Management of uranium mill tailings and associated environmental monitoring in India

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Abstract. Mining of low grade uranium ore commenced at Jaduguda in eastern India in the mid 1960s. Presently, the uranium ore from four underground mines located within a distance of 22 km is processed by the Uranium Corporation of India Ltd. (UCIL). A few more mines are envisaged to meet the nuclear fuel requirements. Management of mine water, mill tailings and the effluents from the tailings containment facility is given due importance. Liquid effluents are treated with BaCl2 and lime slurry to remove 226Ra, Mn and other pollutants. A large portion of the treated effluents is re-used, the rest being disposed to the aquatic system after ensuring that they meet the regulatory standards of discharge. Surface and ground water monitoring results are presented in the paper.

Introduction

The first uranium ore deposit of economic importance in India was discovered at Jaduguda in eastern India where mining and ore processing operations commenced in mid 1960s. Subsequently, three other deposits at Bhatin, Narwapahar and Turamdih, all within a distance of about 22 km, were taken up for underground mining.

The ore from these mines is processed in the mill at Jaduguda. Opening of a few new mines in other parts of the country is envisaged.

Mining and ore processing

Underground mining

The Jaduguda mine was developed in three stages to reach the deepest ore deposit, currently at a depth of about 900 m. A central shaft serves as entry for men, material and as main ventilation intake. The ore excavated from different stopes is brought to a central location and hoisted to surface and discharged on to a conveyor system leading to the mill. Ventilation is provided through two exhaust fans of total capacity of 120 $m^3.s^{-1}$.

Bhatin is a relatively small mine, developed through adits and winzes to reach the ore body. It has entry through an adit, which also serves as intake route for ventilation air and transport of the excavated ore to surface. An exhaust fan provides ventilation of 30 $m^3.s^{-1}$.

Narwapahar mine is one of the most modern mines in the country with a combination of trackless mining through decline and a vertical shaft to reach the deeper ores. Three large fans provide a ventilation of 225 $m^3.s^{-1}$.

The Turamdih mine combining a system of trackless mining through a decline and a vertical shaft is in the advance stage of development (Bhasin 1998, 2001).

An underground mine at Bagjata and an open cast mine at Banduhurang are being developed in the same region. Another large ore processing mill is also under construction.

A few more underground and opencast mines with ore processing mill are envisaged in southern and north-eastern parts of the country.

Ore processing

The low grade uranium ore (<0.1 % U_3O_8) from all the mines are presently processed in the mill at Jaduguda. The initial ore processing operations comprise of crushing, screening, wet grinding to a size of -200 mesh and de-watering to control pulp density. This is followed by leaching with sulphuric acid in presence of pyrolusite (MnO_2) in air agitated vessels.

Depending on the ore, a temperature of 40 - 50 ^oC is maintained by using steam. The leachate is filtered, purified and concentrated using ion-exchange process. After precipitating sulphate and ferric iron by addition of lime slurry, magnesia slurry (MgO) is added to the pure liquor to precipitate uranium as magnesium diuranate (MDU; Beri 1998).

Treatment of mine water and mill tailings

Mine water

Large quantities of water are pumped out of the mines. This comprises of the ground water seepage in to mine galleries containing dissolved radionuclides and that sent to the mine for drilling, dust suppression and stowing or backfilling operations.

As it contains dissolved uranium and radium the mine water is collected, clarified and reused in the mill process after ion-exchange step since it also contains chlorides.

Mine water from Bhatin and Narwapahar mines is brought through pipe lines to the effluent treatment plant (ETP) at Jaduguda. About 4000 m^3 of mine water is reused per day as industrial water after clarification (Beri 1998).

Separate treatment schemes are in place for mine water from Turamdih and Bagjata mines which are in advance stage of development and located about 22 km west and east of Jaduguda, respectively.

Mill effluents

Water sprayed on the ore pile for suppression of dust as well as any runoff water from ore yard is collected and used as a part of the process water in mill after clarification. Overflow from the magnetite (a byproduct recovered from the tailings) settling pits is sent to the ETP for treatment. Water from storm water drains is also treated for use as industrial water.

Tailings treatment and containment

In view of the low grade of the ore processed, the bulk of the ore processed in mill emerges as waste or ‘tailings’. It comprises of the barren cake from the drum filters containing all the un-dissolved radionuclides and the barren liquor from ion exchange columns having some dissolved activity. Disposal of tailings in a permanent containment system is, therefore, an important aspect of uranium mining and ore processing operations.

