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Decommissioning and Rehabilitation of Uranium and Thorium Production Facilities

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Abstract

The use of nuclear energy for military as well as for peaceful purposes was and remains closely connected with the mining and processing of uranium ore and, to a lesser extent, of thorium ore. Mining and processing of radioactive ores are characterised by the generation of huge amounts of radioactive residues, massive impacts upon ecosystems, landscape reshaping (or devastation in some places), and the monostructural socio-economic orientation of human settlement areas. However, a great number of the mines and mills commissioned during the cold war have been already closed, either for deposits being depleted of economically recoverable resources or on political grounds. The specifics of U/Th mining and milling make high demands on the decommissioning and rehabilitation of the production facilities which in addition to radiological aspects would have to address issues such as water pollution control and soil conservation, future site re-use, landscaping, and infrastructure development. The present paper gives an overview of the state of decommissioning and rehabilitation of U/Th production facilities. Radiological specifics and their integration into the decommissioning and rehabilitation management are demonstrated for the rehabilitation of uranium mining legacies in Saxony and Thuringia.

1 Introduction

Discovery of nuclear fission in 1938 and the emerging possibility to use nuclear energy from uranium fission reactions immediately boosted mining and processing of uranium ores. With the onset of the cold car, the quest for nuclear weapons became an issue of global dimension. This quest, but later also the construction of reactors for the peaceful use of nuclear energy on an industrial scale added a new dimension to uranium production worldwide. In addition to uranium, the use of other elements such as thorium was tested as feed material for the fuel cycle.

Mining and processing of uranium and thorium ores with cut-off grades in the order of some hundred grams per tonne ore are associated with the generation of low and medium-level radioactive wastes. From the end of World War II to the mid-sixties, production caused massive environmental impacts, landscape reshaping (or devastation in some places), and the monostructural socio-economic orientation of human settlement areas. As a consequence thereof, operators and stakeholders in a number of uranium and thorium producing countries are confronted with enormous challenges when it comes to decommission facilities and rehabilitate legacies of U/Th mining and processing.

2 Development of worldwide uranium and thorium production

During the 1950ies and 1960ies, along with the U.S., Canada, South Africa, and France became major uranium producers among western countries. In the 1970ies, Australia, Namibia, Gabon, and Nigeria rose to major producers. Figure 1 illustrates the development of uranium production in those countries. Further WOCA producers (but of lesser importance) include or included, respectively, Argentina, Brazil, Finland, Japan, Sweden, Spain, Portugal, and Vietnam.

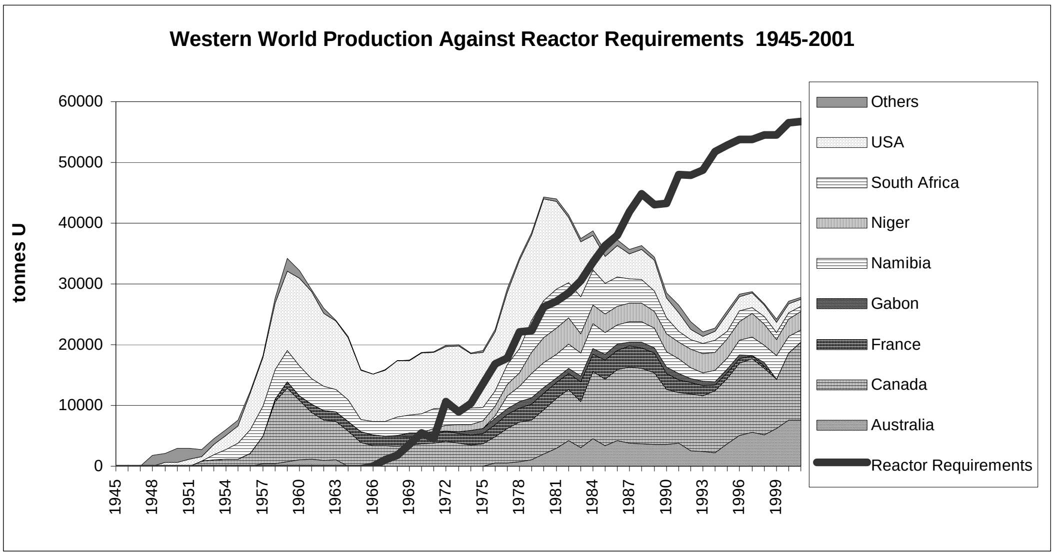

Fig 1: Development of uranium production in WOCA countries (Source: World Nuclear Association Market Report, http://www.world-nuclear.org/info/infh23.htm)

At the end of Word War II, the Soviet Union initiated its own all-out nuclear arms production programme. At that time little was known of uranium deposits located in the Ukrainian, Kazakh, Kirgiz, and the Estonian S.S.R. as well as in the Russian S.F.S.R. and they were in fact undeveloped and totally insufficient to meet the rising needs. As a consequence, prospecting for and mining of uranium ore was pushed across East European countries occupied by the end of the war, in particular in East Germany and Czechoslovakia. Figures on East European uranium production similar to those in Figure 1 were never published till this day, which is certainly due to the secrecy that prevailed throughout the Eastern bloc. However, comparisons made after the iron curtain had come down showed that the GDR was ranking third among world uranium producers.

