NETL Life Cycle Inventory Data
Process Documentation File

Process Name: In-Situ Leach Mining and Processing, Uranium

Reference Flow: 1 kg of Yellowcake (U3O8)

Brief Description: This unit process includes in-situ mining of uranium and assocaited processing activities, including milling and groundwater remediation. Data are based primarily on U.S. in-situ leach (ISL) mines.

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

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

Allocation Applied: No

Completeness: Individual 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:

NG_Use	*[kg NG/kg U3O8] Adjustable parameter; amount of natural gas used per kg of yellowcake; see also Assumption [1]*

Tracked Input Flows:

Power [Electric power]	*[Technosphere] Electricity use from mining/processing*
Natural gas USA [Natural gas (resource)]	*[Technosphere] Natural gas use for processing plant drying*
Carbon dioxide [Renewable resources]	*[Technosphere] Carbon dioxide used for lixiviant preparation*
Oxygen	*[Technosphere] Oxygen used for lixiviant preparation*
Sodium Carbonate	*[Technosphere] Soda ash used for lixiviant preparation and resin elution*
Sodium chloride (rock salt) [Non renewable resources]	*[Technosphere] Sodium salt used for lixiviant preparation and resin elution*
Chlorine	*[Technosphere] Chlorine used for lixiviant preparation*
Hydrogen Peroxide	*[Technosphere] Hydrogen peroxide used for elution and precipitation circuit at processing plant*
Ion Exchange Resin	*[Technosphere] Ion exchange resin used for isolation of yellowcake at processing plant*

Tracked Output Flows:

Yellowcake (U3O8) [Non renewable resource]	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage1_O_InSituLeachMining_Processing_Uranium_2010.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

Goal and Scope

The scope of this unit process models an in-situ leach (ISL) uranium mine, along with a processing, or milling, facility. The modeled facility is based on data available for several existing and proposed ISL facilities located in the US, as well as existing facilities located in Australia. These facilities have varying capacities, and due to the nature of ISL mining, wherein a single 'mine' may include many drilling sites that are applied over time, a mine production capacity was not specified for this process. The processing facility is assumed to be located on site, in close proximity to ISL mining operations. Groundwater remediation, which occurs following completion of yellowcake extraction, is also included. The process is based on the reference flow of 1 kg of yellowcake (U_3O_8), as described below and shown in **Figure 1**.

This unit process is used under Life Cycle (LC) Stage #1 as one of several uranium mining options available to the modeler, and is modeled in parallel with those other mining and processing operations. Output from the unit process is tracked through the various stages of uranium transport, refining, and production that occur under LC Stage #1.

Boundary and Description

This unit process accounts for electricity use for mining, milling, and remediation; natural gas use for milling, chemical use for the injected lixiviant and elution/precipitation phases; air emissions due to natural gas usage, fugitive dust from trucks, and emissions from uranium concentrating and drying; solid waste including mine tailings; water use during mining/milling operations and during remediation; and long term water quality effects, following completion of the groundwater remediation process. **Figure 1** provides an overview of the boundary of this unit process.

Electricity use for mining, milling, and remediation is calculated based on ISL mining and milling data available for mines located in Australia and Kazakhstan (World Nuclear Association 2009), and includes all operations at the mining and processing facilities, totaling 0.0220 MWh electricity per kg yellowcake produced, on average. Groundwater remediation, which is required following completion of mining activity in order to ensure that groundwater contamination with uranium is minimized, also requires electricity to run pumps and drive reverse osmosis or other remediation activities. This results in an additional electricity use of 0.0385 MWh/kg yellowcake (US NRC 2009a).

This ISL mining and processing unit process includes a single adjustable process parameter (NG_Use), which was included due to uncertainty associated with the amount of natural gas used at the processing facility, for milling operations. All available data collected for this parameter were available from a single ISL mining site, located in Australia (World Nuclear Association 2009). However these data were substantially variable on a month-to-month basis. The proposed default value for this parameter, 120.9 kg natural gas per kg yellowcake, is the average of available data, while the suggested minimum and maximum are 48.38 and 241.9 kg/kg yellowcake, respectively.

ISL mining and processing requires the use of a substantial amount of chemicals. Various chemicals are mixed and injected into the subsurface, in order to dissolve and mobilize uranium that is trapped in the underground formation. This chemical composition of this solution, which is termed *lixiviant*, varies widely based on formation characteristics and environmental regulatory constraints of overseeing agencies. However, most ISL mines located in the US use a lixiviant that contains a mixture of carbon dioxide, oxygen, soda ash, sodium chloride (e.g., table salt), and chlorine as an anti-fouling agent. During the elution/precipitation circuit, yellowcake is separated from other leached constituents and lixiviant via ion exchange resin. Elution of the resin and precipitation of yellowcake from the eluate involve the use of hydrogen peroxide, soda ash, and sodium chloride. Ion exchange resin is reusable, but must be replaced periodically, resulting in a total ion exchange resin consumption rate of 0.360 kg resin per kg yellowcake produced.

