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Uranium mining in East Germany ("Wismut"): health consequences, occupational medical care and workers' compensation

Abstract Underground uranium mining was performed in East Germany after World War II on a large scale. Working conditions were very poor during the post-war years from approx. 1946 to 1955. During later years mining conditions improved. In 1990, uranium production was generally stopped as a consequence of German reunification. A company-based health care system commenced in the early years with an annual routine medical check-up including chest X-ray. A central Wismut institution for occupational medicine was founded in 1968. Since reunification, the German Workers' Compensation Board is organizing post-exposural occupational medical care and compensation for former miners. Compensable occupational diseases include silicosis and Schneeberg lung disease (bronchial carcinoma of uranium miners). A current topic is the question of acknowledgement of extrapulmonary malignoma as a compensable disease in uranium miners. With a certain cumulated exposure as a prerequisite, bone and liver cancer and certain types of leukemia are likely to be accepted.

Key words Uranium mining · Radon · Ionizing radiation · Occupational disease · Extrapulmonary cancer

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Introduction

After World War II, in the part of Germany which was occupied by the Soviet Union and later became the German Democratic Republic (GDR), uranium mining was performed on a large scale. Working conditions were very poor during the first post-war years. There was a significant chronic exposure to ionizing radiation and other health hazards.

The following review gives a short historical summary and depicts the spectrum of exposure to potentially harmful agents and the subsequent health impairments and diseases. The current status of exposure assessment, medical care for the former Wismut miners and compensation for occupational disease is described.

History of mining in the Ore Mountains/uranium mining in the German Democratic Republic

For centuries the Ore Mountains in Central Europe, which divide Saxony and Bohemia, have been one of the most important mining regions in the world [1, 2, 3]. There was mining for silver, iron, nickel, cobalt and bismuth. Uranium was discovered as a new element in 1789 by Klaproth in the mines of Johanngeorgenstadt. There has been mining of uranium oxide since the end of the 19th century. It was used for the coloring of porcelain and glass. In 1898, two years after the discovery of radioactivity by Becquerel, Marie Curie isolated the elements radium and polonium from the waste disposals in Jachymov/Joachimsthal. In 1936, in mines near Schneeberg, extensive radon measurements by Rajewsky confirmed the assumption (made earlier by H.E. Müller) of a causal link between radon and lung cancer. But it was only in the early 1950s that the high dose from radon daughters to the bronchial epithelium was realized.

After World War II, the region came under the power of the Soviet Union. In 1946, in the struggle for the atomic bomb, industrial uranium mining was initiated in the Ore Mountains. The southern part of the mining region belonged to Czechoslovakia, the northern part to what later became the German Democratic Republic (GDR). The uranium mining company on the German side was known as "Wismut" (German for bismuth; a camouflage name). It was a limited company in the hands of the Soviet Government (SAG Wismut). In 1953, the ownership was partly transferred to the GDR. The enterprise was now called a "Soviet-German stock company" (SDAG Wismut).

In the first post-war years until approximately 1955, the situation in German uranium mining was characterized by compulsory labor, a high rate of absence, illness and accidents [4]. The working conditions were poor. After 1954/1955 these conditions improved. The company assumed a civilian character.

In the 1950s and later, uranium production was constantly extended. Starting in 1952 and 1961/1968 respectively, mining was also performed in Thuringia and Dresden, regions that were not mining areas before World War II. During the 1970s and later, the company had a well-trained core workforce. Rules of industrial hygiene in accordance with the law of the GDR were accepted and followed. The limits of radiation exposure fulfilled recommendations of the International Commission on Radiological Protection (ICRP).

Uranium mining was generally stopped after German reunification. Wismut changed from a Soviet-German limited company to an enterprise owned by the German state. There was renunciation of any claims towards the former stockholder, the Soviet Union. Wismut Ltd. is now assigned to the federal ministry of trade and commerce and is working on restoration of the region. The GDR was the most important uranium supplier for the Soviet Union, with a total of 220,000 tons of uranium. The country was number 3 in uranium production worldwide.

