RADIOLOGICAL IMPACT ASSESSMENT IN BAGJATA URANIUM DEPOSIT: A CASE STUDY

By

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Abstract

The uranium ore mining facility, in addition to the desirable product, produces wastes in the form of environmental releases or effluents to air, water and soil. The toxicological and other (non-radiological) effects are generally addressed in EIA / EMP studies as per MOEF guidelines. Since the uranium ore is radioactive, it is desirable to conduct a study on radiological effects considering the impacts of radiological releases to the environment.

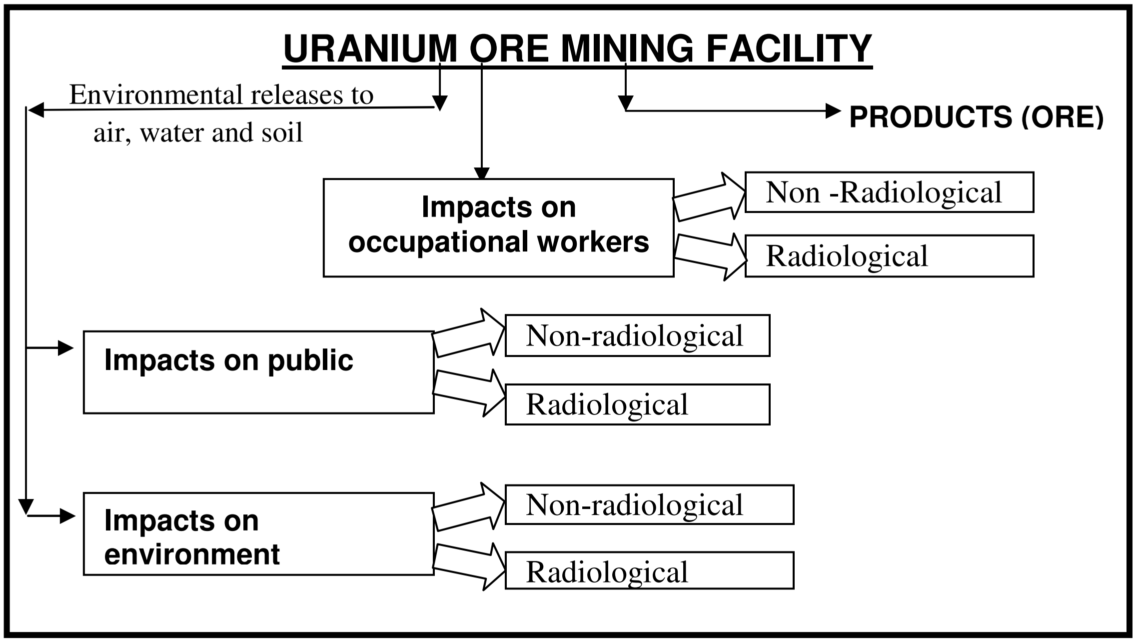
Before undertaking the commercial mining operations at Bagjata uranium deposit in the Singhbhum east district of Jharkhand, pre-operational radiological base line data were generated and a separate study on radiological impact on various environmental matrices was conducted inline with the International Atomic Energy Agency's laid out guidelines. The paper describes the philosophy of such studies and the findings that helped in formulating a separate environmental management plan.

INTRODUCTION:

Uranium is widely distributed in the earth's crust with an average abundance of two parts per million (ppm). Rocks containing uranium bearing minerals with average grades of about 1000 ppm are usually mined by conventional open pit or underground methods depending on the geological condition of the ore, such as deposit size, ore grade, depth and ground condition. The underground operation produces less waste rock than open pit mining. In some cases like Australia and USA where average grades of uranium are between 100 to 1000 parts per million, uranium is recovered as a by-product of other mineral commodities. In Canada, deposits with up to 2,00,000 ppm uranium are being commercially operated. The deposits in India are of very low grade (ranging from 200 to 1000 ppm). Such low-grade deposits of India have significantly less radiological impact on the ecosystem compared to high-grade uranium deposits found elsewhere in the world. In spite of low-grade nature of deposits, the techniques of evaluation of radiological status of the environment at different stages of mining operations and control measures adopted in our country are comparable with the best practices followed anywhere in the world.

RADIOLOGICAL ASPECTS OF URANIUM MINING:

The uranium ore mining, in most cases is similar to other mining facilities generating the product from the raw materials available beneath the surface of the earth. The schematic flow diagram of material in uranium ore mining facility is shown below along with possible environmental impacts.