The barren liquor from the ion exchange columns is treated with lime stone slurry initially to a pH of 4.2 - 4.3 followed by addition of lime slurry to raise the pH to 10 - 10.5. It is then mixed with the barren cake slurry from the drum filters and a final pH of 9.5 - 10 is maintained. At this pH the residual uranium, radium, other radionuclides and chemical pollutants including Mn get precipitated. The treated slurry is classified into coarse and fine fractions using hydro-cyclones. The coarse material forming nearly 50% of the tailings is sent to mines for back-filling. The fine tailings or ‘slimes’ are pumped to an engineered tailings pond for permanent containment. The slimes along with the precipitates settle down and clear liquid is decanted. A series of decantation wells with Hume pipes connected at bottom and side channels are provided to lead the decanted liquid to the ETP through an engineered concrete pipe line.

There are three valley-dam types of tailings ponds at Jaduguda. The first and second stages of the tailings pond of about 33 and 14 hectare (ha) surface area, respectively, are located adjacent to each other in a valley with hills on three sides and engineered embankments on downstream side of natural drainage (Fig.1). The 1^{st} and 2^{nd} tailings embankments were constructed by upstream method in which an initial dam was constructed at the downstream toe. The central line of the embankment was shifted towards the pond area as the height of the dam was increased from an initial elevation of 107 m (RL) to the final height of 130 m in stages. The second stage tailings dam was constructed upstream of the 1^{st} dam at the far upper end from an initial elevation of 126 m to a height of 150 m. To provide additional stability the 1^{st} stage embankment was strengthened (Prasad and Beri 1989; Gupta and Siddique 2003). These two tailings containment ponds are nearly filled up and ready for closure. Experiments are underway to decide the thickness of the cover material to reduce gamma radiation and radon emanation to an acceptable level for the long-term. The third stage of the tailings pond (Fig.2) having a surface area of about 30 ha, which is currently in use, is also located nearby in a similar setting. The third stage tailings pond embankment has been constructed by central line method in which the central line of the top of the embankment remains the same and downstream toe of each subsequent dike rests over the firm ground for better stability (Gupta and Siddique 2003. The height of

Fig. 1. 1^{st} and 2^{nd} Tailings Containment Ponds.

Fig. 2. 3rd Tailings Containment Ponds.

the 3rd tailings pond embankment starts from an initial elevation of 125 m and is expected to reach a final elevation of 160 m. The underlying soil and the bedrock of these tailings ponds have very low permeability. The tailings ponds are fenced.

Effluent Treatment

The treatment of tailings with lime in the tailings treatment plant of the mill helps in precipitating the dissolved radionuclides and other pollutants from the process effluents. After depositing the tailings in the containment pond reduction of pH in the tailings pond due to oxidation of sulphide radicals may occur over a period of time. This increases the concentrations of some radionuclides and chemical constituents in the effluents decanted from the tailings containment system. Hence the effluents requires further treatment to meet the regulatory discharge limits. The effluents coming from the tailings pond to the ETP are, therefore, first clarified and a large portion of this is reused in the milling process. The rest is treated first with $BaCl_2$ and then with lime slurry to precipitate the radioactive and chemical pollutants, especially ^{226}Ra and Mn. It is then clarified and the settled sludge carrying the $Ba(Ra)SO_4$ and $Mn(OH)_2$ precipitates is pumped to the tailings pond with the main tailings and the clear effluent is discharged to environment after monitoring (Beri, 1998).

Environmental surveillance

A Health Physics Unit with Environmental Survey Laboratory established at site maintains a comprehensive surveillance on the environment around the mines, mill and the tailings pond to evaluate the effectiveness of control measures, assess the environmental impacts and ensure regulatory compliance.

