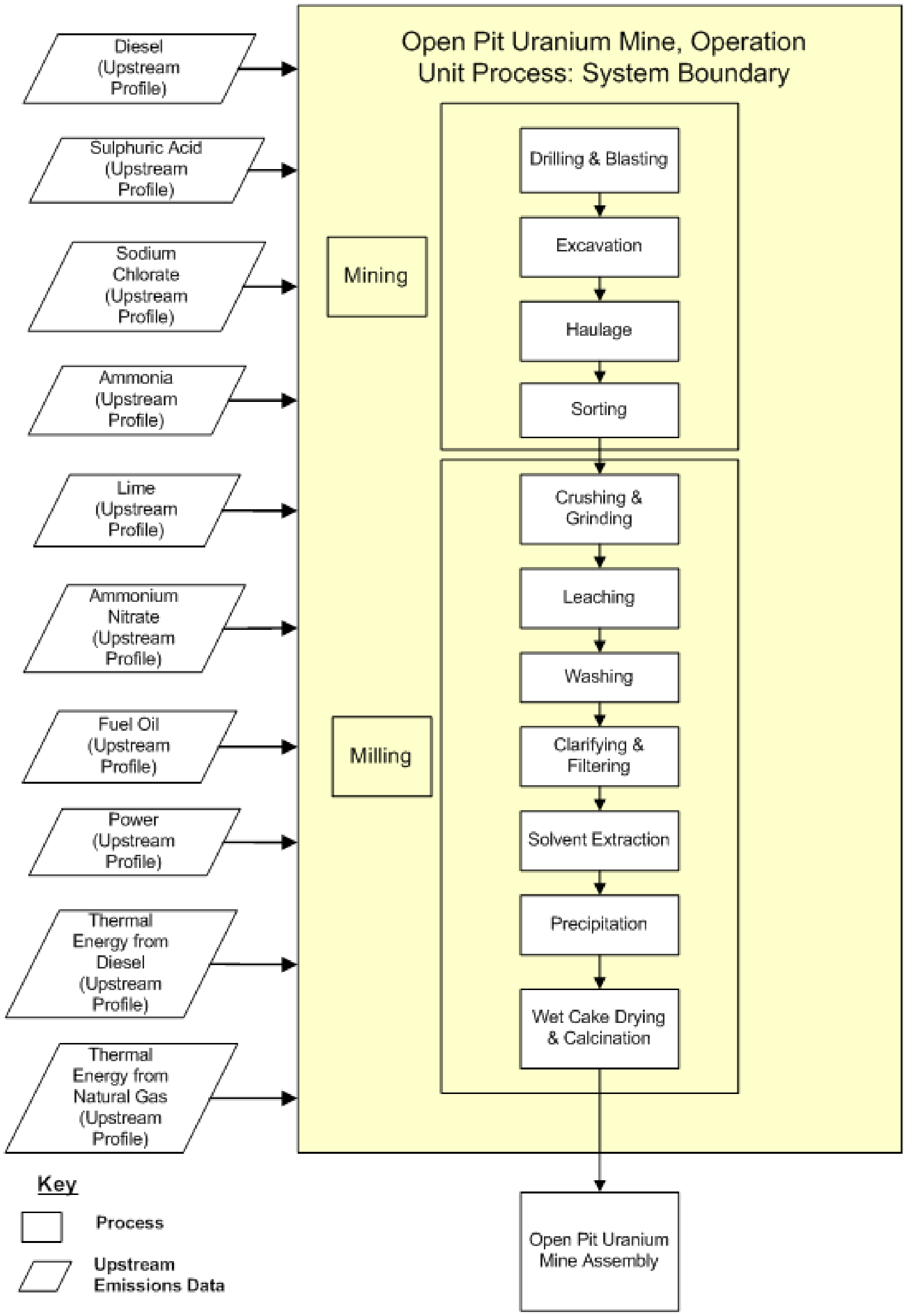
Open Pit Uranium Mine, Operation
Unit Process: System Boundary
Diesel (Upstream Profile)
Sulphuric Acid (Upstream Profile)
Sodium Chlorate (Upstream Profile)
Ammonia (Upstream Profile)
Lime (Upstream Profile)
Ammonium Nitrate (Upstream Profile)
Fuel Oil (Upstream Profile)
Power (Upstream Profile)
Thermal Energy from Diesel (Upstream Profile)
Thermal Energy from Natural Gas (Upstream Profile)
Mining
Drilling & Blasting
Excavation
Haulage
Sorting
Milling
Crushing & Grinding
Leaching
Washing
Clarifying & Filtering
Solvent Extraction
Precipitation
Wet Cake Drying & Calcination
Open Pit Uranium Mine Assembly
Key
Process
Upstream Emissions Data