With the exception of the Czech Republic and Rumania, the former Soviet allies either reduced or discontinued uranium production after the fall of the Berlin wall though uranium production increased in some of the former Soviet Republics. Figures for 2003 on uranium production from mineral deposits[1] show Kazakhstan's rank third, with Russia as number five, and Uzbekistan as number seven among the world's uranium producers (see Table 1).

Table 1: Current uranium production from mineral deposits (in tonnes; source: World Nuclear Association Market Report)

Rank 2003	Country	2001	2002	2003	Rank 2003	Country	2001	2002	2003
1	Canada	12520	11604	10457	10	South Africa	873	824	758
2	Australia	7756	6854	7572	11	China	655	730	750
3	Kazakhstan	2050	2800	3300	12	Czech Rep.	456	465	345
4	Niger	2920	3075	3143	13	Brasilia	58	270	310
5	Russia	2500	2900	3150	14	India	230	230	230
6	Namibia	2239	233	2036	15	Germany*	27	212	150
7	Uzbekistan	1962	1860	1770	16	Rumania	85	90	90
8	USA	1011	919	857	World	Uranium	36366	36063	35813
9	Ukraine	750	800	800	World	U_3O_8	42886	42529	42234

* uranium from mine water treatment under the Wismut environmental restoration project

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[1] Uranium conversion from nuclear warheads today accounts for a significant portion of nuclear reactor fuel.

Although thorium is not itself a nuclear reactor fuel since it will not sustain a chain reaction, it is expected to become increasingly important for conversion into the fissionable fuel uranium-233. To date, thorium as a nuclear fuel is limited to the laboratory stage (test facilities were operated in Germany, India, Japan, Russia, UK, and USA) and a few commercial applications. The mining and processing of thorium ores was and continues to be promoted by non-nuclear applications based on the ThO_2's extremely high boiling temperature of some 3,300°C which makes it eligible for use in welding, production of light bulbs and electronic tubes, and in the ceramics sector.

Countries that developed or develop thorium production which in terms of radioactive residues from thorium ore processing are of interest with a view to forthcoming decommissioning and cleanup include Australia, China, Brazil, India and Malaysia. Figure 2 illustrates the development of world-wide thorium production since 1990 (Source: US Geological Survey, http://minerals.usgs.gov/minerals/pubs/commodity/thorium/690400.pdf). In addition to the countries listed, Indonesia, North Korea, the Republic of Korea, Nigeria, and the former U.S.S.R. may produce thorium, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

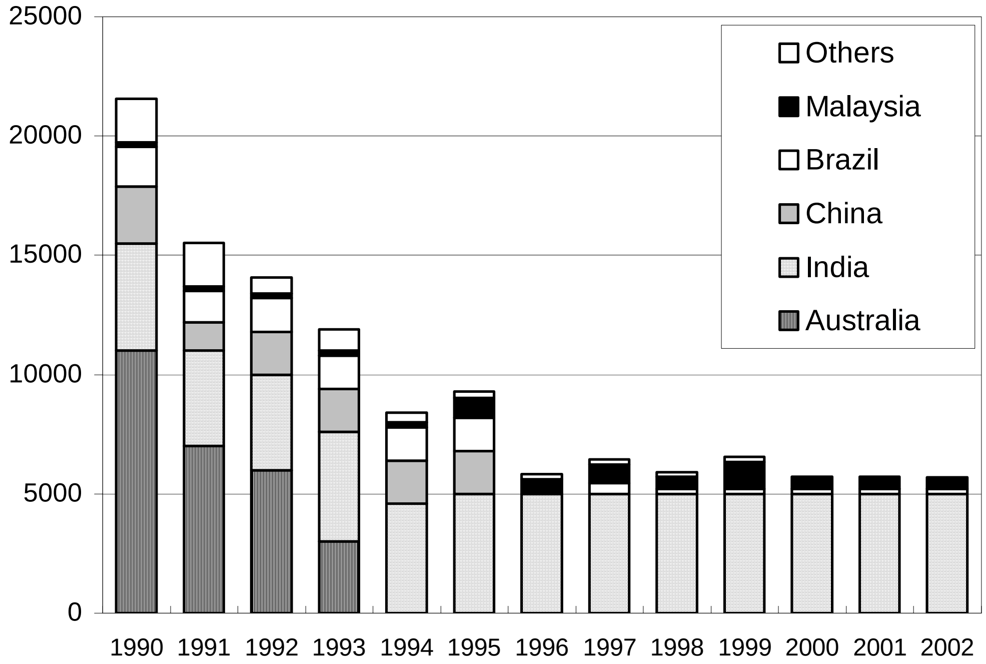

Fig. 2: Development of the thorium production world-wide (in tonnes).