The Wismut enterprise had a total surface area of approx. 37 km^2. The total length of shafts and roadways was 1395 km in the late 1980s. In Hartenstein near Aue, the deepest shaft was 1755 m deep. At this depth, the rock's temperature is 60 °C. Work was performed there in hot, humid conditions. In uranium mining at Wismut Ag, mostly classic underground mining techniques were applied (hydrothermal ore veins in the Ore Mountains). However, different geological conditions required substantial modifications in the technical approach. In Thuringia (sedimentary rock), apart from underground mining, there was also surface mining with excavations more than 200 m deep.

In Königstein near Dresden, the uranium deposits were of low ore content. Therefore, a special extraction technique (with sulfuric acid) was used. As a consequence of different geological and technical conditions, there were different patterns of exposure to harmful agents for the miners, resulting in a broad range of health impairments.

The number of persons that were employed at the Wismut enterprise was found in Wismut archives to be approx. 307,000 for the total Wismut period [5]. Some experts reckon the real number to be much higher [4]. There can only be guesses because of the rather chaotic post-war conditions.

Uranium mining: working conditions and profile of exposure

At the Wismut mining enterprise, there was underground and surface mining and there was extraction of uranium from its ore and precipitation as "yellow cake". The working conditions of underground mining [6] in the Ore Mountains in the early post-war years (1946–approx. 1955) were characterized by the following features:

- Absence of industrial health and safety standards
  - Drilling in rock with air flushing ("dry drilling"), which led to high dust concentrations
  - Absence of forced ventilation in the mine
- Extremely heavy work due to lack of technical aid
- Long working hours

After 1956 conditions changed for the better. Artificial ventilation of the mines and drilling with water flushing ("wet drilling") led to lower dust and radon concentrations.

The underground workers in Wismut uranium mining were confronted with a complex mixture of several harmful agents and stress factors:
Heavy work · forced attitude · vibration · heat · noise · ionizing radiation · dust (inert/fibrogenic) · blasting fumes (CO NO_x) · EGDN (blasting agent) · heavy metalls (As, ...) · rubber components · oil fumes · adhesives · synthetic material · fungi

The levels of exposure in the first 10–15 years are uncertain as there was no measuring of radon or radon progeny. In 1955, assessment of radon concentrations in the mines at selected locations was instituted. Direct measuring of radon daughters did not begin until 1966.

As of 1971, the data for work sites have been assigned to the individual miners using their working schedule. Compliance with the annual exposure limit was checked.

The exposure to dust in the mines was first recorded in the 1950s. Systematic assessment started in the 1960s. Noise began to be recorded in 1965. Vibration, climatic conditions etc. for several types of work in the mines were assessed from the 1970s. In the last years of the enterprise, there were systematic records on toxic substances in the mines (solvents, diesel fumes, arsenic, etc.) and there was biomonitoring (e.g. manganese in welders). The evaluation of these data was used to modify working conditions and to improve the annual routine medical check-up.

Exposure to α-radiation is the most important health hazard, originating mostly from radon progeny. The noble gas radon-222, originating from uranium-238, enters the air of the mines. The decay products of radon-222, such as polonium-218 and wismut-214, are solids.

Shortly after their generation in the air of mines, they either form condensation nuclei or adhere to the dust in the air. When inhaled into the lung, they attach to the mucous layer of the bronchial epithelium. Here they disintegrate in several fast steps to the relatively stable lead-210, hereby emitting α-(plus β- and γ-) radiation.

To describe the accumulated α-energy exposure of miners, the historical unit "working level month" (WLM) is still in use. In the GDR, a potential α-energy concentration for radon-222 progeny of 40 MeV/cm^3 was allowed for exposed persons. This corresponds to an exposure of 4 WLM/year, which led to a dose calculation of 40 mSv/year (in October 1993, the ICRP recommended a reduction of the dose assigned to 1 WLM from 10 mSv to 5 mSv [7]. The annual exposure limit was reduced from 4.8 WLM to 4 WLM.

