UR/LLW-88

CODE OF PRACTICE ON THE MANAGEMENT OF RADIOACTIVE WASTES FROM THE MINING AND MILLING OF RADIOACTIVE ORES (1982)

GUIDELINE

The Mining of Uranium by
In Situ Leaching

Date of adoption or revision: 1982

Primary related Clause: 9

CONTENTS

Section 1 - Introduction

1 In situ leaching in this guideline refers to the method of mining of a uranium orebody located in an aquifer by injecting leach solutions into the aquifer to dissolve the uranium. In this method, injection and recovery wells are constructed and operated to confine the leaching solutions to the orebody and its associated aquifer, called the receiving aquifer.

2 In this guideline, the term "Mine" refers to the equipment used for removing the uranium and any associated products from the ground. As such it includes the plant and equipment used in the wells and the surface piping. The term "Mill" refers to the remainder of the operation and includes:

- the equipment and plant to make up and recover the solutions used to extract and carry the uranium from the mine, and to control the spent or waste solutions; and

- the equipment and plant to extract, purify and prepare the final product (usually U_3O_8); and equipment and plant used to dispose of any waste products.

3 Radioactive contamination can occur in three areas as a result of an in situ leaching operation:

- atmospheric emissions consisting of radon 222 and its decay products, and particulates. As radon gas will be dispersed into the atmosphere, its release requires care to prevent specific groups from receiving significant radiation doses. Particulate emissions are controllable by a variety of measures and, in general, will be at a very low level;

- mill wastes at surface level, including:

  - wastewaters,
  - sludges,
  - contaminated earth, and
  - plant and equipment; and

- below-surface wastes, including:

  - radionuclides in solution,
  - radionuclides capable of being dissolved over a long period of time, and
  - leaching solutions which are capable of dissolving radionuclides from the host rock.

4 This guideline is restricted to aspects only applicable to in situ leaching of uranium from aquifers and does not address aspects common to other forms of uranium mining, i.e. the extraction of uranium from solution, its conversion to yellowcake, the overall planning of waste management programs, etc. In this guideline, where applicable, the term:

- aquifer includes reference to a body of rock which, if filled with water, would become an aquifer,

- potentiometric surface is a surface which represents the static head. As related to an aquifer, it is defined by the levels to which water will rise in tightly cased wells. Where the head varies appreciably with depth in the aquifer, a potentiometric surface is meaningful only if it describes the static head along a particular specified surface of stratum in that aquifer. More than one potentiometric surface is then required to describe the distribution of head. The water table is a particular potentiometric surface, and

- water table is that surface in an unconfined water body at which pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. In wells which penetrate to greater depths, the water level will stand above or below the water table if an upward or downward component of groundwater flow exists.

Section 2 - General Requirements

5 While the operator of an in-situ leaching mine or mill must comply with all the relevant Sections of the "Code of Practice on the Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores (1982)", this guideline should also be read in conjunction with other appropriate guidelines to the Code.

6 The operator should obtain the approval of the appropriate authority for all physical and chemical testing which may alter the characteristics of the aquifer or ore body.

7 Prior to the commencement of an in situ leaching operation, the operator should demonstrate to the appropriate authority, either by operation of a pilot plant, or by reference to similar operations in the same geological environment, that proper control of the leach solution can be maintained and that the water in the aquifers can be restored to a condition which complies with the requirements of Section 9 of this guideline.

Section 3 - Application

8 An application for an in situ leaching operation should demonstrate that the operation is designed so as to minimise adverse impacts on the environment. The application should include :

- a description of the local and regional surface hydrology
- a description of the regional and detailed site geology and groundwater hydrology,
- a mining plan containing details of the aquifers to be mined, and
- a rehabilitation plan.

The local and regional surface hydrology

9 A description of the local and regional surface hydrology should be provided which would include the following:

- the name, description and map of all surface waters in the mining area and surrounding areas;
- the name, description and map of all non-perennial water courses in the mining area and surrounding areas;
- a list of all surface water rights within and adjacent to the mining area;
- the location, nature and extent of present and projected surface water use within the mining area and surrounding areas; and

- seasonal flow patterns and rates as well as the frequency of floods for water courses or water bodies in the mining area and surrounding areas.

The regional and detailed site geology and groundwater hydrology

10 A description of the regional geology and a detailed description of the site geology, supported by maps, plans and sections, which show :

- formations and aquifers,

- structural features and lithologic facies changes which may indicate variations in aquifer characteristics,

- areal and stratigraphic position of the production zone in relation to other geologic features, and

- the extent of confinement or limitation of the production zone to show the degree to which migration of recovery fluids or pollutants resulting from solutions can be restricted.