3 Uranium/Thorium production: impacts, decommissioning and rehabilitation options

Uranium and thorium occur in the earth's crust in average concentrations in the order of 2.7 ppm and 8.5 ppm (g/t rock), respectively. However, for a deposit to be in a workable condition, the cutoff grade is 100 ppm. Production of uranium (and to some extent of thorium) involves one of the basic options below:

a) underground mining, chemical processing on surface;
b) open pit mining, chemical processing on surface;
c) underground or surface in-situ leaching (ISL), uranium extraction from the leach liquor on surface.

These options entail different environmental impacts which have to be taken into account in decommissioning and rehabilitation of mining legacies. What the first two options have in common is that they produce enormous amounts of low to medium level radioactive wastes. Piled up waste rock from underground mining shows specific activities in the order of 0.3 – 1 Bq/g U-238, in radioactive equilibrium with decay products. Ore processing on surface involves leaching (both acid and alkaline flow sheets). Major uranium processing sites include sophisticated complex structures as shown in Figure 3. Sludges from ore processing (tailings) are deposited in tailings impoundments (or tailings ponds). Specific activities of tailings for the predominant nuclide Ra-226 are in the 2 – 20 Bq/g range. The nuclide vector in the tailings is out of equilibrium to the disadvantage of the extracted uranium. Ra-228 is the predominant nuclide in mill effluents from thorium ore processing. In addition to radionuclides, other minerals mined from the deposits as well as chemicals used in the mill process are of environmental relevance (sulphates, nitrates, heavy metals, etc.).

Fig. 3: Former uranium ore processing plant at Seelingstädt in Thuringia, East Germany (photo shot in 1991, the facility has been demolished and the site reclaimed)

In-situ leaching involves adding chemicals to the ore to be treated in place. Acid leaching using sulphuric or nitric acid is a very common flowsheet. The acids penetrate a water-saturated geological ore formation (underground) or a pile of high-grade ore (on surface) to mobilise the uranium. The leach liquor is intercepted in underlying geological layers (underground) or at the toe of the pile (on surface). The metal is then extracted from the pregnant liquor. Extraction may involve precipitation processes or use of ion exchange resins. In quantitative terms, this procedure produces less residues (resin, slurry) than conventional U/Th production involving mining and processing on surface. As a consequence, the higher specific activities of the residues are in the 10 to 100 Bq/g range. There are significant environmental impairments due to the addition of chemicals. This goes in particular for the underground in-situ leaching which might have an impact on ground water quality. Table 2 below lists the remaining objects and residues at u/th production sites, risks of environmental impairments, and decommissioning and reclamation options.

Table 2: Residues, environmental impairment, and reclamation options

a) Conventional mining

Remaining objects/Residues	Environmental impairment/ Exposure pathways	Reclamation options
Underground ore mining		
Mine	Ground water contamination when the mine is flooded	Controlled flooding with pumping of mine water to surface for treatment
	Subsidence, surface break	Stabilisation of near-surface workings (backfilling)
Mine dumps	Water contamination / Radon inhalation; external radiation; incorporation of contaminants;	Relocation of mine dumps (underground voids, remote locations); in-situ reclamation involving regrading, capping, and seeding
Open pit mining		
Worked-out open pit, mine dumps	Landscape devastation, impact on ground water,	Moving mine dumps into worked-out open pit, capping

b) Ore leaching, ore processing

Remaining objects/Residues	Environmental impairment / Exposure pathways	Reclamation options
Underground in-situ leaching		
Contaminated rock formations	Impact on ground water	Disturbance of ground water flow, controlled flooding, water treatment
Surface in-situ leaching		
Leach dumps and pads, also chemical contamination	Contamination of water bodies / radon inhalation; external radiation; incorporation of contaminants;	Relocation of mine dumps (underground voids, remote locations); reclamation in-situ involving regrading, capping and seeding
Contaminated dump bases	Impact on ground water, use restriction	Surface remediation (excavation /disposal of material), soil remediation in-situ
Chemical ore processing / Uranium extraction		
Tailings	Impact on ground water / radon inhalation; external radiation; incorporation of contaminants;	Dry in-situ stabilisation (slimes dewatering, capping, water treatment), wet in-situ stabilisation

c) Plant buildings and facilities

Remaining objects/Residues	Environmental impairment/ Exposure pathways	Reclamation options
Contaminated buildings and structures	Use restriction	Dismantling and demolition, decontamination, salvage, disposal of contaminated materials
Contaminated plant areas	Impact on ground water, use restriction	Surface remediation (excavation /disposal of material), soil in-situ remediation