Mankind has always been exposed to natural radiation because of the terrestrial and cosmic radiation present everywhere on earth. The average global dose received by an individual is 2.4 milli Sivert (as per the UNSCEAR report)
Natural radioactivity due to uranium and its associated decay products is widespread on the earth's crust. As the uranium ore is radioactive, its mining is a potential source of radiation exposure to workers, and to some extent to the members of the public and the environment. In addition, the wastes of uranium mines in the form of environmental releases or effluents to air, water and soil may have some radiological impacts on humans (workers or public) and other living organisms, and on the physical environment such as water, sediment and air quality.

NON-RADIOLOGICAL IMPACTS –

Many different substances and types of equipment are used in uranium mining facilities. In most cases they are same as those used in other mining industries. Thus, the effects of using these substances and equipment are also much the same. Mitigative measures consist of proper codes of practice, appropriate waste disposal systems and a good safety culture.

RADIOLOGICAL IMPACTS –

Natural uranium comprises of ^{238}U (99.276 %), ^{235}U (0.718 %) and ^{234}U (~0.005 %). Contribution from ^{235}U decay chain being very small, daughter elements of ^{238}U only are important for uranium mining operations. The typical radiological releases from underground uranium mines are radon and radon progeny, and radioactively contaminated water, dust and others.

Gaseous radioactivity (radon and its progeny, long lived alpha emitters) released from the mines to the atmosphere is transported downwind and gets dispersed due to the turbulence present in the atmosphere. The dispersed radionuclides may lead to direct (inhalation / external) or indirect (food chain contamination) exposure for members of the public. The effluent of the mine may contain some dissolved radionuclides, which may make its way into the aquatic environment and sediments posing a possibility of further migration to the neighbouring population by means of intake of water or biota (consuming sediments / silt / suspended solid). Weathering of mine waste (uneconomical portion of ore) over a long period of time may also cause similar exposure to the environment.

The radioactivity of uranium and associated impacts implies the use of specific safety precautions in addition to those implemented in similar workplaces where there is no radiation risk. The extend of precautions required to control the radiation dose for mine workers is, for most part, a function of the ore being mined. The intensity of radiation decreases as the uranium content in the ore decreases.

EIA / EMP AND RADIOLOGICAL IMPACT ASSESSMENT STUDIES

Under Environmental (Protection) Act 1986, it is mandatory like any other industries to carryout a full season / rapid environmental impact assessments (EIAs) prior to the development of any new uranium mining operations. Similarly, it is also desired to make a detailed radiological impact assessment of the proposed operation and prepare a management plan addressing the significant impacts. International Atomic Energy Agency (IAEA) has formulated a model for evaluation of the impacts at uranium mining and milling facility in this regard.

In preparing such assessments, the project proponents identify the actions, which need to be taken to limit the impacts. Acceptance of the proposed action plan / management plan is subject to the scrutiny and approval of governmental regulatory agencies. Regulatory agencies monitor the activities when the facilities come under operation. Based on site specific experiences during operational phases, the management plan is also subjected to modification / revision by competent agencies with an aim to strengthen the control measures.

URANIUM MINERALISATION AT BAGJATA

Bagjata uranium deposit (Lat: 22° 28’ 07” Long: 86° 29’ 36”) is located in Dhalbhumgarh subdivision of Singhbhum East district in Jharkhand state. It is about 30km east of Jaduguda uranium mine and 7km south-east of Moosabani copper mine. The steel city of Jamshedpur is located about 60km west of this area.

Uranium mineralisation at Bagjata was first reported during 1963-64. Subsequent detailed exploration resulted in identification of sufficient reserves upto a depth of 270m. During 1988, exploratory mining at Bagjata had started. The mine was developed up to 100 meters from surface with two inclines developed following the orebody at two extreme ends. Levels were developed at 60m and 100m following the orebody. Subsequently, the work was discontinued and the openings were sealed. During 1990, a few additional deep boreholes were drilled at Bagjata to establish the down-dip persistence of footwall lode upto a depth of 600m. This enhanced the reserve base of the deposit significantly.

REGIONAL SETTINGS AND MINING ACTIVITIES:

The area around Bagjata uranium deposit falls within NW-SE trending Singhbhum Thrust Belt (also known as Singhbhum copper belt or Singhbhum Shear Zone). Singhbhum Thrust Belt (STB) is a zone of intense and deep tectonisation with less than 1km width and hosts a number of copper and uranium deposits with associated nickel, molybdenum, bismuth, gold, silver, tellurium and selenium etc.