11 Geological sections, intersecting approximately at right angles within the production zones and well-field areas, should show detailed local stratigraphy in the vicinity of the production zones and well-field areas, and the extent of the low-permeability confining layers which may surround the aquifer. The sections should be referenced to a cross-section location map which identifies the drill-holes used to construct such sections.

12 With regard to the hydrological features within and around the mining site, the following information is required :

- a geochemical description of the groundwater, the receiving aquifer, and any strata that may be affected by the injection of leaching solutions,

- location, ownership and type of use of all existing wells within 5 kilometres of the mining area, with well-completion data, producing interval(s), and variations in water level (to the extent that such information is available from public records and from a reasonable inspection of the property),

- details of all exploration and investigation wells, bores and drillholes sunk by the applicant,

- for all abandoned wells and drill-holes within 5 kilometres of the mining area, a tabulation of their location, depth, type of use, condition of casing, plugging procedures and completion details (to the extent such information is available in public records and from a reasonable inspection of the property),

- for all recorded wells and drill-holes (including abandoned) that penetrate the receiving aquifer, a description of the procedures for their completion and plugging, and

- a groundwater potentiometric surface contour map with data points and static water level measurements for the receiving aquifer and all other aquifers within 5 km of the mining area which may be affected by the mining process, indicating where the static head is higher than the upper confining layer of the receiving aquifer.

13 Characteristics of the receiving aquifer and adjacent aquifers throughout the proposed well-field area(s) including:

- aquifer geometry,
- velocity and direction of natural groundwater movement,
- aquifer storage coefficients and/or specific yields,
- aquifer transmissivities and hydraulic conductivities,
- direction of preferred flow under hydraulic stress in the receiving aquifer,
- the geometry and hydraulic characteristics of confining layers and the extent of hydraulic connection between the receiving aquifer and adjacent aquifers, and
- the hydraulic characteristics of any influencing boundaries in or near the proposed well-field area(s).

14 To substantiate geological and hydrological interpretations, test data for example from geological logging, core analyses, permeability and porosity tests, and any other tests deemed necessary, should be included in the mining application. Also included should be the results of water quality analyses for samples collected from the receiving aquifer, and from all groundwater in hydraulic communication with the receiving aquifer and/or which may be affected by the operation. Sampling should be sufficiently comprehensive to characterise the pre-mining groundwater quality and its variability.

Details of the aquifers to be mined

15 The mining plan submitted to the appropriate authority should include details of the proposed mining operation, and of procedures and measures for monitoring and controlling resultant hydrological impacts, including information on :

- the proposed sequence of mining;

- the method of operation noting the anticipated injection pressures, volumes, type(s), and detailed chemical and physical characteristics of the leach solution;

- a subsidence analysis, using established engineering principles, to estimate the possible effects on the land surface, and on aquifers overlying the receiving aquifer, as a result of the proposed mining operation;

- the proposed well completion, for each type of well to be utilised, detailing the average, minimum and maximum total depths (expressed as elevations), typical open interval and range, type of completion and grouting required, and casing specifications;

- a description of chemical changes which may occur as a result of solution injection and which may change groundwater quality in the receiving aquifer or in other aquifers;

- the continuous monitoring program to operate during the life of the mine to detect pollution of water resulting from excursions, migration of contaminated water, and any other mining or restoration activity, noting the location and depth of the stratigraphic horizon(s) to be monitored, time schedules and other related details. (Proposals not to monitor aquifer(s) above or below the orebody should show that aquifers are protected by an

adequate intervening thickness of strata yielding negligible hydraulic continuity with the receiving aquifer.)

- a description of all measures to be employed to prevent excursions, and contingency plans to be implemented in the event of an excursion, indicating :

  - procedures to verify that the monitor wells employed for detecting excursions are hydraulically connected to the appropriate aquifers,

  - procedures to ensure that the installation of wells will not result in hydraulic communication of the receiving aquifer with adjacent aquifers,

  - procedures for periodically checking for leakage from recovery and injection wells, and

  - an estimate of the overpumping required to contain the solution in the receiving aquifer and prevent excursions; and

- an assessment of the impacts on the groundwater dynamics (including groundwater quality in the receiving aquifer), and on water resources within and adjacent to the mining area, which may reasonably be expected to result from the mining operation, and the steps to be taken to mitigate the adverse impacts.

- the applicant should include details of measures to be taken to mitigate the adverse effects of flooding.

The rehabilitation plan

16 The rehabilitation plan submitted to the appropriate authority should identify the standards and procedures to be used to achieve the restoration of groundwater within and outside the mining production area.