An analysis of exposure pathways based on typical radiological parameters reveals that radiological exposure to the public from legacies left by mining may be at the level of or in excess of natural radiological exposure. Figure 4 shows the findings of the analysis for an infant of the age group 2 - 7 years and an adult reference person living permanently in the immediate vicinity of a sizeable uncapped mine dump and watering their garden with contaminated seepage. The study was based on the following assumptions:

- average specific activity of U-238 in waste rock material = 1 Bq/g, in radioactive equilibrium with daughter nuclides;
- concentration of Rn-222 on and alongside the mine dump: 150 Bq/m³;
- gamma dose rate on and alongside the mine dump: 650 nSv/h;
- concentration of long-lived alpha emitters on and alongside the mine dump: 1 mBq/m³
- concentrations in seepage: 1 mg/l U_{nat} ; 0.5 Bq/l Ra-226; 0.1 Bg/l Pb-210 in radioactive equilibrium with Po-210; 0.01 Bq/l Pa-231 in radioactive equilibrium with Ac-227.

Dose calculation was done in compliance with [BbergB-99] for subsequent exposure pathways:

- ingestion of contaminated horticultural products (Food)
- external radiation (Ext)
- inhalation of Radon and of Radon decay products (Rn/DPr)
- inhalation of dust-borne long-lived alpha emitters (LLA-Inh)
- direct ingestion of waste rock material (Dir-Ing)

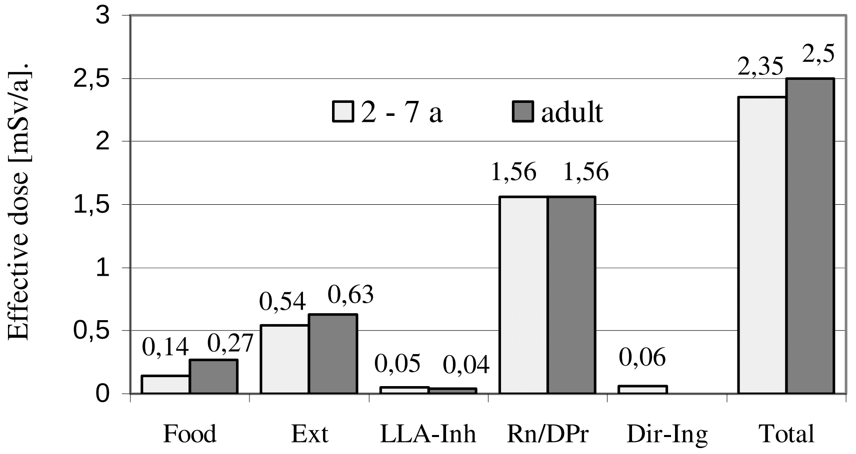

Fig. 4: Typical radiological exposure to locals from unremediated mining legacies

Generally one can say that the process of decommissioning and rehabilitation of large uranium mining facilities and the mitigation of environmental impacts is both time-consuming and expensive, and that its optimised implementation calls for thorough expert knowledge. In terms of radioactive inventory, the dimension of wastes involved is comparable to the disassembly of nuclear facilities since the volumes of material to be dealt with are eight to nine orders of magnitude greater than those from a nuclear reactor while specific activities are in the same order of magnitude smaller. This is the reason why costs inferred with the decommissioning of large uranium production facilities are comparable to those incurred by the decommissioning of nuclear power stations.

