The International Conference on Mine Waste Management – BAT Project Application.
2-3 June 2003, Wrocław, Poland. ISBN 83-906885-7-3

Christian Kunze
WISUTEC Wismut Environmental Technologies GmbH
Jagdschänkenstr. 33
D-09117 Chemnitz
www.wisutec.de
c.kunze@wisutec.de

Handling, treatment and disposal of naturally radioactive wastes (NORM) from mining and water treatment

Abstract

Some mining activities, particularly Uranium mining, but also other mining sectors and related fields, including the remediation of abandoned mining and processing facilities, generate wastes which must be evaluated from a radiological point of view and handled, treated and stored accordingly. These wastes contain naturally occuring radionuclides (NORM, naturally occurring radioactive material).

In this short paper, we will give a rough overview of activities in the field of mining, mining remediation and related areas where NORM wastes occur, how they are contaminated and how they are treated.

We will emphasise the need to find solutions for handling NORM wastes which are acceptable to all stakeholders which means solutions that are cost-effective while, at the same time, satisfying sensible requirements of those concerned with radiological safety.

After a general overview of origins and typical contaminations of NORM wastes we will focus on the rich experience obtained in the mining and milling site remediation project of WISMUT. Again, after an overview of the various types of NORM in the WISMUT project, we will focus on water treatment residues which allow us to highlight some of the typical features of NORM problems and solutions in a condensed manner.

1 Introduction: Sources of NORM wastes in mining and related fields

NORM wastes in mining and related fields occur whenever the materials (ores, coal, gas, water etc.) contain radionuclides or have contact with them. Radionuclides are ubiquitous, and are, in principle, present in all natural matter. Often however, the nuclide concentrations are relatively low so that they don't play any significant role.

However, there are some branches where radioactivity does play a role and hence needs to be considered:

- mining of minerals which are inherently radioactive (in particular, Uranium)
- mining of coal which contains small amounts of radioactive elements such as uranium which is concentrated to significant specific activities during processing
- extraction, pipeline-bound transport and purification of natural gas, where high concentrations of Radium-226 and Lead-210 may occur as incrustations in pipes and other equipment,
- mining of other minerals which are found in geological formations with elevated concentrations of radionuclides (e.g. in granite host rock)

It is not only the mined minerals as such which pose a radiological problem, but also the water which is pumped out of a mine during operation or after mine closure. In the process of mine flooding, large rock surfaces come into contact with water which acts as solvent and transport medium for radionuclides to the surface. The contaminated waters must then be treated, often over a long period of time, before the can be discharged directly into streams and rivers. When removing radioactive contaminants from mine water, they remain, highly concentrated, in the residues which must then be disposed of appropriately. In a sense, after-closure treatment of mine effluents is part of the life cycle of a mine and therefore forms an integral part of mining.

Often, the original material (minerals, gas etc.) does not contain any significantly elevated amount of radioactivity which would give rise for concern. However, in some technical processing steps, the activity is accumulated so that the resulting residues must be treated under radiological aspects, too. For example, scales (incrustations in gas pipes) may contain specific activities of up to some 100 Bq/g.

A striking example is the abstraction of raw water from streams with only minor radionuclide concentrations which is then purified for drinking water. In the sludges resulting from the purification process, radionuclides are strongly accumulated so that some operators of waterworks face problems with the disposal of their sludges. This often occurs in regions which are otherwise known to have an elevated natural radioactivity background. The resulting specific activity may reach some 10 Bq/g. The occurrence of NORM in the environment of drinking water purification often causes public concern.

There are also established radon spas in which the spring water contains also relatively high concentrations of Radium which must be removed before the water can be used for medical or wellness purposes.

Furthermore, there are cases where a certain level of radioactive elements has been present in water for a long time without causing any regulatory problems. Due to proposed lower levels for Uranium in drinking water, for example, regulators demand additional purification stages which produce residues which must be somehow disposed. Passive water treatment technologies (e.g., reactive filter materials) have been developed to reduce the Uranium content in the water (Hermann, Dullies, Griebel & Kießig 2001). But these filter materials become a NORM problem themselves because they must be disposed of somewhere. Although high capacities of some 100 mg Uranium per kg of filter material and above are feasible, it may be more cost efficient not to use the full filter capacity but to avoid the NORM disposal problem.

Some of these examples lead quite far away from the original mining context but they show that regulatory problems with NORM are a widespread phenomenon. Much can be learned from the mining sector where there is extensive experience in how to handle these problems. Uranium mining and the remediation of its legacy by WISMUT in Eastern Germany, can serve this purpose very well, due to the large amounts and the great variety of problems and solutions that have been developed.