17 Information to be provided should demonstrate that all affected groundwater is returned to a condition so as to be available again for those uses carried out prior to the mining operation. Moreover, the information should also demonstrate that groundwater outside the production zone will not be adversely affected. The information provided would include estimates of the chemical composition of the restored groundwater, and specific note should be made of those potential changes to the chemical, physical or ion-exchange characteristics which may hinder or enhance restoration. In addition, the information should demonstrate that the techniques used are appropriate and suitable, taking into account the known hydraulic and geochemical properties of the receiving aquifer, other aquifers and confining beds in the area.

18 The rehabilitation plan would also specify procedures for the abandonment of all wells associated with the mining activity, including details of plugging, sealing and capping.

Section 4 - Operation

19 At all times the operation of the mine or mill should be in accordance with the approved waste management plan.

20 At all times liquids should be disposed of in accordance with the approved waste management plan and, in particular, the operator should not discharge any liquid at ground level or into uncased wells unless approved by the appropriate authority. This

would include water produced during sampling from monitoring wells, water from trial pumping of injection or production wells, water produced in well development, and water pumped from any aquifer during operations to control excursions.

21 All wells should be completed by approved techniques to the satisfaction of the appropriate authority. These techniques should ensure that liquids cannot penetrate into aquifers or strata other than the designated aquifer.

22 When wells are no longer required for any purpose they should be suitably filled and sealed to prevent transfer of water between aquifers. Wells should be plugged, capped at least 1 metre below surface level, and filled to surface level or as otherwise required by the appropriate authority.

Section 5 - Groundwater Monitoring

23 Wells for monitoring of water quality and water level should be established in the receiving aquifer and in adjacent aquifers.

24 Locations of the monitoring wells should be such as to permit the collection of effective evidence of containment of the leach solution within the production zone. Their position should also reflect due regard to the stratigraphy of the area and the possible directional variations in permeability of the aquifers and confining strata, including the possibility of channelling.

25 The active well-field should be surrounded by monitoring wells placed so that the appropriate authority is satisfied that any excursion will be detected. Monitoring wells in the receiving aquifer should be located so that variations in water level caused by variation in pumping ratios can be readily detected, but should be placed no further than 300 metres from the well field and such that the angle subtended by any two adjacent monitoring wells from the closest injection well is not greater than 60°.

26 The period between groundwater sampling from monitoring wells for chemical analysis should not exceed 14 days. The method used to obtain the groundwater sample should ensure that the sample is representative of the groundwater surrounding the well. This objective may be achieved by pumping the well for at least ten minutes, during which period at least two well-volumes of water are to be removed. Subsequently, pumping should be continued and determinations of conductivity made at two-minute intervals. When the conductivity of three successive samples differs by less than 5%, the final sample would then be retained for chemical analysis.

27 The water level should be measured in each monitoring well at least on a daily basis and preferably continuously.

28 The chemical or physical groundwater parameters to be monitored will be site specific and determined after discussions between the operator and the appropriate authority.

29 For each parameter (and possibly each location) monitored, control limits would be established. These limits would be based on the variability in the parameters measured during the previous 6 months, adjusted where appropriate for changes due to seasonal variations, for each monitoring well, although they may be based on theoretical estimates. Any deviation outside these limits may indicate that an excursion is occurring and that appropriate investigative action should be initiated.

30 If the assay is outside the control limits for two parameters, sampling should be repeated within 48 hours. If the second analysis again gives results outside the control limits in two parameters, appropriate investigative and corrective action should be initiated and the appropriate authority notified within 48 hours.

Section 6 - Excursions

31 Excursions may be detected by a number of means and the operator should assess all information available in determining if an excursion may occur or has occurred. An excursion is established when selected chemical or physical parameters (e.g. sulphate, chloride, pH or conductivity) in a monitoring well give deviations outside the control limits. Early indication that an excursion may have occurred can be gained from other evidence, for example, variation in injected or recovered liquid volumes, variation in water levels in injection, recovery or monitoring wells, or changes in chemical composition of recovered solutions.

32 Following the detection of an excursion, corrective measures which may be applied to one or more wells within the mining area or to the whole well-field should be taken. Possible corrective measures include :

- Increased overpumping involves adjustment of pumping rates so that the rate of flow into the injection wells is exceeded by the flow from the recovery wells. The result is a general flow of groundwater into the recovery-well area.

- Reordering is a variation of overpumping whereby different pumping ratios of injection rate to recovery rate are applied to different areas in the well-field. As a result, the inward movement of groundwater may be emphasised at one point or another. Reordering may further include direct pumping from one part of the field to another.

- Reducing injection is an alternative method of adjusting the ratio of injection flow to recovery flow by reducing the amount of leach solution introduced into the mining area, while maintaining the rate of recovery flow. As a result, the excursion may be halted.