Air emissions are quantified based on fugitive dust emissions from operations traffic (trucks and automobiles at the ISL site), radon-222 emissions associated with yellowcake drying, and natural gas fired boiler emissions that result from yellowcake processing. Air emissions from natural gas fired boilers is calculated based on the amount of natural gas required for uranium processing (discussed previously), and based on a natural gas fired boiler emissions profile calculator that is maintained by the Illinois State EPA (Illinois EPA 2010). The emissions profile calculator generates emission factors based on federal and state emissions regulations and requirements.

Solid waste from the ISL process includes radioactive mine tailings, which require remediation. Mine tailings are generated at a rate of 0.107 kg/kg yellowcake (USNRC 2009a). Other uncontaminated solid wastes generated on site amount to 0.360 kg/kg yellowcake, while low level hazardous wastes (primarily lubricant oil and spent batteries) amount to 8.82E-05 kg/kg yellowcake (USNRC 2009a).

Water is required during mining and processing, and also during remediation. At the ISL mine, a small portion of mine bleed water containing extracted uranium and other materials, is injected into a deep well for disposal. This is done to maintain a negative groundwater gradient, such that migration of groundwater away from mining operations is minimized, reducing the chances for contamination of adjacent aquifers. This amounts to approximately 70.2 kg water per kg yellowcake. During the elution/precipitation circuit, water is consumed at a rate of approximately 224 kg/kg yellowcake. Finally, water is also consumed during groundwater remediation operations, which accounts for an additional 87.0 kg water/kg yellowcake (USNRC 2009a)

No surface water runoff is permitted from the ISL mining and processing site, at least under US regulations. Therefore, no surface water quality contamination is anticipated due to ISL mining. However, ISL mining can degrade groundwater. A study produced by the US Geologic Survey (USGS 2009) indicated potential for increased groundwater contamination following ISL operations, even following remediation activities. Increases in pollutant levels were consistently reported for groundwater concentrations of arsenic, selenium, uranium, sulfate, manganese, molybdenum, and total nitrogen.

Table 1 summarizes the relevant properties and assumptions used to estimate energy requirements, as well as other key components of the ISL mining and processing unit process. **Table 2** provides a summary of modeled input and output flows. Additional detail regarding input and output flows, including calculation methods, is contained in the associated DS.