Table 1: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Diesel [Crude oil products]	3.40E+00	kg/kg yellowcake
Sulfuric Acid	1.54E+01	kg/kg yellowcake
Sodium Chlorate	4.65E-01	kg/kg yellowcake
Ammonia	1.83E-01	kg/kg yellowcake
Lime	4.41E+00	kg/kg yellowcake
Ammonium Nitrate	3.66E-01	kg/kg yellowcake
Fuel Oil	2.34E-02	kg/kg yellowcake
Thermal Energy from Diesel Combusted in Construction Vehicle	2.10E+01	MJ/kg yellowcake
Thermal Energy from Diesel Combusted in Industrial Boiler	2.79E+02	MJ/kg yellowcake
Power [Electric power]	1.53E-02	MWh/kg yellowcake
Outputs		
Uranium Yellowcake (U3O8) [Energy Carrier]	1.00E+00	kg/ kg yellowcake
Uranium Tailings [Solid Waste]	1.94E+03	kg/ kg yellowcake
Dust (PM10) [Particles to air]	3.62E-02	kg/ kg yellowcake
Radionuclide [Radioactive emissions to water]	0.00E+00	Bq/ kg yellowcake
Radionuclide [Radioactive emissions to soil]	1.15E+06	Bq/ kg yellowcake
Radionuclide [Radioactive emissions to air]	3.51E+00	Bq/ kg yellowcake
Arsenic (+V) [Heavy metals to industrial soil]	1.33E+00	kg/ kg yellowcake
Iron [Heavy metals to industrial soil]	2.38E+03	kg/ kg yellowcake
Lead (+II) [Heavy metals to industrial soil]	9.51E+00	kg/ kg yellowcake
Mercury (+II) [Heavy metals to industrial soil]	2.46E-02	kg/ kg yellowcake
Selenium [Heavy metals to industrial soil]	1.58E-01	kg/ kg yellowcake
Thallium [Heavy metals to industrial soil]	1.15E+00	kg/ kg yellowcake
Vanadium (+III) [Heavy metals to industrial soil]	7.26E+00	kg/ kg yellowcake
Aluminum (+III) [Inorganic emissions to fresh water]	2.54E-05	kg/ kg yellowcake
Ammonium / ammonia [Inorganic emissions to fresh water]	5.86E+01	kg/ kg yellowcake
Arsenic [Heavy metals to fresh water]	1.27E-06	kg/ kg yellowcake
Cadmium (+II) [Heavy metals to fresh water]	2.54E-08	kg/ kg yellowcake
Chromium (+VI) [Heavy metals to fresh water]	2.54E-07	kg/ kg yellowcake
Copper [Heavy metals to fresh water]	1.02E-06	kg/ kg yellowcake
Mercury (+II) [Heavy metals to fresh water]	6.60E-09	kg/ kg yellowcake
Iron [Heavy metals to fresh water]	7.61E-05	kg/ kg yellowcake
Lead [Heavy metals to fresh water]	1.78E-06	kg/ kg yellowcake
Nickel [Heavy metals to fresh water]	2.54E+01	kg/ kg yellowcake
Selenium [Heavy metals to fresh water]	2.54E-07	kg/ kg yellowcake
Silver [Heavy metals to fresh water]	2.54E-09	kg/ kg yellowcake
Zinc (+II) [Heavy metals to fresh water]	7.61E-06	kg/ kg yellowcake

Uranium [Heavy metals to fresh water]	7.61E+01	kg/ kg yellowcake

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

Accott 2004 — Acott, G. and Polloc, B, 2004.. Planning for Decommissioning at the Cluff Lake Uranium Mine in Northwestern Saskatchewan. 16th Int'l Conference, Society for Ecological Restoration, August 24-26, 2004, Victoria, Canada http://www.ser.org/serbc/pdf/Planning_for_decommissioning_the_Cluff_Lake_Uranium_Mine_in_northwestern_Saskatchewan.pdf (Accessed July 28, 2010).

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Section III: Document Control Information

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