- Ceasing pumping which stops both the injection and recovery flows. As natural migration of groundwater occurs much more slowly than migration under pumping, the cessation of pumping should retard the further migration of leach solution.

- Beginning restoration can be utilised when all other efforts have failed to halt migration of the leach solution.

33 The action taken to contain an excursion should be appropriate for the extent of the excursion. The operator should however employ the above measures if he suspects that an excursion may have occurred and not necessarily wait until an excursion is established before taking action. In this way it should be possible to avoid major excursions.

34 Corrective action should continue until the appropriate authority is satisfied that conditions are suitable for resumption of the normal operation of the well field.

Section 7 - Solid Wastes

35 The operator should dispose of all solid wastes in a manner approved by the appropriate authority. The operator should give consideration to the following :

- the volume of waste to be disposed of,

- the toxicity and/or radioactive content of the waste - radioactive waste should only be disposed of in waste disposal facilities approved for that purpose, or in a manner approved by the appropriate authorities, and

- the future land-use at the disposal site.

36 Types of solid waste which may need consideration for disposal include :

- drilling mud and spoil from wells,
- solids generated from pumping of wells,
- precipitates and sludges deposited in pipes, reaction vessels, etc.,
- contaminated ion-exchange resins, filters from reverse osmosis or other water or solvent purification stages,
- sludges from evaporation ponds,
- contaminated soil, plant foundations and building materials, and
- contaminated pipe-work, fittings, plant, machinery and equipment.

Section 8 - Liquid Waste

37 An in situ leaching operation should be designed to minimise the quantities of liquid radioactive waste generated. Initial treatment of excess water may include reduction in volume by evaporation, or by separation of the radioactive contaminants by water treatment. If these methods cannot sufficiently reduce the volume or total activity of radioactive liquid waste, the waste may be disposed of, subject to approval by the appropriate authority, by surface discharge from the site or by injection into suitable aquifers. Aquifers used for waste disposal would normally be well-confined and contain water unsuitable for any foreseeable use.

38 Where appropriate, monitoring of disposal wells and adjoining aquifers should be carried out to ensure that this liquid waste is confined.

39 For the purpose of in situ leaching operations, the restricted release zone should be defined as the area of the surface operation, plus that portion of the mined aquifer contained within the boundary defined by the monitoring wells, plus any portion of an aquifer designated for waste-liquid disposal.

40 Where temporary storage of liquid above ground is used for evaporation or other purposes, the ponds should be constructed to prevent loss of water by seepage or overflow. This objective would normally be achieved by constructing storage ponds with impermeable liners and adequate capacity. In addition, a collecting drain would be constructed under the impermeable liner.

Section 9 - Restoration

41 With respect to rehabilitation of surface areas, reference should be made to other guidelines to the Radioactive Waste Management (Mining and Milling) Code (1982).

42 Restoration of water quality in all aquifers should be based on the quality of the water prior to mining and the actual or potential water-use. In restoring water quality, the operator may be required to return all groundwater parameters to values existing before commencement of operations. If this cannot be achieved, then the operator may be required to restore the affected groundwater to a quality such that the water is still suitable for all uses for which the water was suitable prior to the commencement of the operation. If this cannot be achieved

and if the quality of the groundwater is such that it has no foreseeable use, the operator may be required to restore all affected groundwater to a quality, which is justifiable and related to the condition and quality necessary to ensure protection of public health and safety.

43 Having established the standards to which the water is to be restored, the operator should establish a procedure for restoring water in mined out aquifers to those standards. Restoration should be confirmed by monitoring the water quality for a period long enough to demonstrate that the water quality has stabilised and meets the standards previously determined.

44 Restoration should be carried out progressively as the mine is developed.

Section 10 - Records

45 In addition to other records required by Section 6(4) of the Code, operators of in situ mines should maintain records containing :

- details of all wells installed, with information on location, completion, plugging and abandonment,
- details of solutions, including volumes injected and the total quantities recovered for each well-field area on a daily basis,
- measurement of chemical compositions and water levels in monitoring wells,
- potentiometric surface data on all aquifers which may be affected by the mining activity, and
- data from areas where groundwater restoration is in progress or has been achieved.

46 Maps should be maintained showing the location of all installed wells where mining is in progress, where mining is complete but restoration has not commenced, and where groundwater restoration is in progress or has been achieved. Maps should also be maintained to show the potentiometric surface based on recent measurements for aquifers potentially affected by the mining operation.

Section 11 - Selected References

These references have been selected to include examples of environmental impact statements from Australia and the USA, and to provide an overview of methods and technologies which may be applicable in the evaluation of potential in situ leaching operations. It should be noted that the mining of uranium by in situ leaching is a rapidly evolving area and that new methods and technologies are continuously being introduced.

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