Figure 1: Unit Process Scope and Boundary

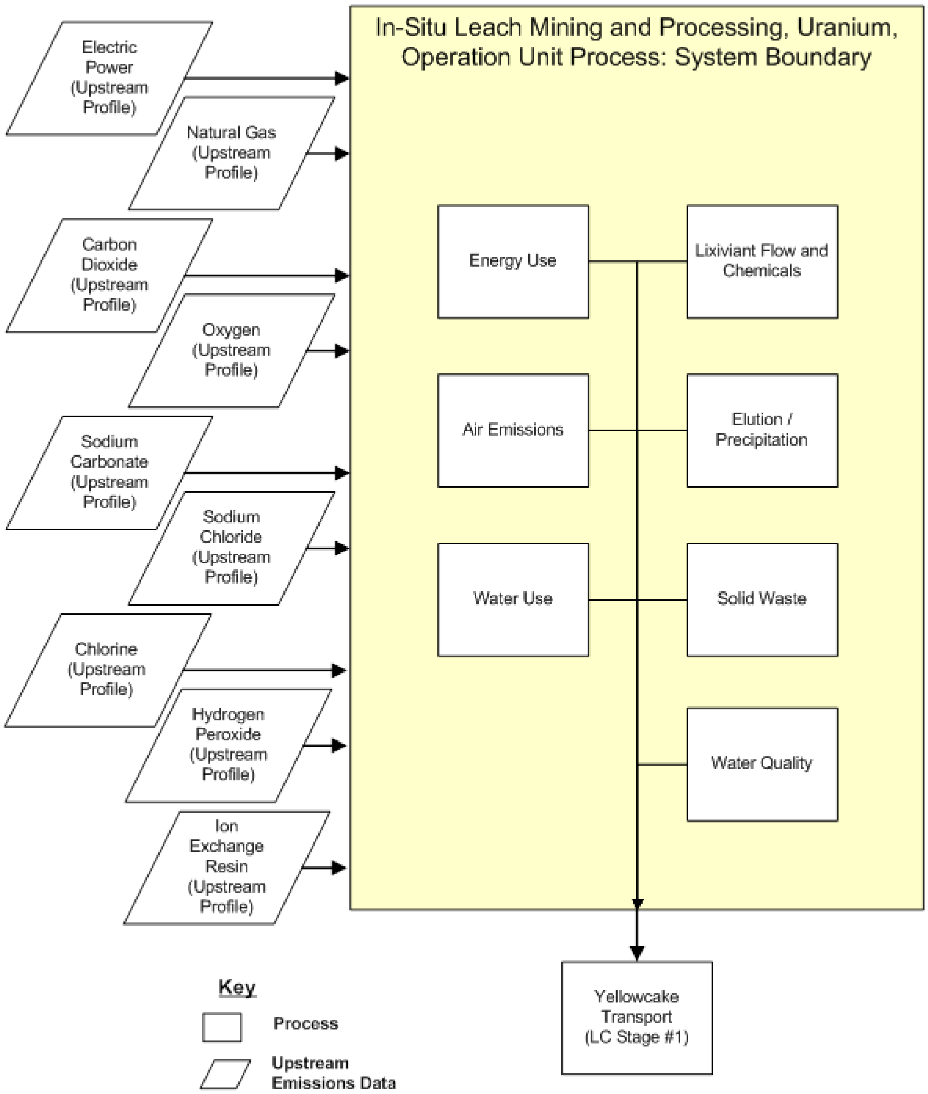

Table 1: Properties of ISL Mining and Processing

Item	Value	Reference
Natural Gas Use, for Processing (Milling) (kg natural gas/kg yellowcake)	120.9 (suggested) 48.38 (min) 241.9 (max)	World Nuclear Association 2009
Electricity Use, Mining and Processing (MWh/kg yellowcake)	0.0220	World Nuclear Association 2009
Aquifer Remediation Period (years)	4.25	USNRC 2009a
Ion Exchange Resin Replacement (kg resin/kg yellowcake)	0.360	USNRC 2009a
Radon-222 Emissions from Yellowcake Drying (Ci/kg yellowcake)	5.33E-04	USNRC 2009a

Table 2: Unit Process Input and Output Flows

Flow Name	Value	Units (Per Reference Flow)
Inputs		
Power [Electric power]	3.85E-02	MWh/kg U_3O_8
Natural gas USA [Natural gas (resource)]	1.21E+02	kg/kg U_3O_8
Carbon dioxide [Renewable resources]	9.10E+00	kg/kg U_3O_8
Oxygen	1.90E+00	kg/kg U_3O_8
Sodium Carbonate	1.81E+01	kg/kg U_3O_8
Sodium chloride (rock salt) [Non renewable resources]	3.85E+01	kg/kg U_3O_8
Chlorine	2.28E-02	kg/kg U_3O_8
Hydrogen Peroxide	2.00E-01	kg/kg U_3O_8
Ion Exchange Resin	3.60E-01	kg/kg U_3O_8
Water (ground water) [Water]	3.11E+02	kg/kg U_3O_8
Outputs		
Yellowcake (U3O8) [Non renewable resource]	1.00E+00	kg
Carbon dioxide [Inorganic emissions to air]	3.45E-01	kg/kg U3O8
Methane [Organic emissions to air (group VOC)]	6.62E-06	kg/kg U3O8
Nitrous oxide (laughing gas) [Inorganic emissions to air]	6.33E-06	kg/kg U3O8
Nitrogen oxides [Inorganic emissions to air]	2.88E-04	kg/kg U3O8
Sulphur dioxide [Inorganic emissions to air]	1.73E-06	kg/kg U3O8
Carbon monoxide [Inorganic emissions to air]	2.42E-04	kg/kg U3O8
NMVOC (unspecified) [Group NMVOC to air]	1.58E-05	kg/kg U3O8
Dust (unspecified) [Particles to air]	1.24E-02	kg/kg U3O8
Radon (Rn222) [Radioactive emissions to air]	5.33E-04	Ci/kg U3O8
Arsenic (+V) [Heavy metals to fresh water]	2.03E-04	kg/kg U3O8
Selenium [Heavy metals to fresh water]	1.18E-04	kg/kg U3O8
Uranium [Radioactive emissions to fresh water]	2.24E-03	kg/kg U3O8
Sulfate	8.22E+00	kg/kg U3O8
Nitrogen [Inorganic emissions to fresh water]	2.47E-01	kg/kg U3O8
Manganese (+II) [Heavy metals to fresh water]	9.57E-04	kg/kg U3O8
Molybdenum [Heavy metals to sea water]	7.05E-03	kg/kg U3O8
Waste (solid) [Waste for disposal]	3.60E-01	kg/kg U3O8
Radioactive tailings [Radioactive waste]	1.07E-01	kg/kg U3O8
Water (wastewater) [Water]	8.70E+01	kg/kg U3O8

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

Embedded Unit Processes

None.

References

Illinois EPA 2010	Illinois Environmental Protection Agency. (2010). *Calculate Emissions.* http://www.epa.state.il.us/air/aer/calculate/boiler_ng.html (Accessed July 28, 2010)
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USNRC 2009a	United States Nuclear Regulatory Commission. 2009. *Environmental Impact Statement for the Moore Ranch ISR Project in Campbell County, Wyoming; Supplement to the General Environmental Impact Statement for In-Situ Leach Milling Facilities; Draft Report for Comment.* http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1910/s1/ (Accessed August 25, 2010)
World Nuclear Association 2009	World Nuclear Association. 2009. *In Situ Leach (ISL) Mining of Uranium.* http://www.world-nuclear.org/info/inf27.html (Accessed July 15, 2010)

Section III: Document Control Information

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