The extent of radiation exposure in Wismut uranium mining was subject to a broad investigation by several experts (Lehmann et al.) on behalf of the Bergbau-Berufsgenossenschaft (German Miner's Compensation Board). They used existing data of the Wismut enterprise and knowledge of geological and technical conditions in the mines and made several genuine measurements. This investigation resulted in an ample exposure matrix that gives radiation exposure:

- For several types of work
- For every year of work between 1947 and 1990
- For different locations in the mines

In the resulting report [8], radiation exposure is differentiated into the following categories:

1. Exposure by short-lived radon progeny
2. Exposure by long-lived dust-associated nuclides
3. External gamma-radiation

The exposure in the early years of mining, before 1955, can only be estimated by using analogies and general knowledge of geological and technical conditions.

For the years from 1955 until 1966/1975, there were measurements of radon concentration in the mines. The decisive alpha-energy concentration of radon progeny can only be computed from the radon concentration by use of the equilibrium factor. The evaluation of the equilibrium factors in mines is an important part of the radiation assessment. The radioactive equilibrium factor characterizes the disequilibrium between the radon daughter mixture and their mother nuclide. Lehmann et al. used equilibrium factors from $F=0.6$ to $F=0.3$, depending on the technology of ventilation in the mines.

Figure 1 shows the results of this investigation for mine no. 09. This was a "new" mine that did not originate from pre-war times. The exposure to radon progeny in this mine started at relatively low levels and increased along with the progress in uranium production. According to Lehmann et al. the α-energy exposure in the air of mines, unless there is forced ventilation, is correlated with the progress in uranium production. The growing area of ore veins in contact with the mine air meant enhanced exposure for the miners. The high radiation exposure in the years before 1955 is due to the lack of ventilation in the mines and to the high dust concentrations from "dry" drilling. Since 1956, the effect of forced ventilation and drilling with water addition can be noticed.

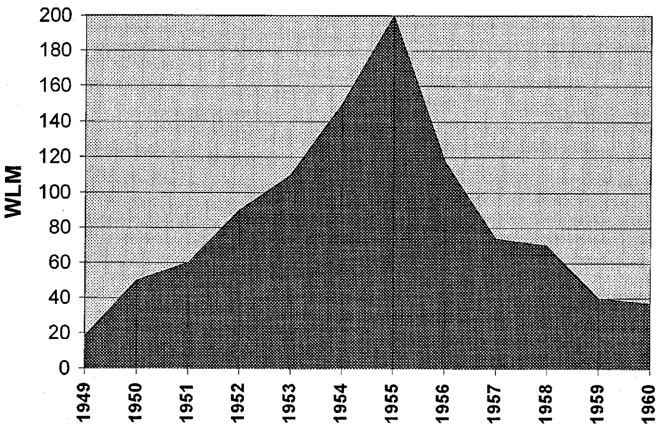

Fig. 1 Annual exposure to radon progeny in mine no. 09 (region Schneeberg-Schlema-Alberoda) of SDAG Wismut (data from Lehmann et al., Bergbau-Berufsgenossenschaft)

In another mine, mine no. 02 (located in the same region), the exposure did not start at a low level, because in this case the mine originated from pre-war times.

Figure 2 shows both mines, no. 02 and no. 09, in comparison. There are quite different exposure conditions to radon progeny for the several different mines in the Wismut enterprise. Before completion of this sophisticated study in 1996, the best estimation of the exposure to radon progeny in the early Wismut years was 150 WLM per year from 1947 to 1956.

In surface mining in Thuringia, exposure to radon progeny is highest in the year 1976 with an estimated level of 6 WLM per year.

