Management of wastes from uranium mines and mills

by K.T. Thomas*

Uranium mining and milling operations have not given rise to much concern about their hazards, and with advancing technologies for mill processing and waste management, the situation will continue to improve. However, the disposal of large quantities of waste produced in mining and milling does have an environmental impact, owing to the long half-lives and the ready availability of the toxic radionuclides Ra-226 and Rn-222.

Mining

The waste rocks produced in mining, though not containing radioactivity of any significance, need control. Those which are not used for backfill of mines are often used in other ways: for the construction of embankments on the mine site, road-building, etc. If the material is used for building, then it should be monitored by the appropriate competent authority to ensure that any resulting radiation exposures of the public will stay within acceptable limits. The effects of any seepage from waste rock piles which contain concentrations of natural radionuclides higher than the surrounding background levels have to be assessed and, where required, the seepage has to be collected and treated.

Mine-water is as far as possible usually reused in the mine and the mill. It may contain dissolved uranium, thorium, radium, or other metals which could increase radon levels in underground mine air. Where more mine-water is produced than can be used, it is held in a waste retention system or, in some cases, discharged under controlled conditions to surface waters.

Mine-exhaust ventilation is contaminated with radon and its daughter products, and to some extent with ore-dust, rock-dust, and fumes. This is monitored and treated where required before dispersal into atmosphere, so that individuals and the public are not exposed to unacceptable levels of radon or dust.

Milling

The mineralogy of the host rock and the choice of the extraction process influence the waste management problem. Since characteristically uranium-bearing minerals are considerably softer than the quartz and silicate minerals that comprise the bulk of the gangue, the uranium, radium, and other minerals of interest tend to be reduced to fine slimes and mixed with clays. The handling of the slime portion of the ore is of disproportionate importance in milling and in waste management practices.

Acid-leach processing is more commonly adopted unless the ore contains a high proportion of limestone or other gangue materials favourable for alkaline treatment. The deposits which contain pyrites present a major waste management problem. This oxidizes gradually in the tailings producing sulphuric acid and high concentrations of sulphates. The effect is compounded if other heavy metals such as copper and zinc are also present as sulphides which can be oxidized and leached from the tailings.

The barren solutions from the alkaline-leaching process are mostly reused. Water slurry is used to transport the leached washed tailings which will contain chemicals such as carbonates, sulphates, and nitrates. The barren solution from acid-leach process is used for transport of tailings and contains greater concentrations of contaminants including sulphuric acid, heavy metals, nitrates, sulphates, amines and chlorides. The major radionuclides present in these solutions are Th-230, Ra-226, Rn-222, Pb-210 of which the most critical is Ra-226. Water reuse, control, and reduction in use are recommended to reduce the volume of waste solutions. The main treatment of acidic mill effluents is neutralization with lime or combination of limestone and lime to alkaline pH followed by barium salt and sodium salt of long-chain fatty-acid treatment. Starting with effluents containing 4–40 Bq/litre (100–1000 pCi/litre) radium such treatment can reduce it to levels of about .07–.2 Bq/litre (2–5 pCi/litre) which are considered acceptable. The decant solutions from the waste retention system, where excess water is present, are treated in a similar manner.

The seepage solutions change in character with time, especially in aged sulphide-bearing tailings with the consequent production of acid. By adequate engineering of the waste retention system, seepage is reduced. Where it occurs, the solution can be pumped back to the system or treated along with the decant liquor. Long-term control of seepage on a continuing basis is a problem needing attention.

Dry ore-dusts from operations, fumes arising from acid treatments, airborne contaminants during "yellow-cake" separation and drying stages, are treated by conventional

*Member of the Agency's Waste Management Section, Division of Nuclear Fuel Cycle.

methods such as dust extraction, cyclones, scrubbing, and electrostatic precipitation. Radon released at the milling stage, though difficult to remove, can be safely handled by proper design of exhaust.

Tailings

Uranium mill tailings, containing radioactive and non-radioactive materials, are the solid residues and the associated liquids which remain after uranium has been extracted from the ore. The solids consist primarily of the finely-ground bulk of the original ore, and also of a variety of chemicals precipitated from the tailings liquids.

The tailings slurry is pumped to a waste-retention system where the solids settle out and accumulate. In a few locations the ore is processed without fine grinding, and the resultant tailings are transported in a nearly dry form to a waste disposal area.

The specific radioactivity of uranium mill tailings is low. About 15% of the total radioactivity which was originally contained in the ore is retained in the yellow-cake produced by the mill. Once the shorter-lived radioactive nuclides have decayed, some 70% of the radioactivity originally present in the ore is left in the tailings. Because thorium and radium have long half-lives, and also because of the presence in the tailings of residual uranium which also has a very long half-life (hundreds of millions of years), the tailings will remain radioactive for practically an indefinite period.