Decommissioning and rehabilitation of U/Th production facilities is a complex process involving iterative approach of gradual steps (see Figure 5):

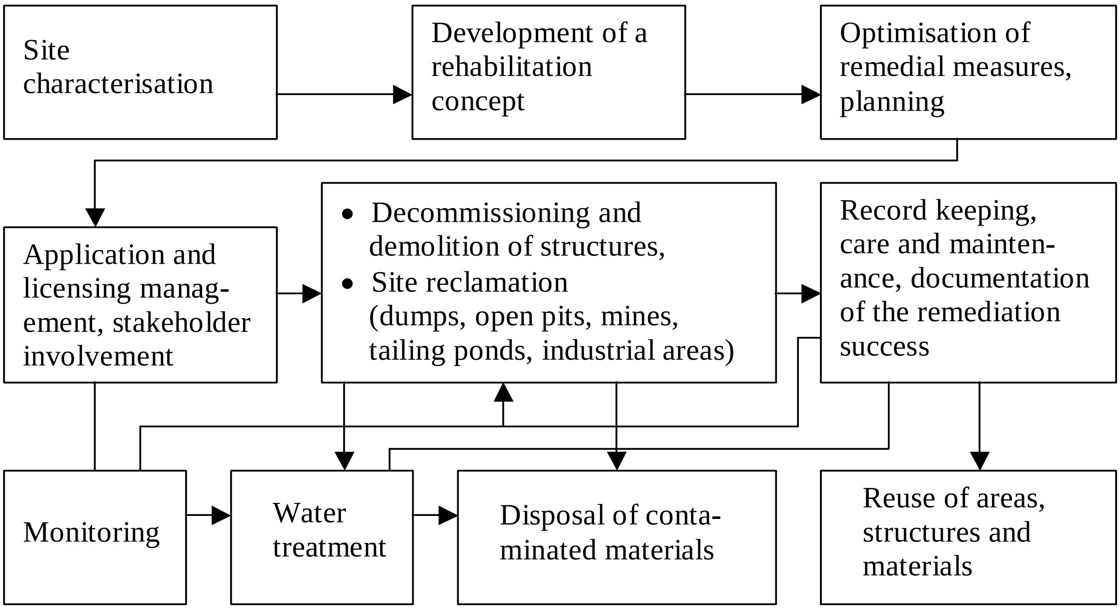

Fig. 5: Stages in decommissioning and rehabilitation of U/Th production facilities

Decision-making on remediation measures has to take radiological environmental impacts into account as well as the spread of conventional contaminants (As, Ni, Cu, Fe, chemicals from the mill process, etc.). In addition to potential environmental impacts, decisions will have to consider regional and local site development plans (zoning, ideas on infrastructure and socio-cultural development). Over and above cost-benefit considerations, optimisation of the remedial project will have to pay due attention to stakeholder interests.

4 State of decommissioning uranium production facilities

Sites in the U.S. (mainly located in Colorado, Arizona, New Mexico, Utah) and also in France (mainly located in the Massif Central region: sites of Bessines, Le Cellier; in Southern Brittany: Ecarpière, Commanderie) which used to be major uranium production centres have lost their former importance. In France, uranium mining ceased in 2002. The same holds true for Canada where a great number of mines and mills were closed (mainly in the provinces of Ontario, Saskatchewan, Northwest Territories), while at the same time new important deposits were developed in Saskatchewan in particular. These countries implemented sizeable decommissioning projects. Of outstanding importance is the UMTRA Programme (Uranium Mill Tailings Remedial Action) in the USA. Under this programme, a great number of remedial technologies were developed and pilot solutions devised. Under the Programme, a total of 24 processing sites (of that number 10 in Colorado alone) with 5,200 associated vicinity properties were comprehensively shut down and rehabilitated since 1978 (see http://web.em.doe.gov/bemr96/umtra.html).

In Western and Central Europe there is no longer uranium production worth mentioning. The Czech Republic alone continues uranium mining to be phased out in the very near future. Decommissioning and rehabilitation of production facilities in France is almost complete. In Sweden, shutdown of the Ranstadt site initiated a reference project and generated remedial experience that is applied to sites of comparable locations and size (Ranstadt Project, 1990 – 1993). In African countries, co-operation of large-scale enterprises headquartered in Western Europe and North America ensures that decommissioning and rehabilitation are conducted in compliance with advanced standards /OEC-02/.

The situation in Eastern Europe is completely different with three particular features common to all countries which distinguish them from large-scale remediation projects overseas:

1. Termination of production in these countries was very abrupt in the wake of political changes in 1990/1991. No preparations had been made to initiate decommissioning, remedial concepts and know-how were available on a limited scale only.
2. No financial reserves were established during the time of production. Given the economic situation in those countries, state-run enterprises were unable to perform remediation according to western standards at short notice.
3. Uranium production in East European countries was mainly located in densely populated areas which greatly adds to the remediation challenge.

To date not a single decommissioned project in the former Soviet republics (with the exception of Estonia) has been put to remediation along state-of-the-art lines. Facilities were closed (e.g. Lermontov, Russia; Ust-Kamenogorsk, Kazakhstan) but are still awaiting final remediation. Remediation concepts are currently being developed under the TACIS Programme of the European Commission.