Radiation levels

Uranium tailings are low specific activity material and hence a source of low levels of gamma radiation and environmental radon. Gamma radiation and radon levels over the tailings pile, on the embankment and nearby areas are monitored. The ^{226}Ra content of the tailings is in the range of about 4 to 8 Bq.g^{-1}. The gamma radiation levels directly 1 m above the tailings pile range from about 0.8 to 3.3 μGy.h^{-1}, depending on thickness of the pile. This reduces to about 0.3 to 0.5 μGy.h^{-1} on the embankment and attains the local background levels of 0.10 to 0.15

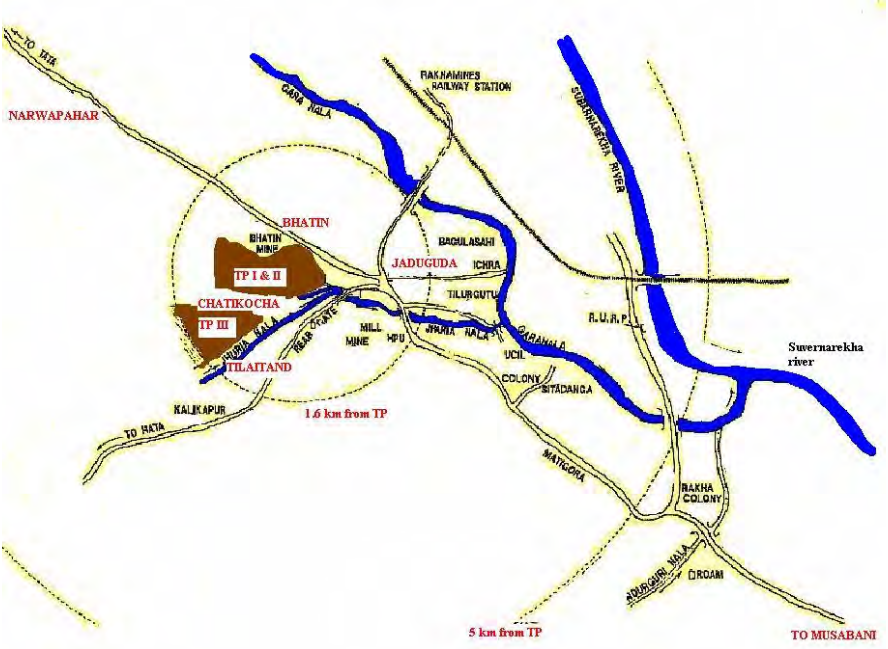

Fig. 3. Environmental Map of Jaduguda Showing Jaduguda, Bhatin, Narwapahar and TPs.

μGy.h^{-1}within a short distance from the embankment. The average radon emanation rate from the tailings pile is of the order of 1.5 Bq.m^{-2}.s^{-1}and the atmospheric radon concentration directly above the tailings averages around 35 Bq.m^{-3}compared to the natural background level of about 10 – 15 Bq.m^{-3}in the region (Khan et al, 2004).

Surface and ground water

The liquid effluents released after treatment and monitoring have a small potential to contribute to the radioactivity level of the recipient surface water system in the immediate vicinity. In view of the clayey soil and hard rock at the bottom of the tailings containment system, the hydraulic conductivity is low. However, any underground migration of radionuclides from the tailings pond may show up in the local ground water. The environmental surveillance, therefore, also includes monitoring of uranium (nat.) and ^{226}Ra in surface and ground waters in the vicinity of uranium mining and tailings containment. The surface and ground waters are monitored regularly in the environment around the facility (Fig. 3).

The Gara, a relatively small river and tributary of the Subarnarekha River, receives the treated effluents from the uranium mining and milling industry. The mean of pH, U(nat) and ^{226}Ra concentrations observed in the surface waters for the last 9 years are summarized in Fig. 4. It may be noted that uranium and radium concentrations in water from the Gara and Subarnarekha rivers downstream of UCIL operations are nearly of the same order as the respective background levels observed upstream. Slightly elevated levels of uranium and radium in the immediate recipient Gara River are well within the respective derived water concentration limits. The levels in Subarnarekha River reduce further and approach the regional background values.

The ground water sources comprising of dug wells, hand pumps (tube wells) and some deep holes drilled for geological prospecting in the past are monitored for uranium (nat.) and radium-226. The results obtained during the last 9 years are summarised with respect to distance from the tailings containment system and presented in Fig. 5.

Uranium and radium levels in the ground water sources in the region vary over a wide range of <0.5 – 55 μg.l^{-1} averaging around 4 μg.l^{-1} for uranium and in the range of <3.5 – 455 mBq.l^{-1} averaging around 23 mBq.l^{-1}for radium. The higher values are observed in water flowing out of some deep drill holes made for geological prospecting in the past, over 3 – 5 km away from the uranium mining and tailings pond sites. The lower values of about 2.5 μg.l^{-1} for uranium and about 18 mBq.l^{-1} for radium observed within 0.5 km from the tailings pond are comparable to the regional average of 4.2 μg.l^{-1} for uranium and about 23.5 mBq.l^{-1} for radium. This also indicates that tailings containment facility does not have any discernible impact on the ground water in its vicinity.