2 NORM wastes: The WISMUT example

WISMUT GmbH, a company owned by the Federal Republic of Germany, is a direct successor to the former Soviet-German Stock Company Wismut, one of the largest producers of Uranium ores in the world. The legacy of WISMUT on which the efforts of the remediation activities of WISMUT have been focused since the early 1990's, is shown in Table 1.

Table 1 The WISMUT Project (1990)

a) The legacy (selected data)

- Rehabilitation of 3500 hectares of toxic and radioactive land with 31 open shafts
- 64 waste rock piles with 228 million m³ of NORM on 1080 hectares
- 10 tailings ponds with 154 million m³ of tailings on 685 hectares
- 256 km of underground mines beneath an area of 132 km²
- Open pit mine with 69 million m³ and 160 hectares

b) Actions involving NORM wastes (examples)

- Mines: flooding, treatment of effluents, producing NORM sludges which must be solidified and stored
- Waste rock piles and contaminated soil: backfilling of approx. 70 million m³ of NORM waste rock pile material into open pit
- Tailings ponds: removing of free water and dewatering the fine sludges, profiling of dams, seepage water collection and treatment
- Demolishing of contaminated buildings and equipment, decontamination and recycling of the NORM scrap and concrete rubble

The average specific activity depends on the type of the waste, of course. The following list gives typical ranges for some of the matter handled by WISMUT (Geowissenschaften 1996):

Table 2 Typical ranges of specific activities of NORM at WISMUT sites

Waste rock material: 0.5…5 Bq/g U_{nat}, 0.2…1 Bq/g Ra-226
Contaminated soil (e.g., under ore storage areas): 1…20 Bq/g
Surface contamination, scrap metal from mining installations: 0.1-20 Bq/m² (Pb-210, U-238)
Water treatment sludges 200…1000 Bq/g U_{nat}, 10…100 Bq/g Ra-226
Filter materials (biofilters, sorbents) in constructed wetlands: 20…200 Bq/g Ra-226

Apart from the radionuclides, the wastes (sludges, waste rock material etc.) are often also contaminated by toxic elements such as Arsenic and/or hazardous organics. Therefore, a conventional waste management problem must often be solved before the radiological aspects come into consideration.

We will now focus on the water treatment activities and the NORM wastes in this part of the Wismut remediation project, because they highlight many of the typical problems associated with NORM in general.

a) Volumes and time frame

A typical water treatment plant based on precipitation produces sludges at a specific rate on the order of 150 g per m³ treated water. At a flow rate of 1000 m³/h (such as at the Schlema mine site), this gives 1300 tons per year.

Some of the water treatment plants will be operated over a relatively long time span of at least 15 years. This means that also disposal space must be available over this time frame.

Immediately after flooding a mine, high contaminant loads in the mine effluent require a conventional chemical treatment. However, after some years of operation, the loads often drop significantly, and conventional treatment systems are no longer justified. They will be replaced by passive alternatives such as constructed wetlands, removing the inorganic contaminants by means of bacterial processes (e.g. sulphate reduction) or contaminant retention by macro-algae or plants. These systems, however simple they may be, generate wastes containing organic matter which must be dealt with.

b) Solidification

Sludges are solidified by Portland cement and/or filter ashes which gives satisfactory immobilisation of most heavy metals. If Portland cement is not sufficient with respect to long-term stability, Geopolymer is a proven alternative (Gatzweiler et al. 2001, Hermann et al. 1999). As a rule of thumb, solidification increases the volume of the residues by a factor of 2.

Solidification requires careful radiation protection measures, because the doses received by workers dealing with the wastes may be relatively high due to high gamma dose rates and dust.

c) Disposal

All WISMUT disposal sites for NORM wastes are situated either on waste rock piles, tailings beaches or otherwise previously contaminated sites where specific activities are elevated with respect to the natural background. So far, a policy has been maintained to dispose of the NORM where they belong to:

For example, a landfill for the sludge-concrete residues of the Schlema mine water treatment plant has been build on top of a waste rock pile stemming from operations at the same mine. The solidified sludges of the Helmsdorf tailings water treatment facility are stored on the dewatered fine grain beaches of the same tailings pond.

Depending on the quality of solidification, the requirements to the disposal site differ. Apart from the uniaxial pressure strength and leachate concentrations as prime measures for the stability of the solidified wastes, it is also the erosion of fine grain fraction if water infiltrates into the disposal site which is a criterion of how the disposal cell must be designed and monitored. The fine grain fraction shows especially high specific concentrations of radionuclides.