The area has a long history of mining operations. Copper mining activity in this region started during mid 19^{th} century and continued with glory till recent time. Unfortunately, all the well-known copper mines in this region have been closed down presently because of slump in copper market in the country.

Uranium mining activity in the region started during mid fifties. Presently, Uranium Corporation of India Ltd. (a PSU under department of Atomic Energy) operates four underground mines in this belt and a few more mines are under construction. Bagjata uranium deposit is being developed by UCIL as an underground mine.

PROPOSED MINING AT BAGJATA:

The Detailed Project Report for opening of Bagjata mine has been prepared proposing underground mining upto a depth of 300m at the first stage and highlighting the techno-economics of the operation. The proposed mining method shall make full utilization of the existing underground development made during exploratory mining. The ore of Bagjata mine will be transported to Jaduguda ore processing plant by road. The de-slimed mill tailings from Jaduguda will be brought for filling the stopes.

EIA / EMP STUDIES AT BAGJATA:

The baseline environmental data generation at Bagjata site was started in December 2002. In line with the guidelines of Environmental (Protection) act 1986 and environmental impact assessment notification 1994, environmental impact assessment studies were conducted considering various environmental attributes like physiography and drainage, meteorology, air quality, soil quality, water quality, noise level, land use pattern, socio-economic environment and infrastructural development, health etc. Different activities causing impacts on the above matrices have been considered under various stages *viz.* siting, operation of underground mines and secondary activities and also post operational phase. After identifying the major environmental impacts by way of impact identification matrix, environmental management plan has been formulated addressing the issues.

RADIOLOGICAL IMPACT STUDIES AT BAGJATA

The safe and effective assessments of radioactive releases from uranium mines have been given utmost importance from the very beginning of uranium mining industry in India. The necessary codes and safety guidelines for achieving this objective is based on indigenous science and technology conforming to national policies and internationally accepted standards. In our country, these activities are properly regulated by the Atomic Energy Regulatory Board (AERB), the national regulatory authority in line with the standards prescribed by the international expert bodies like the International Commission for Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA).

The radiological impact assessment study carried out at Bagjata is based on IAEA model of evaluation of the impacts at uranium mining and milling facility. (Annexure-I extracted from Appendix A of the 1996 IAEA report on Health and Environment Aspects of Nuclear Fuel Cycle Facilities, IAEA-TECDOC-918.) This aims at identifying the potential impacts of uranium mining to workers, local population and the environment.

The parameters of the mining at Bagjata with respected to IAEA model is as follows.

a) Operation type – Underground mining
b) Grade of ore – Low
c) Age of facility – New
d) Local population – Dense

On the basis of Table-A and Table-B of Annexure-I, the probable radiological effects due to uranium mining on workers, local population and the environment around Bagjata are tabulated below.

Operation type	**Grade of ore**	**Age of facility**	**Local population**	**Significant impacts (ID no.)**				
				Workers	**Local population**		**Environment**	
				During	**During**	**After**	**During**	**After**
Underground	Low	New	Dense	**(R1)** - External radiation exposure **(R2)** – Radon progeny exposure **(R5)** - Long-lived dust exposure	**(R6)** – Radio-nuclide releases to air			

RADIOLOGICAL IMPACT MANAGEMENT PLAN AT BAGJATA

The underlying objective that governs the management of all such impacts is protection of man and environment, now as well as in future. It also underlines the development aspiration of the people in and around the area where the deposit is already located with an existing radiological status.

As a lead up to drawing an effective management plan, baseline radiological database around Bagjata has been generated. The underground mining at Bagjata has been planned to adopt most modern technology employing the latest equipment. Most of the strenuous mining operations are planned to be mechanized, thereby eliminating direct handling of radioactive ore.

The state-of-the art Health Physics Unit and Environmental Survey Laboratory set up at Jaduguda by Department of Atomic Energy will independently monitor all the significant radiological and other relevant parameters. The monitoring will involve measurement of overall radiological and conventional parameters for the work areas, associated personnel, members of the public and the environment. The control measures proposed to be put into practice are in accordance with the recommendations of International Commission for Radiological Protection "(ICRP Publication – 60)" as adopted by the IAEA Basic Safety Standards (IAEA-SS-115, 1996) and by the Atomic Energy

Regulatory Board (AERB), the national regulatory body. The ICRP's basic framework of radiological protection intends to prevent / reduce the effects by keeping doses below the relevant thresholds. Accordingly, dose limits for occupational workers, and members of the public are prescribed by ICRP. Further, based on these primary limits as prescribed by ICRP, secondary limits are derived for actual working conditions and adopted accordingly.