The total dust concentration at miners work sites was estimated in 1987 (Fachausschuss Staubbekämpfung der Kammer der Technik, 15th May 1987, internal communication) as follows:

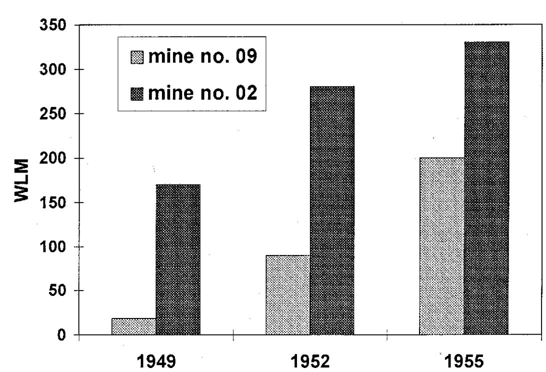

Fig. 2 Annual exposure to radon progeny in mine no. 09 and mine no. 02 (region Schneeberg-Schlema-Alberoda) at SDAG Wismut (data from Lehmann et al., Bergbau-Berufsgenossenschaft)

1946 to 1950	50–100 mg/m^3
1951 to 1954	20–40 mg/m^3
1955 to 1960	10–20 mg/m^3

This estimation, with regard to the post-war years, is only roughly consistent with results of an extensive reconstruction of all available data about exposure to dust and dust-related hazards [9]. The project was performed by German Workers' Compensation Boards (gewerbliche Berufsgenossenschaften; representing the German Occupational Accidents Insurance System). Due to lack of data from the early years, operational conditions typical of the early phase of uranium mining were reproduced in simulation experiments. For dry drilling, these measurements showed, for the area immediately around the workplace, total dust concentrations of approx. 100–470 mg/m^3 (dependent on rock humidity and sample collection technique) at a ventilation rate of 0.1 m/s. Such a ventilation rate is estimated to correspond to the "natural" ventilation rate of the post-war years.

The dust in mines was contaminated not only with the short-lived radon-daughters, but also with long-lived α- and γ-radiating substances such as uranium-238, radium-226 or lead-210. It is assumed that 10–20% of radiation exposure in mines originates from those long-lived isotopes [9]. Simulation of post-war working techniques in Wismut mines (in Schlema) gave an inhalative incorporation of U-238 of approx. 20 kBq per year. In a worst-case scenario, the incorporation was up to 60 kBq per year [9].

To assess the dose resulting from an incorporation of long-lived nuclides in mines, dosimetric computations were performed by Jacobi and Roth [10] using the ICRP respiratory tract model [11]. Disintegration of an annual uranium-238 incorporation of 20 kBq (uranium in equilibrium with its progeny) in the following 50 years would result in an equivalent dose of 2.9 Sv to the bronchial mucosa, for example.

At Wismut, exposure to uranium was dependent on time and mine localization. Long-lived radionuclides were measured since 1967. The course of exposure in the years before – the post-war years – was assessed by Lehmann et al. [8] (Fig. 3). Uranium content in rock steadily increased with increasing depth of mining. Ore mining with pneumatic hammers, which led to high dust exposure, was performed until 1965. Both factors accounted for the maximum in uranium exposure in 1964. In contrast, the maximum of exposure to short-lived radon progeny was in 1955 (Fig. 4).

The dust in Wismut mines contained as an important factor crystalline silica. The quartz content of fine dusts varied greatly according to geological conditions. According to results of simulation experiments [12], the mean cumulative quartz fine dust dose for a miner working from 1946 to 1954 amounted to 33.7 mg/m^3 × years. This is much more (factor 6.4) than the recent maximum permissible cumulative quartz fine dust dose, i.e. the recent maximum workplace concentration of quartz fine dust over a period of 35 years.

