Health Effects by Uranium Mining and the German Experience

Berlin 2011

Prof. Inge Schmitz-Feuerhake

German Society of Radiation Protection

ingesf@uni-bremen.de

The aim of uranium mining is to gain the isotope uranium-235 which is suitable for nuclear fission. It is only 0.7 % of the uranium in natural composition. The main radioactivity in uranium ore is given by the main isotope uranium-238.

If the ore contains 0.1 % uranium it is still considered to be explored. Then
1 ton of extracted uranium corresponds to 1,000 tons of radioactive waste,

if U-235 is enriched to 3 %
1 ton of reactor uranium corresponds to 4,000 tons of radioactive waste.

Natural decay chain of uranium-238

Nuclide	Half-life	Radiation	Relative activity
Uranium 238	4,5 10^9y	α γ	100
Th 234	24 d	ß γ	〃
Pa 234m	1,2 m	ß γ	100
U 234	2,5 10^5y	α γ	100
Th 230	8,0 10^4y	α γ	〃
Radium 226	1622 y	α γ	100
Radon 222	3,8 d	α	100
Po 218	3,05 m	α	〃
Pb 214	26,8 m	ß γ	〃
Bi 214	19,7 m	ß	〃
Po 214	1,6 10^{-4}s	α γ	〃
Tl 210	1,3 m	ß γ	〃
Pb 210	22 y	ß γ	〃
Bi 210	5,0 d	ß	〃
Po 210	138 d	α	〃
Tl 206	4,2 m	ß	〃
Pb 206	stable		

Radioactivity of uranium waste

The mean concentration of U-238 in soil is about 25 Bq/kg.
The mean concentration of U-238 in ore of 1 % is
124,000 Bq/kg

Normal U-238 in soil is estimated to cause about ¼ of the natural terrestrial exposure and the Radon exposure.

Exposure pathways for populations living near uranium mines:

Inhalation of radon
Inhalation and ingestion of radioactive dust
Radioactivity in drinking water
Radioactivity in agriculteral products, milk, and meat

Diseases in populations exposed in regions by uranium, radon, and other radioactive daughters of uranium

Diseases	Exposed collective	*References*
Leukaemia	Radon in houses, France Radon in houses, Danmark Radon environmmental, Italy Radon environmental, international Uranium regions Radium in groundwater	*Viel 1993; Evrard 2006* *Raaschou-Nielsen 2008* *Forastiere 1992* *Henshaw 1990* *Hoffmann 1993* *Lyman 1985*
Soft tissue tumours	Radon environmental, international	*Henshaw 1990*
Stomach cancer	Uranium regions	*Wilkinson 1985*
Lung cancer	Radium in drinking water, Iowa	*Bean 1982*
Bone cancer	Radon environmental, international	*Henshaw 1990*
Prostate cancer	Radon environmental, U.K.	*Eatough 1990*
Kidney cancer	Radon environmental, international Radon environmental, Italy	*Henshaw 1990* *Forastiere 1992*
Bladder cancer	Radium in drinking water, Iowa USA	*Bean 1982*
Reproductive cancers	Radon in drinking water, Maine USA	*Hess 1983*
CNS cancers	Radon environmental, international	*Henshaw 1990*
Skin cancer	Radon environmental, international Radon environmental, Italy	*Henshaw 1990* *Forastiere 1992*
Birth defects	Uranium regions Radium in drinking water, Texas	*Shields 1992* *Cech 2007, 2008*

Exposure pathways in uranium mining, milling, and processing:

External gamma irradiation
Inhalation of radon
Inhalation and ingestion of radioactive dust

Diseases in miners and uranium workers in consequence of an exposure by radon, uranium, and radioactive daughters of uranium, except of the respiratory tract.

Diseases	Exposed collective	*References**
Solid tumors	Workers in uranium industry	*Ritz 1999*
Benign/unspecified tumors	Uranium miners	*Roscoe 1997*
Blood diseases	Uranium miners	*Roscoe 1997*
Leukaemia	Uranium miners Radon in iron mines	*Möhner 2006; Rericha 2006** *Darby 1995*
Lymphomas	Workers in uranium industry	*McGeoghegan 2000*
Multiple Myelomas	Uranium miners	*Tomásek 1993*
Stomach cancer	Radon in iron mines	*Darby 1995; BEIR IV 1988* *Wilkinson 1985*
Liver cancer	Uranium miners	*Tomásek 1993*
Cancer of the intestine	Radon in iron mines	*Darby 1995*
Cancer of the gallbladder & extrahepatic bile ducts	Uranium miners	*Tomásek 1993*
Kidney cancer	Workers in uranium industry	*Dupree-Ellis 2000*
Skin cancer	Uranium miners	*Sevc 1988*
Cerebrovascular diseases	Uranium miners	*Nusinovici 2010*
Mental diseases	Uranium miners	*Tomásek 1994*
Birth defects	Uranium miners	*Müller 1962, 1967*