A detailed description for management of each of the significant radiological impacts (as identified above) along with limits prescribed by ICRP / AERB is presented below.

External radiation exposure of workers during the operating life of mine:

The radiations (β & γ) originating from the radioactive disintegration of uranium and its decay products present in the ore and waste rock are the main sources of external radiation exposure. Beta radiation being less penetrating is an insignificant source in mining environment unless the subject is in very close contact with the source for appreciable period. It results mostly in a shallow dose to the skin, hands and feet. Alpha particles being the least penetrating do not constitute any significant external exposure. Gamma radiation is important, as the whole body is prone to radiation exposure. For the average ore grade at Bagjata, the external gamma radiation dose rate in the center of the mine gallery will be approximately 2.25 $\mu Gy.h^{-1}$. Similarly, the external radiation exposure rate from the mine waste rock, 1 m above the surface will be < 1.0 $\mu Gy.h^{-1}$ and will be limited only to the immediate vicinity.

Measurement of external gamma radiation in mines will be carried out using radiation survey meter of micro R to milli R per hour (μR/h to mR/h) range containing Geiger Muller tube as detectors. Each worker in mines will be provided with thermo-luminescence dosimeters (TLD). Integrated gamma dose for occupational workers will be evaluated on quarterly basis. Annual dose will be evaluated and this will form the basis for implementing the control measures, if needed.

As the ore grade is low, overexposure to external radiation is not expected in present mining conditions. Most of the mining operations will be mechanized thereby ensuring justified safe distance from the source. If needed, period of exposure will be reduced in line with the ALARA principle. The limit for external gamma radiation is 8 micro Gray per hour (μGy / h)

Radon progeny exposure to workers during the operating life of mine:

Inhalation of radon (^{222}Rn), a gaseous decay product of the uranium with its short-lived decay products (^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po) is the main source of internal exposure in mines. The concentrations of radon and its progeny in underground uranium mine is dependent on factors like ore grade, mining conditions, ventilation status etc.

Monitoring of radon in mines at different locations will be carried out using scintillation cell of standard dimension. Individuals engaged in different mining operations will be provided with radon dosimeters. Integrated dose from radon and its progeny for a known period of time (quarterly) will be evaluated at the Environmental Survey Laboratory at Jaduguda.

A well-designed ventilation network will be in practice ensuring adequate supply of fresh air to all the working areas in underground. Proper ventilation will help in removal of radon and thereby limiting the exposure of its progeny. The limit for radon progeny exposure is 1000 Bq / m^3 Equilibrium Equivalent Radon (EER).

Long-lived dust exposure to workers during the operating life of mine:

During mining fine ore dust containing uranium and other long-lived radio-nuclides of the series may get airborne. In this regard, IAEA safety series-95 clearly states that for low-grade ore (ore below 1%), the long-lived alpha activity in airborne ore dust is not a source of significant internal exposure to the mine workers. However, monitoring of long-lived alpha activity is pre-requisite to fulfill the regulatory protocols.

The technique for measurement of activity of ore dust by drawing air samples through filter media of the particulate matter / aerosol deposited on the filter will be adopted. Individuals will be provided with personnel air sampler and evaluation of exposure will be done based on the generated data.

The controlling the generation of dust at the source will be taken care of by maintaining wet condition as far as practicable (regular spraying of water on freshly broken ore / waste). High level of mechanization proposed in mines will ensure maintaining a safe distance for occupational workers from the dust generation point. In addition to the several engineering control measures, workers in potentially dust prone areas will be provided with respirators having appropriate filter for collection of respirable dust. It will be mandatory to use respirators at dust generation sources.

The limit for dust exposure is 150 milli Bq / m^3 based on the toxicity of free silica content in ore dust (Derived limit is 600milli Bq / m^3 for long-lived alpha-active dust).

Radionuclide releases to the air from mine for local population during operating life:

Radon (primarily radon-222) and radioactive dust are released to the atmosphere when an ore body is exposed and broken during underground mining operations. Short-lived radon progeny are produced as a result of decay of radon. Radon and its short-lived daughters are the main constituent of the gaseous releases from underground mines. Proper ventilation is used in underground mines to remove radon and thereby limit the exposure to its progeny. However, the expelling of the radon and its progeny from underground mines results in dispersal of these radio-nuclides into the environment and hence a potential source of exposure for the members of the public. Due to large atmospheric dilution radon concentration comes down to background level only at few meters distance from the source. Maintaining wet conditions to carry out different mining operations, it is expected that particulate dust releases during these operations shall remain insignificant for the local population.