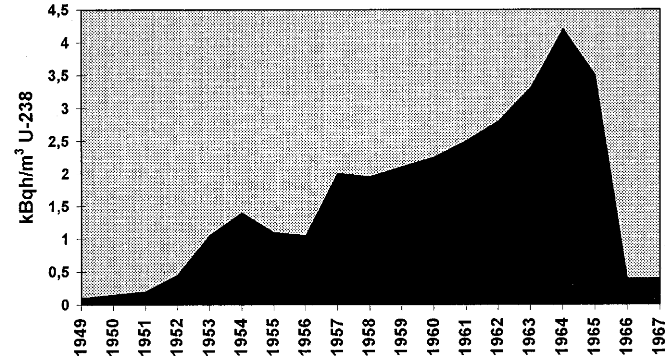

Fig. 3 Annual exposure to long-lived U-238 in mine 09 ("Objekt 09") (data from Lehmann et al., Bergbau-Berufsgenossenschaft)

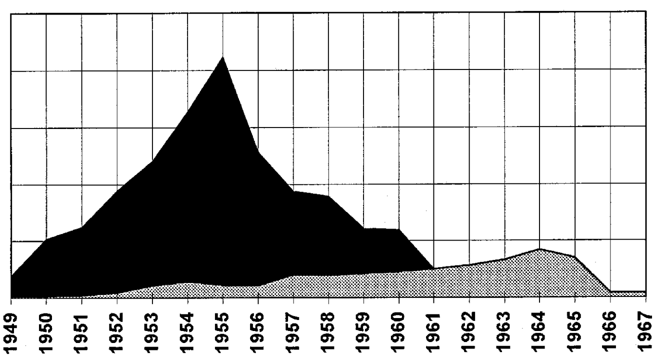

Fig. 4 Wismut mine 09 ("Objekt 09") (data from Lehmann et al., Bergbau-Berufsgenossenschaft). (1) Annual alpha-energy exposure to radon progeny (in *black*, ordinate without defined scale); (2) annual exposure to long-lived U-238 (in *gray*, ordinate without defined scale)

Among the chemical substances in Wismut mines, arsenic needs special consideration as a potential health hazard in the Aue region. Indications of the level of exposure to arsenic at Wismut were given in an 1988 investigation [13]. Concentrations of arsenic particles in 77 long-term air measurements ranged from 0.1 to 267 μg/m^3. Concentrations of arsenic trioxide in the air at miners' workplaces were found to be 86–479 μg/m^3. The maximum limit in the GDR for arsenic in air was set at 0.5 mg/m^3 for short-time exposure and at 0.2 mg/m^3 for a work shift.

In pathological investigations in lung tissue samples from uranium miners, increased concentration of uranium, chrome and arsenic in the dust of the lung can be found [14].

Asbestos played a certain role in Wismut underground miners when they used special hauling techniques. In several cases of pathological investigation, increased concentrations of asbestos fibers in lung tissue of uranium miners could be found. There was no proof of a general increase of asbestos fiber concentration in the lungs of uranium miners [14].

Smoking was very common among Wismut miners. An individual smoking history was recorded not earlier than in the 1970s.

Occupational diseases in uranium mining

In the assessment of radiation-induced health impairment, the Wismut company confined itself to evaluation of morbidity. A systematic investigation of the causal relationship between exposure and disease was not undertaken [15].

The number of compensable occupational diseases reflects the consequences of exposure to harmful agents. At the same time, the acknowledgement of occupational illnesses bears some elements of convention through legal regulations [16].

A synopsis of compensable occupational illnesses in Wismut uranium mining is given in Table 1 for the period until 1990 [17].

The crucial component is pulmonary morbidity. Very common was the combination of bronchial carcinoma with silicosis.

The causation of lung cancer by radon progeny (Schneeberg lung disease) is established by several epidemiological studies in various mines throughout the world. Eleven studies have been summarized in a meta-analysis by Lubin [18]. The result is an excess relative risk for lung cancer per unit of cumulated exposure (ERR/WLM) of 0.49% (95%CI: 0.2–1.0%). In Wismut miners, more than 95% of all bronchial carcinomas (and silicosis) correspond to exposure from 1946 to 1957 [19]. Arsenic could contribute to lung cancer causation in uranium mines [18]. At Wismut, arsenic is found in the Aue region (Ore Mountains).