If long-term stability can be shown by artificial stress tests, the requirements to the barriers and monitoring of a disposal site can be greatly relaxed. For example, Geopolymer has been approved by authorities as a binder guaranteeing highest long-term stability. Its higher cost are more than compensated by the weaker standards set by regulators for the disposal site (e.g., infiltration barriers, bottom liner etc.).

d) Acceptance of NORM from other sources

A question often asked if whether NORM wastes from other sources (outside of WISMUT) could be accepted at WISMUT sites. Although it would be technically feasible, the formal and regulatory aspects still need to be evaluated. For the time being, NORM wastes can be disposed of at mining and/or milling sites if their origin is clearly related to WISMUT.

3 NORM wastes in mining: some lessons learned

How NORM wastes are evaluated and subsequently treated and disposed of, depends very much on the national regulatory framework. However, there are some basic principles which we believe to be valid despite national differences:

- If radioactive materials must be disposed of, it is sensible to use sites which are already contaminated or where NORM wastes are already present for other reasons. Opening up a new, formerly uncontaminated, site could be unacceptable to local stakeholders, and thus cause long delays.
- There are often limits to the dose rate for workers and the public (say, 1 mSv per year) which must be obeyed when handling and disposing of NORM wastes. Computer-based dose calculation models such as DosMod® by B.P.S. Engineering have been developed to assess the effective dose for all possible exposure pathways, and enjoy wide acceptance with regulators.

- Alternatively there is an exemption limit below which NORM wastes are allowable to be disposed in a landfill (e.g., 10 Bq/g of a single nuclide or a series of them, or 50 Bq/g if the landfill satisfies additional requirements), while the fraction above the limit must be stored elsewhere, often at very high cost. Separation of a small but higher contaminated fraction from the large rest can significantly reduce the disposal costs. Good examples are contaminated rubble and scrap metal from the demolition of mining and milling installations.
- Simple measurement procedures can greatly help in clearing contaminated from uncontaminated fractions. Ideally, regulators should be involved in the technical development process in order to have their acceptance when it comes to the operational application of the techniques.
- Solidification of NORM wastes (particularly sludges, incrustations and similar solid or wet residues) which leads to immobilisation of radionuclides over a long time horizon, can often help to reduce the effort required at the landfill or disposal site itself. For example, the use of Geopolymer®, an inorganic binder based on alkali-activated alumo-silicate (Hermann et al.1999), has made it possible to dispose of NORM residues from the gas industry on an ordinary industrial landfill in Germany (Hermann and Kunze 2001, Gatzweiler et al. 2001). In other cases, Portland cement is sufficient as binder, but requires more care in designing the disposal site to prevent uncontrolled release of contaminants.
- In most cases, toxic and radioactive components are inseparably part of the wastes. Therefore, before considering the radiological part of the problem (which is often new and confusing to authorities), all technical questions related to the toxic "ordinary waste management" part of the waste should be solved.
- In some national legislations, the mining sector enjoys a number of formal simplifications as compared to other industries. For example, handling of NORM and other wastes is much simpler under the German Mining Act for mine operators if the wastes stem from their own mining activities. In this case, the usual landfill and disposal directives apply only to a limited extent. It may well be that similar simplifying regulations exist in other countries as well.
- Last, but not least, consultation with an expert who knows both the radiological and the "ordinary" waste side, has handled problems of sufficient scale, and has a good understanding of the technologies that are available and suitable, should be sought.

4 References

Gatzweiler et al.: WISMUT remediation – Concepts and technologies. Geowissenschaften 14 (1996), issue 11, pp. 448-451

Gatzweiler R., E.Herrmann, G.Kießig., C.Kunze, P.Schmidt: Treatment and disposal of NORM at special landfill sites and former uranium mining sites in Germany – Practical approaches and solutions. NORM III, Brussels, 17-20 September 2001

Geowissenschaften: Volume 14, issue 11 in 1996 of the journal Geowissenschaften was dedicated to the WISMUT project. Many of the data was drawn from there.

Hermann,E., F.Dullies, I.Griebel, G.Kießig: Filter Material and Process for the Removal of heavy metals, Arsenic, Uranium and Radium from contaminated waters. Patents DE 101 16 951, DE 101 16 953 (2001)

Hermann,E., C.Kunze, R.Gatzweiler, G.Kießig, J.Davidovits: Solidification of various radioactive residues by Geopolymer with special emphasis on long-term stability. Proc. 2nd Int. Conf. Geopolymers, Saint Quentin 1999

Hermann, E., Kunze, C.: Schadlose Beseitigung von Rückständen mit erhöhten spezifischen Aktivitäten natürlicher Radionuklide. Umweltpraxis 1-2 (2001)

Weise et al.: Geochemical Aspects of the remediation of waste rock piles at the Ronneburg site. Geowissenschaften 14 (1996), issue 11, pp. 470-475