The radon content of exhaust mine air will be monitored at the exhaust point using scintillation cell. Monitoring of adjoining villages for radon and its progeny will be carried out using low level radon detection system (LLRDS) and passive radon dosimeters.

It has been experienced at other underground uranium mines of UCIL that the radon concentration falls to background level only at few meters distance from the origin owing to the large atmospheric dilution. The similar ore grade at Bagjata shall not warrant any special control measures. Although no limit is specified by ICRP/ AERB for releases into atmosphere from the mines, it will be ensured that the releases do not significantly change the pre-existing radiological status of the area in public domain.

CONCLUSION:

Safe operation of uranium mines in our country for about four decades is a testimony to the systematic and elaborate radiological impact management programme pursued by the uranium mining industry.

The radiological impact assessment and radiological management plan along with the environmental impact assessment and environmental management plan (EIA/EMP) are now the pre-requisites for any new uranium mining and milling facilities. Applications in the prescribed format along with these documents need to be submitted to various regulatory bodies to obtain necessary clearances before the commencement of site construction work. Modifications / improvements suggested by regulatory agencies are incorporated with an aim to strengthen the management procedure. In case of Bagjata underground mining project, the study has helped to clear many doubts regarding the radiation and radiation related misconceptions. The documents so prepared have been appreciated and accepted by all regulatory bodies without any alteration to the management plan. The site clearance from Ministry of Environment & Forest, New Delhi, no-objection certificate from Jharkhand State Pollution Control Board, the final environmental clearance from Ministry of Environment & Forest and approval of Atomic Energy Regulatory Board have already been obtained. The project has also got the approval of Atomic Energy Commission and site construction activities have already started. The project is expected to be commissioned as per the schedule implementing all environmental and radiological control measures.

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<u>ANNEXURE – I</u>

(**Extracted from Appendix A of the 1996 IAEA report on** ***Health and Environment Aspects of Nuclear Fuel Cycle Facilities*****, IAEA-TECDOC-918**)

EVALUATION OF THE IMPACTS AT URANIUM MINING AND MILLING FACILITY

Some of the various impacts that may result from uranium mining and milling are limited to certain types of operations. The following table (Table A) lists the impacts and types of operations in which they are likely to occur.

Table A

Hazard	Pathway	Group at risk	Agent	Operation	ID
Radiological	Air	Workers	External Radiation	O U M	R1
			Radon Progeny	O UA B M	R2
			Skin Dose	O U M	R3
			Ingestion	O U M	R4
			Long-Lived dust	O U M	R5
		Others	Radionuclide Release	O U A B M	R6
	Water	Others	Radionuclide Release	O U A B M	R7
Toxicological	Air	Worker	CO and CO_2	O U A B M	T1
			NO, Mox	O U	T2
		Worker	Diesel particulates	O U	T3
			Blasting fumes	O U	T4
			Noise	O U M	T5
			Temperature/humidity	O U A B M	T6
	Water	Others	Metals leaching	O U A B M	T7
Other	N/A	Worker	Blasting	O U	O1
			Travel/Transportation	O U A B M	O2
			Ground failure (major and minor)	O U	O3
			Fire	O U M	O4
			Vibration	U	O5
			Damp conditions	U	O6
			Heavy equipment	O U A B M	O7
			Reagents	A B M	O8
		Others	Ground opening	O U	O9
			Dam failure	M	O10
			Land alienation - temporary	O U A B M	O11
			Land alienation - permanent	O M	O12
Other	N/A	Others	Subsidence	U	O13

The letters appearing in the column labeled "Operation" indicate where the impacts may occur, and have the following meanings:

O - open pit mining
U - underground mining
A - in situ leach using acid
B - in situ leach using alkaline
M - milling (including tailings management)

The various agents in Table A are assigned a code, which is given in the column labeled "ID" for reference later in this document.

Evaluation of impacts

Uranium mining and milling can impact workers, the local population and the general environment. Such impacts can be of three types: radiological, toxicological and other. The significance of these impacts for a particular mine or mill is controlled, primarily, by four factors: the type of operation, the grade of ore being mined or milled, the age of the facility (since older facilities do not, in general, have the same radiation and environmental protection controls available), and the density of the local population. Combining the factors leads to the possibility of 40 different categories of facilities that may exist. In practice, however, not all factors are significant in all cases, and the number of cases is less.