Regarding silicosis, an analysis found no evidence for new cases corresponding to a Wismut mining exposure after 1961 [20].

Both findings illustrate the extreme working conditions in the first years of Wismut mining.

Until 1982, vibration damage and vertebral column disease were recorded together in statistics of the Wismut health care system. Vibration damage refers to the use of pneumatic hammers and the consequent strain on the hand-arm system. In the 1970s and 1980s, industrial safety measures brought a decline in new vibration damage.

For vertebral column disease, the threshold for acknowledgement as an occupational disease was high and the numbers of occupational diseases were consequently small.

Hearing loss makes up approx. 15% of all occupational diseases. The number of newly acknowledged diseases was especially high in the 1960s, due to a lowered threshold of acknowledgement. In the 1980s, industrial safety measures brought an important reduction of occupational hearing loss.

Skin disease at Wismut uranium mining was related to the use of disinfectants (prophylaxis of mycosis), rubber components and chromate (in cement). Eight cases were explained by exposure to arsenic.

Several types of diseases – extrapulmonary cancer for example – were not recorded as occupational diseases at the Wismut health care system, but have recently been discussed with respect to uranium mining. For extrapulmonary cancer in uranium miners, no clear and significant exposure-morbidity relationship is described in the recent literature [21].

Fritzsche reported four cases of basalioma which were accepted as compensable occupational diseases at Wismut [13]. They were interpreted as malign neoplasms of the skin caused by arsenic. Yet, Czech authors describe basaliomas in uranium miners as radiation induced [22].

Lung fibrosis was not acknowledged to be radiation induced at Wismut. Yet, there were reports of interstitial lung fibrosis in East German miners exposed to radon progeny in non-uranium mines [23].

No indication of a generally enhanced rate of pleural mesothelioma was found in recent investigations of pathological samples of former Wismut employees. Yet, there have been individual cases of pleural mesothelioma in Wismut miners with enhanced numbers of asbestos fibers in lung tissue. (Müller and Wiethege, personal communication)

Table 1 Compensable occupational illnesses in Wismut uranium mining

	Data source	
	Wismut	HVBG
Silicosis, silicotuberculosis	14592	14531
Schneeberg lung disease (bronchial carcinoma)	5275	5492
Vibration damage, vertebral column disease	5053	5232
Hearing loss	4657	4878
Skin disease	607	601
Other (e.g. sclerodermia, tropical diseases.)	637	591
Total	30821	31325

(Data source 1: from annual records 1952–1990 of occupational diseases at Wismut, formerly confidential data. Data source 2: Workmen's Compensation Boards (HVBG, Hauptverband der gewerblichen Berufsgenossenschaften), data from 1947 to 1990)

Medical care for the Wismut miners/workmen's compensation

The development of a company-based health care system ("Gesundheitswesen Wismut") commenced in the 1950s. This system consisted of hospitals, ambulances and convalescent homes. In 1989, the penultimate year of its existence, the Wismut health care system employed 5000 persons, among them more than 550 physicians and dentists. They also acted as family doctors.

The archives of the Wismut health care system contain results of routine chest X-rays and other medical examinations, including autopsies. Also, a great number of workplace assessments can be found there.

In 1990, the Wismut health care system was closed down as a consequence of the changes after reunification. The archives of the Wismut health care system were transferred to the Federal Institution of Occupational Hygiene and Occupational Medicine (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin).

In the reunited Germany, it was a challenge for politics, economy and science to manage the manifold problems that arise from uranium mining in the former GDR. Apart from the restoration and redevelopment of the region, the future medical care and compensation for the former Wismut miners had to be organized. The German state paid the sum of 400 million DM to the institutions of accident insurance to transfer its responsibility for dealing with occupational accidents and illnesses related to Wismut uranium mining. Accordingly, the German Workers' Compensation Boards [Hauptverband der gewerblichen Berufsgenossenschaften (HVBG)] assumed this responsibility on 1st January 1991. There was no experience with uranium mining in western Germany before reunification. In 1992, the Workers' Compensation Boards set up a coordinating agency (Zentrale Betreuungsstelle Wismut, ZeBWis) to organize the future medical care for the former Wismut miners. The first task for ZeBWis was the determination of the names and addresses of the living ex-miners (39). Amongst the approx. 306 000 employees that were recorded in several archives, 165 000 persons could be located in 1992. A regular detailed medical examination was offered to them [24].