In former Eastern bloc countries and Estonia, different emphasis was placed on decommissioning and remediation efforts which to some extent were supported by the European Commission's Phare Programme, by the World Bank, by NEFCO, and other financial backers. The following Table 3 gives a survey of facilities (data collected in 1997, in the context of /PHA-97/) and the state of decommissioning in 2003 /UMR-03/:

Table 3: Uranium mining legacies and state of decommissioning in former Eastern bloc countries

Country	No. of sites	Mill sites	ISL sites	Wastes [million t]:		State of decommissioning and rehabilitation (2003)
				Dumps	Tailings	
former GDR*	8	2	2	311.5	160.8	remediation well advanced, see chapt. 6
Czech Rep.	13	4	38	51.9	54.9	under way, ongoing production
Bulgaria	31	2	37	11.0	19.5	technical winding-up complete; no remediation to western standards
Hungary	3	1	1	10.4	16.6	remediation nearly complete
Rumania	4	1	-	8.4	4.3	continued mining and production
Estonia	1	1	-	-	8.0	remediation well advanced
Slovenia	1	-	-	1.6	0.7	remediation well advanced
Poland	6	1	-	1.4	0.13	remediation well advanced
Slovakia	3			1.0	-	technical winding-up complete; no remediation to western standards

* Relates to objects belonging to the former Soviet-German stock corporation SDAG WISMUT, ownership of which was transferred to the Federal Republic of Germany in 1991. Since then, these objects were decommissioned, and reclamation is in different states of completion (see Chapter 6). In addition to these objects, there is a number of smaller objects which were abandoned before 1953 with transfer of ownership but were not remediated to meet present-day requirements. Jointly funded by the German Federal Government and the State of Saxony, rehabilitation of such contaminated sites was initiated in 2003.

Costs of decommissioning and rehabilitation are country- and site-specific. They are determined by the type of mining method used, by infrastructural and organisational conditions, national environmental standards, labour costs, and costs of materials. /OCE-02/ quotes unit costs (without water treatment) for the decommissioning and remediation of uranium mines in a range from US$0.76 to US$16.9 per tonne of mined uranium ore or of US$0.55 to

US$13.62 per kg of uranium produced, respectively. Costs of decommissioning and remediation of mill plants (again without water treatment) are in the range from US$3.1 to US$32.9 per kg of uranium. Inclusion of water treatment will push up costs between 10 and 50 %.

5 National and international legislation and recommendations

On the part of competent US agencies (EPA – US Environmental Protection Agency; FDA – U. S. Food and Drug Administration, DOE – U. S. Department of Energy) high standards were set for the decommissioning and remediation of uranium production facilities during the 1980ies (e.g. in /EPA-83, EPA-89/, DOE-95/). These standards emerged as a yardstick for national and international legislation and recommendations. Meanwhile, countries confronted with decommissioning and rehabilitation of uranium and thorium production facilities have all enacted appropriate legislation and standards (see National Reports in /OECD-02/). International organisations such as IAEA have adopted their own recommendations and standards, e.g. /IAE-92, IAE-94, IAE-97a/. IAEA and OECD/NEA attach the same importance to the decommissioning of U/Th production facilities as to that of nuclear facilities /IAE-97b/. This is reflected by symposia (e.g. /IAEA-00/), advanced training courses, expert delegations, funding of study visits, and direct project participation. In the framework of Phare and Tacis programmes, the European Commission has promoted numerous projects in Eastern European countries and in the former USSR in recent years.

In Germany, rehabilitation of the uranium mining legacies left by SDAG WISMUT is to a certain extent regulated by laws and ordinances enacted by the former GDR /VOAS-84, HAO-80/ which made provisions for the handling of uranium mining legacies in Saxony and Thuringia and which therefore continue to be applied. Moreover, the Radiation Protection Ordinance applies to workers' protection. The German Commission on Radiological Protection has published additional recommendations /SSK-92/. Justification of remedial measures is substantiated in /SSK-92/ with the 1 mSv/a criterion as a primary effective dose guidance level. This level is geared to the variation width of the natural radiation exposure. Meanwhile, other European countries do also apply this criterion to the remediation of mining legacies. It is comparable to the "clean-up criterion" of 1 mSv/a above background as recommended in the U.S. and in Canada and to be applied to areas contaminated with natural radionuclides.