It is impossible to develop a single model that is representative of all categories, as there are major differences that cannot be averaged when determining the impacts. However, it is theoretically possible to develop a model for each category, and then to determine the total impact of uranium mining and milling operations world-wide by summing the impacts category, weighted by the amount of uranium that comes from the category.

To make this task manageable, Table B has been developed. This table identifies the impacts that may be significant under a particular set of circumstances. In order to determine the total impact, only those impacts that are significant need be evaluated. While other impacts may be present, their contribution to the total impact is likely to be small.

It should be noted that the impacts on the local population and on the environment are likely to be different during operations and after closure of the facility. The entries under milling include the possible impacts from the tailings management facility during operations and after closure.

The entries for in situ leaching include the possible impacts from both the mining and processing. For conventional mining and milling operations, it will generally be necessary to consider the impacts from mining and milling independently.

The letters and numbers appearing in the columns labeled "**Significant Impacts**" indicate the identification of the impact that may occur, as listed in the column marked "ID" in Table A. Where there is no entry, no significant impacts are anticipated.

It is not intended that the differentiation between high and low grade, between a new facility and an old one, and between dense population and sparse population in the vicinity of the facility be absolute. As a general guide in interpreting the table B, the following definitions may be used:

High grade: uranium content of the ore greater than 0.5%.

Low grade: uranium content of the ore less than 0.5%.

New facility: facility constructed as per currently accepted environmental and safety standards.

Old facility: other facilities.

Dense population: an average of more than 3 people / km^2 living within 25 km.

Sparse population: an average of less than 3 people / km^2 living within 25 km.

Table B

Operation Type	Grade of Ore	Age of facility	Local popualtion	Significant Impacts				
				Workers	Local population		Environment	
				During	During	After	During	After
Open pit	High	New	Dense	R1, R2, R5 T2, T4, T5, T6, O1, O2, O3, O7	R6, O11	R7, T7, O9	R6, R7, T7	T7
			Sparse			O9		
		Old	Dense	R1, R2, R5 T2, T4, T5, T6, O1, O2, O3, O7	R6, T7, 011	R7, T7, O9	R6, R7 T7	R7 T7
			Sparse		R6,T7	O9		
	Low	New	Dense	T2, T4, T5, T6 O1, O2, O3, O7	R6 T7, O11	T7 O9	T7	T7
			Sparse			O9		
		Old	Dense	T2, T4, T5, T6 O1, O2, O3, O7	R6 O11	T7 O9	R7, T7	R7, T7
			Sparse			O9		
Underground	High	New	Dense	R1, R2, R3, R5, T1, T3, T4, T5, 01, 02, 03, 04, 05, 06, 07	R6, 011	O13	R6	
			Sparse					
		Old	Dense	R1, R2, R3, R5, T1, T3, T4, T5, 01, 02, 03, 04, 05, 06, 07	R6, 011	O13	R6	R7
			Sparse					
	Low	New	Dense	R1, R2, R5, T2, T3, T4, T5, 01, 02, 03, 04, 05, 06, 07	R6, 011	O13		
			Sparse					
		Old	Dense	R1, R2, R5, T1, T2, T4, T5, O1, O2, O3, O4, O5, O6, O7	R6, 011	O13	R6	
			Sparse					
In situ leaching- acid	High or low	New or old	Dense or Sparse	T6, O2, O7, O8	O11	R7, T7		R7, T7
in situ leaching alkaline	High or low	New or old	Dense or Sparse	T6, O2, O7	O11			
Milling	High	New	Dense	R1, R2, R3, R4, R5,T5, T6, 02, 04,	R6, R7, O11	O10, O12	R6, R7	O10
			Sparse			O12		
		Old	Dense	R1, R2, R3, R4, R5, T5, T6, 02, 04, 07, 08	R6, R7, 011	R7, T7, O11	R6, R7	R7, T7, O12
			Sparse			R7, T7, O12		
	Low	New	Dense	R1, R2, R4, R5, T5, T6, 02, 04, 07, 08	O11	O12		O10
			Sparse			O12		
		Old	Dense	R1, R2, R4, R5, T5, T6, 02, 04, 07, 08	R6, R7, 011	O12	R7	R7, T7, 010
			Sparse			O12		

T – Toxicological R – Radiological O – Others