At first, approx. 80 000–85 000 persons were interested in such medical care. In the meantime, this number is at 77 000. A detailed working history was assessed for this group of former Wismut employees using information from the Wismut archives. Every miner had the opportunity to report errors in the documentation of his personal working history.

The purpose of the medical examinations of the former miners is threefold:

1. Individual assessment and acknowledgement of work-related late effects (for therapy, rehabilitation and compensation)
2. Providing data for epidemiological studies
3. Supporting basic research for early diagnosis of cancer and for establishing the causal relationship between occupational exposure and disease

A detailed examination schedule and questionnaire (apt for scanner and computer evaluation) was designed for the examination of the former miners (Table 2).

Up to now 88 000 examinations have been performed. Offering an examination of a miner every second year, the workers' compensation boards expect approx. 20 000 examinations annually for the next 5 years.

In the case of evaluation of a disease with regard to possible occupational causation, an individual assessment, considering the individual working history, is needed. To this aim, a job-exposure matrix has been developed for radiation exposure (Lehmann et al.) and is planned for dust and heavy metal exposure (Bauer et al.).

Whereas the criteria for acknowledgement of silicosis as an occupational disease were comparable in East and West Germany, this is not true for the acknowledgement of bronchial carcinoma. For the Wismut miners in the GDR, bronchial carcinoma was regularly acknowledged as a compensable occupational disease at an exposure level above 450 WLM. Below this exposure level of 450 WLM, acknowledgement was only granted in special cases. Smoking habits were not considered.

After reunification, in 1991, the level for acknowledgement of bronchial carcinoma as a compensable occupational disease was lowered to an cumulated exposure level of 200 WLM.

Since 1992, as a guideline in the individual evaluation of bronchial carcinom as a occupational disease, a model by Jacobi et al. allows the computation of the probability of causation of lung cancer by occupational radiation exposure in uranium mining [25]. Epidemiological studies from mines in Bohemia, Colorado, New Mexico, Ontario and Sweden are used. In this model, the excess relative risk for lung cancer is dependent on: age at exposure; cumulated exposure (in WLM); age at disease.

Probability of causation (PoC) is defined as $PoC = ERR_{exposed}/1 + ERR_{exposed}$. Acknowledgement as occupational disease is suggested for $PoC > 0.5$. Individual assessment is suggested for $PoC < 0.5$.

Extrapulmonary cancer was not a compensable occupational disease in Wismut miners before 1990.

After reunification, the question of possible causation of malignoma other than lung cancer from uranium mining arose. There was no proof for such a causal relationship in the international epidemiological literature [21], but the considerable inhalation of long-lived α-radiating substances in Wismut mining with subsequent distribution in the body suggested a cancer risk for other organs than the lung.

Jacobi and Roth performed, on behalf of the Workers' Compensation Boards in Germany, a dosimetric approach for the estimation of the risk of extrapulmonary cancer at Wismut AG [11]. As a first step, they assessed – with dosimetric knowledge – the tissue dose of various organs resulting from incorporation of nuclides. Then, they computed the risk of cancer from that dose using the epidemiological knowledge from the atomic bomb survivors in Hiroshima and Nagasaki ("Life Span

Table 2 Medical examination of former Wismut employees

- Complete working history including periods other than at the Wismut-enterprise
- Medical history
- Physical examination
- Spirometry (IVC, FEV_1)
- Chest X-ray (p.a. and oblique)
- (Body plethysmography)
- Laboratory diagnosis (blood sedimentation rate, whole blood count with diff. blood count, creatinine, transaminases, γ-GT)

Study''). According to Jacobi and Roth, the uranium-238 incorporation in 1 year of underground mining in the early years of Wismut mining would result – in the following 50 years – in an equivalent dose of 5 Sv to the larynx and pharynx region, for example.