As at least 97% of the Ra-226 fed to the mill remains undissolved through the leaching process, the concentration of radium in the tailings is only slightly less than that in the ore. Radon will be continually produced because of this Ra-226 in the tailings. Whereas windborne particulates from the tailings' surface may be of some significance, radon releases are the most difficult to control. They can be reduced by minimizing the exposed tailings' area, covering the tailings with water or an impermeable membrane, or with a thick layer of earth. In addition to those measures, the radiation dose to the public can be decreased by siting waste-retention systems as far as possible from established residential areas and by restricting the development of new residential areas close to tailings areas. A maximum limit for the emanation of Rn-222 from stabilized tailings of 0.07 Bq $m^{-2}s^{-1}$ (2pCi $m^{-2}s^{-1}$) has been proposed by some countries.

At present there does not appear to be any generally applicable alternative to the disposal of solid tailings in waste-retention systems. These can and should be carefully sited, built to the best standards, operated in a careful manner and maintained at a high standard.

The basic design and operating objectives for the impoundment of mill tailings are to provide for the physical and chemical stability of the tailings and to keep the loss of radioactive elements to acceptable low levels. Seepage is minimized primarily by ensuring that water barriers of low permeability and low transmissivity are in place in all directions over which a hydraulic head or driving force is acting to drive water away from the impoundment. Several liner options exist and the choice for each site depends on many factors, including the degree of control required and the costs.

After the mill has been decommissioned, control, surveillance, and maintenance of waste-retention systems present problems which will last into the future Among the problems are the fluid nature of the slime portion, difficulties of revegetation, adverse weather and rainfall conditions, seepages, and acid production from ores containing pyrites. The design, and construction of an embankment system should, if optimized, take care of these problems. Successful revegetation of a tailings surface can stabilize the waste dump against wind erosion and, with appropriate surface contouring, vegetation can reduce water erosion and, to some degree, the ingress of moisture.

During the recent past, significant efforts have been made to improve the techniques for managing mill tailings and reduce their potential environmental impact. Design practice is currently undergoing a technical evolution

Because of the low specific radioactivity of the tailings, the consequences of breaching the confinement system and the resultant slow dispersal of tailings would not lead to catastrophic or even to any significant radiological impact, since long and sustained exposure to the radioactivity in tailings would be required to produce adverse results. Even though the potential consequences of breaching a tailings' confinement system over the long term are expected to be small, our responsibility to future generations suggests that the aim of mill-tailings management should be to stabilize and confine the tailings for an indefinite period using the best practical means available.

When assessing the adverse effects on health, the radioisotopes Ra-226, Rn-222, Pb-210 in the tailings and U-238 and U-234 from yellow-cake operations are important. The emanation of Rn-222 could conceivably continue for several hundred thousand years as the activity of Ra-226 is in equilibrium with Th-230. However, the continued presence of these parent nuclides over such long periods seems unlikely and a mean residence time of 1000 years for radium and thorium has been assumed in some assessments. These studies estimate a collective dose-commitment varying from 10 to 33 kman-rem per GWyr for the different fuel cycles. This assumes that all Ra-226 moves from the tailings to fresh waters after 1000 years. The radon release makes only a minor contribution to the total effect. On the basis of detailed analysis, the contribution from the radioactivity remaining in mill tailings to the collective dose-commitment is small compared to that from natural background.

IAEA activities

The Agency has been active for many years in studying the radiological and technological bases for the management of uranium-processing wastes. Sessions pertaining to these subjects have been included in symposia, seminars and international meetings on waste management.

At the United Nations Conference on the Human Environment, which took place in Stockholm 4–16 June 1972, governments were asked to explore with the Agency and other appropriate organizations, international co-operation on radioactive waste problems, including the problems of mining and tailings' disposal. The IAEA has therefore maintained its interest in this field.

A manual on radiological safety in uranium and thorium mines and mills was published in 1976, in co-operation with the International Labour Organization (ILO) The IAEA convened a panel of experts to develop the background reference material required to formulate a code and guide on management of wastes from the mining and milling of uranium and thorium ores This was published in 1976 (IAEA Safety Series Report No.44). In approving the publication of the code and guide, Member States were recommended to take it into account when formulating national regulations.

Starting in 1978, IAEA expert groups have been considering the current practices and options for confinement of uranium mill tailings. A technical report on the subject will be published in 1981. This will present an overview of current practices for the impoundment of mill tailings, and of site selection. Related to the subject was a co-ordinated research programme on the source, distribution, movement, and deposition of radium in inland waterways and aquifers. This was performed in the years 1976 to 1980, and will result in a report in 1982.

In view of the developments which have taken place in recent years, and the current and future importance of this subject, it is considered timely to convene an international symposium in 1982 (in co-operation with OECD/Nuclear Energy Agency) to review processing technology and practices for the management of wastes from uranium mining and milling. This will be the first IAEA symposium devoted exclusively to this field and will provide an account of the status of research and development programmes with indications of any future developments which could be expected in the near future. It is planned to review and update the code and guide on management of wastes from the mining and milling of uranium and thorium ores, starting in 1982.

A heap-leaching project in Wyoming, USA, where uranium is recovered from low-grade material as leaching solution seeps through the piles of ore. The environment has to be protected from the effluents and wastes of this and other types of ore-processing operations by the methods described in the article.