6 Case study: Rehabilitation of mining legacies in East Germany - the WISMUT Project

Originally a Soviet state-run company, converted into a joint Soviet-German stock company in 1953, SDAG WISMUT operated uranium mines and processing facilities from 1947 through 1990. The company's cumulative production of 231,000 tonnes of uranium made the former GDR rank third among uranium producers world-wide. In times of maximum output, WISMUT employed a workforce of up to 130,000; it had been slimmed down to 28,500 when production was terminated. Since 1991 the federal government-owned Wismut GmbH is rehabilitating uranium mining legacies at the Königstein, Gittersee, Aue, Pöhla, and Crossen sites in Saxony as well as at the Ronneburg and Seelingstädt sites in Thuringia (see http://www.wismut.de). The current workforce is 2,300 strong. The size of the affected areas and the fact that uranium mining in East Germany had been conducted in densely populated areas with detrimental effects on the environment and human living conditions gave rise to one of the most challenging decommissioning and rehabilitation projects world-wide /HA-00, JAK-02/. The sheer dimension of the project is illustrated by the legacies listed in Table 4 :

Table 4: Uranium production legacies in Saxony and Thuringia, Germany

Site		Aue Pöhla	Königstein Gittersee	Ronneburg	Seelingstädt Crossen
Operation		ore mining	ore mining underground leach.	ore mining	milling
Plant area		5.7 km^2	1.4 km^2	16.7 km^2	13.1 km^2
Mine dumps	number	20	3	16	9
	area	3.7 km^2	9.4 km^2	6.0 km^2	5.3 km^2
	volume	47 million m^3	4.5 million m^3	188 M m^3	72 million m^3
Tailings ponds	number	1	3	3	7
	area	0.035km^2	0.046km^2	0.09km^2	7.1 km^2
	volume	0,3 million m^3	0,2 million m^3	0,25 million m^3	160 million m^3
Open pit mine	number			1	
	area			1.6 km^2	
	volume			84 million m^3	

Given different hydrological, geological, and morphological conditions as well as the different types of mining methods employed, the main emphasis in decommissioning and rehabilitation operations varies from site to site:

In **Aue/Pöhla** emphasis of decommissioning and rehabilitation operations is both on mine flooding and waste rock pile remediation. Waste rock piled up in and close to the town of Schlema-Alberoda (Aue site) is a source of radon emissions which cause unacceptable effective population doses via the exposure pathway inhalation of radon and its decay products. Most waste rock piles are remediated in place. Major remediation phases include regrading of slopes, capping with a cover of consisting typically of 0.8 m of inert material and an overlying layer of 0.2 m of topsoil, and seeding for revegetation.

During flooding of the **Königstein** mine, aquifer protection against pollution due to former underground leaching has top priority. To this end, WISMUT conceived and implements the concept of controlled flooding with mine water being pumped to surface for treatment.

In addition to mine flooding, rehabilitation at the **Ronneburg** site is dominated by the relocation of more than 120 million m^3 waste rock material into the worked-out Lichtenberg open pit mine. A haul fleet of dump trucks – some carrying up to 136 tonnes – is on the job hauling some 40,000 cubic metres of waste rock daily (see Figure 6).

Fig. 6: Backfilling of the worked-out open pit mine

At the former uranium mill sites of **Seelingstädt** and **Crossen**, remedial operations focus on demolition of structures, surface cleanup, and tailings pond stabilisation. Stabilisation of tailings impoundments (removal of supernatant water, increase in shear strength by pore water removal using vertical drains, covering with geotextiles) and the covering of exposed tailings are technologically challenging tasks which are both time-consuming and expensive (see Figure 7).

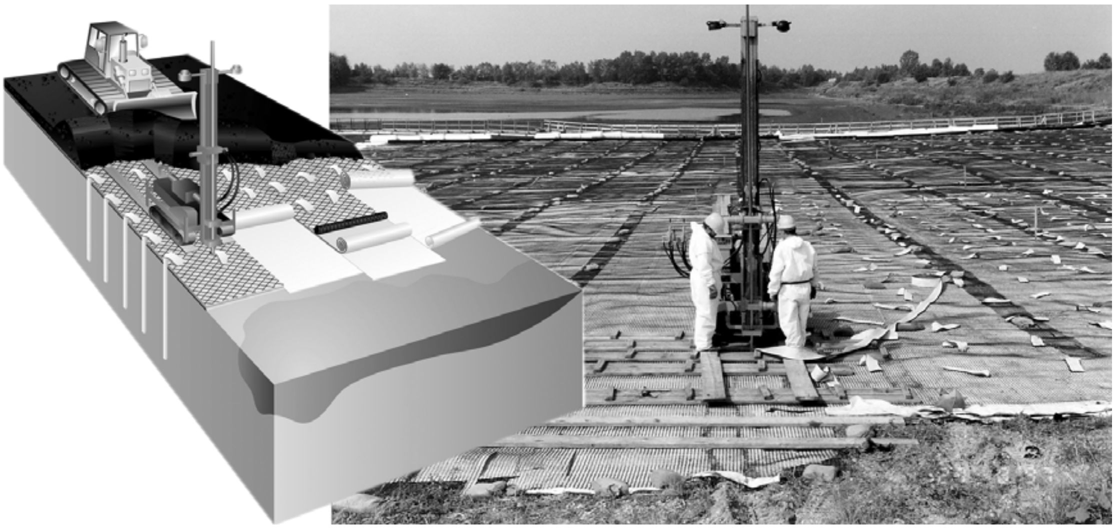

Fig. 7: Technology used to stabilise tailings impoundments, installation of vertical drains on the Trünzig tailings pond, subsite of Seelingstädt