Altogether, this method could be called ''indirect epidemiology''. It is not approved by the German Workers' Compensation Boards as a base for acknowledgement of occupational disease except for leukemia (other than chronic lymphatic leukemia and Hodgkin lymphoma).

For two localizations of extrapulmonary cancer in uranium miners, there is less indirect epidemiological evidence: (1) bone cancer in radium-224 patients/radium workers and; (2) liver cancer in Thorotrast patients.

From this evidence, again on behalf of the HVBG, Jacobi and Roth developed methods for the evaluation of the bone and liver cancer risk of workers in the previous uranium mining facilities of the Wismut AG [26]. They determined for the relevant radionuclides the excess absolute risk rate as function of activity intake and time since exposure or the attained age, respectively. They took into account the new biokinetic and dosimetric models proposed by ICRP Committee 2. For the calculation of the excess relative risk and the corresponding probability of causation the incidence data on bone and liver cancer from the GDR Cancer Registry are used as normal background rate.

The German Workers' Compensation Boards approve this model as a basis for acknowledgement of liver and bone cancer as occupational diseases. In cases with a probability of causation over 50% according to the model, an individual expert evaluation is commissioned.

Present situation and research acitivities

An improved knowledge about health consequences of uranium mining can be expected from epidemiological studies on Wismut uranium mining. For lung cancer caused by radon progeny in mines, the existing studies are based on 2700 cases [18] or less, while in Wismut miners there is already a data base of more than 6000 disease cases.

A prospective cohort study is intended (Bundesamt für Strahlenschutz) in a random sample of 60,989 exposed persons with a history of mining in the Wismut enterprise. Mortality from bronchial and extrapulmonary carcinoma and other diseases will be monitored and differentiated into subgroups of low, average and high exposure to ionizing radiation. The data will be analyzed for causation of disease by radon progeny, arsenic, dust, smoking and other exposures.

Statistical power is even more critical for the assessment of the risk of extrapulmonary malignoma in uranium miners. A case-control study will be performed using data from the cancer registry of the GDR and from the archives of the Wismut health care system (Möhner, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin).

However, even after improvement of epidemiological knowledge, we will still be confined to general risk assessment (probability statements). For an individual prognosis, biological markers of exposure and health impairment are needed. For example, increased numbers of chromosomal aberrations in individuals in the general population can be correlated with an increased individual cancer risk [27]. In Wismut uranium miners, enhanced rates of chromosomal aberrations have been shown [28].

The bronchial carcinoma of the Wismut uranium miner seems to show no special histopathological characteristics. This is – simplified – the preliminary result of evaluations of the central archive of the institute of pathology at Stollberg [29].

In Summary, uranium mining at the Wismut enterprise in the GDR from 1946 to 1990 is an important historical example of considerable chronic exposure to radon progeny for several hundred thousands of people. Exposure was highest in the early post-war years. A total of 5000–6000 cases of bronchial carcinoma are already accepted as compensable occupational diseases to date. Estimations for the total number of lung cancer cases in Wismut mining reach a number of 10,000 or more. A special feature of Wismut uranium mining in the early post-war years is the exposure to very high dust levels and to considerable concentrations of long-lived α-radiating substances such as uranium-238. Furthermore, the possible contribution of toxic chemicals, such as arsenic and silica, and other factors to miners' morbidity needs careful pathophysiological consideration. The extensive data from Wismut uranium mining have improved and will further improve our understanding of such a complex exposure situation resulting in a variety of health impairments other than lung cancer. Great efforts have been made and are being made by all the involved institutions in the medical care and compensation of persons who suffered health impairment as a consequence of uranium mining.

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