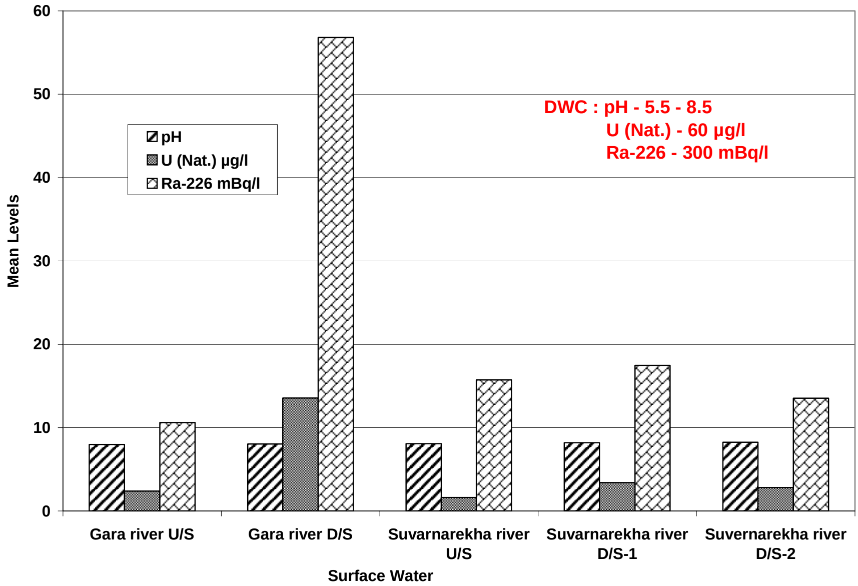

Fig. 4. pH, Uranium (nat.) and Ra-226 Levels in Surface Water around Uranium Mining Complex.

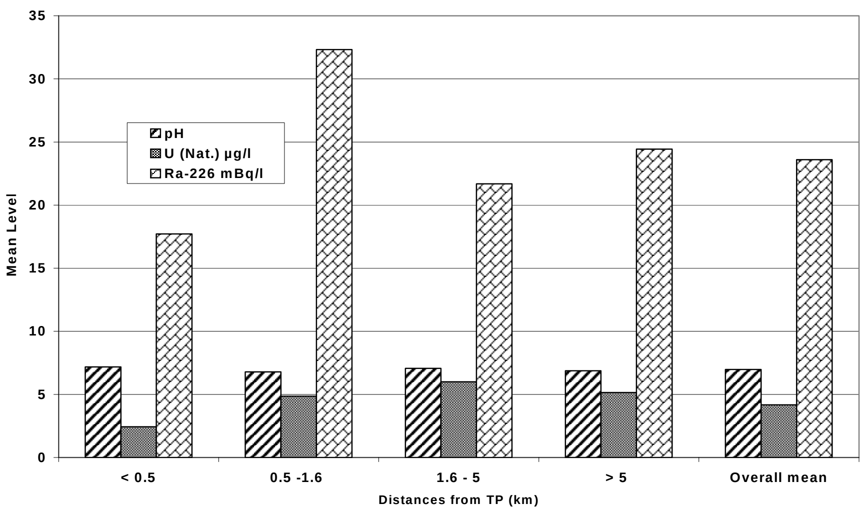

Fig. 5. pH, Uranium (nat.) and Ra-226 Levels in Ground Water around Tailings Pond.

Conclusions

In view of the importance given to the safe management of mine and mill effluents including uranium tailings from the very beginning, uranium mining and ore processing operations have not resulted in any discernible impact on the environment. The continuous environmental surveillance has been effective in controlling the environmental releases of radioactivity. Treatment and reclamation of waste water for reuse in the plant is another positive feature as it helps in conserving fresh water.

Acknowledgement

The authors are grateful to Mr. H. S. Kushwaha, Director, Health, Safety and Environment Group, for the encouragement and support received. Thanks are due to Mr. R. Gupta, Chairman & Managing Director, Uranium Corporation of India Ltd for extending necessary facilities during the course of this work.

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