The WISMUT environmental restoration project includes both site-specific and site-spanning operations:

Water treatment: State-of-the-art water treatment plants (WTP) are on stream at all WISMUT sites. These plants use various techniques to remove radiological main components (uranium, Ra-226) as well as chemico-conventional contaminants (As, Mn, Fe, etc.). Feed includes mine water, seepage from mine dumps and tailings ponds as well as water from the consolidation of tailings impoundments. WTP capacity range is from 20 to 1050 m^3/h. Studies are under way to develop passive water treatment procedures (constructed wetlands, reactive barriers) to replace treatment plants in the long-term.

Waste management and residue disposal: Water treatment produces residues with specific activities of U-238 and Ra-226 in a range from 5 to 500 Bq/g, depending on site-specific conditions. Residues generated amount to almost 30,000 t annually. Specific immobilisation procedures were developed for such residues which following immobilisation are deposited in engineered areas of waste rock piles or tailings impoundments.

Besides residues, remediation produces materials having the most different levels of contamination such as 350'000 m^3 of concrete and masonry debris as well as 260,000 t of scrap metal. Depending on the level of contamination, tailor-made technologies allow the separation of higher-level materials for disposal or the release of lower-level materials for recycling.

Environmental monitoring: The remedial process is prepared by numerous studies and investigations, its implementation is monitored, and following completion the remedial success and performance are documented by long-term monitoring. Monitoring relates to contaminant components via the air, soil, and water pathways as well as geotechnical and subsidence parameters. The basic environmental monitoring programme currently samples 360 ground water levels and 337 air quality measurement points.

The Federal Republic of Germany has earmarked a total of €6.2bn for the remediation of the legacies left behind by WISMUT (equal to €26.8 per kg of uranium produced, see chapter 5). Out of this total for the entire project, €4.3bn (= 69 %) were spent by mid-2004. Processing plants have completely gone. Current effort is on surface remediation. Waste rock piles will be for the most part rehabilitated by 2012; the same goes for mine flooding. It is anticipated that stabilisation of tailings impoundments will be complete by 2015. Post-remedial care and maintenance to ensure performance, treatment of contaminated waters, and environmental monitoring will be a longer-term effort.

At the end of the day, success of the WISMUT environmental restoration project will be judged by the following criteria:

- rehabilitated objects no longer represent any serious risk to public health nor any unacceptable environmental impairment;
- minimum or next to no care and maintenance;
- remedial solutions are chiming in with regional and local land development plans.

The last item is exemplified by the development of the Schlema-Alberoda community, Aue site. Ranking high among leading Radon spas in Europe before 1945, Schlema was hard hit by uranium mining operations of SDAG WISMUT, in particular by the piling up of more than 47 million m^3 of waste rock right among or very close to residential areas. By 1998, with the mine installations gone and mine dumps rehabilitated, spa activities could be resumed. Present-day Schlema is a booming community which has returned to the fold of top spa locations.

Last but not least, unique experience and know-how were gained from the WISMUT environmental restoration project. WISMUT experts apply these findings to environmental projects in Germany and abroad. In the framework of TACIS and Phare programmes, projects are either under way or completed in Bulgaria, Estonia, Kazakhstan, Russia, Slovenia, and Hungary. Since 2002, know-how gained during the remediation process is marketed by the subsidiary WISUTEC Wismut Umwelttechnologie GmbH.

7 Conclusions

Decommissioning and rehabilitation of U/Th ore mining and processing sites represents a challenge in ecological and economic terms for many a former site operator. The amount of wastes from production, environmental impacts, and monostructural development of mining districts add to the complexity of the task. Early planning of decommissioning and rehabilitation activities was a common feature in corporate strategies and national programmes in Western Europe and North America. In Eastern Europe, on the other hand, great efforts will have to be made to ensure an economically sound shift from production to decommissioning and rehabilitation in compliance with local and national development plans. Any evaluation will have to take into account that these countries must not be lumped together. International organisations back this process by appropriate funding and promoting transfer of know how.

8 Reference

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