*) including Chronic Lymphatic Leukaemia

Other non-cancer diseases to be expected after the experience of the Chernobyl accident from chronical low doses exposures

- Cataracts
- Fertility distortions
- Endocrinal system
- Neural system
- Circulatory system
- Digestive system
- Skin & subcutaneous tissue
- Muscular-skeletal system

WISMUT Uranium company 1946-1989 in Eastern Germany

1,200 million tons extracted mineral mass
200 million tons processed
1,000 million tons tailings

About 500,000 miners, workers in processing facilities and others, most of them underground

15,000 accepted cases of silicosis
5,600 accepted cases of lung cancer

Estimated number of exposed miners alive in 1995: 104,000
(Brüske-Hohlfeld et al. 1997)

Wismut after the German reunification:

The **German Statuary Accident Assurance started a program to reconstruct workplace exposures (Job- exposure matrix JEM)**

Accepted as occupational diseases between 1991-2008

3500 lung cancers

4000 others

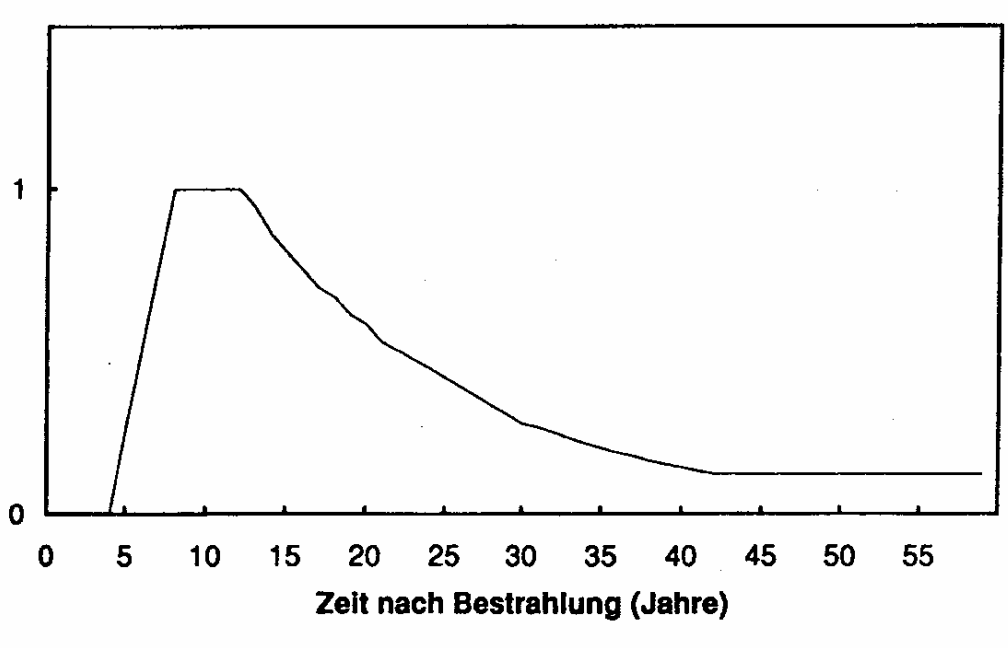
12,000 requests of Wismut workers were not accepted,

1200 went to court, 60 of them successful

Criteria of acceptance as occupational disease for Wismut workers since 1990

- **Exposure 200 WLM and more: lung cancer cases are compensated without special investigation**
- **Lung cancers below 200 WLM: after report of expert Jacobi**
- **Extrapulmonary cancers: after report of expert Jacobi or now-adays after result of German uranium miner´s cohort study**
- **Pulmonary fibrosis: not below 12 Sv lung dose after report of expert Arndt**
- **Other diseases: generally not accepted**

Radiation-induced lung cancer after Jacobi (1992)



Reference: atomic bomb survivors

underestimation because of dose-rate reduction factor, low effectiveness of A-bomb radiation, use of mortality data

Criteria of acceptance as occupational disease for Wismut workers since 1990

Extrapulmonary cancers:

after Jacobi (1995), reference A-bomb survivors

or German uranium miner´s cohort study

German uranium miner´s cohort study

Results:
Lung cancer mortality elevated 2-fold
Extrapulmonary cancers: Excess relative risk 0.014 % per WLM

Problems:

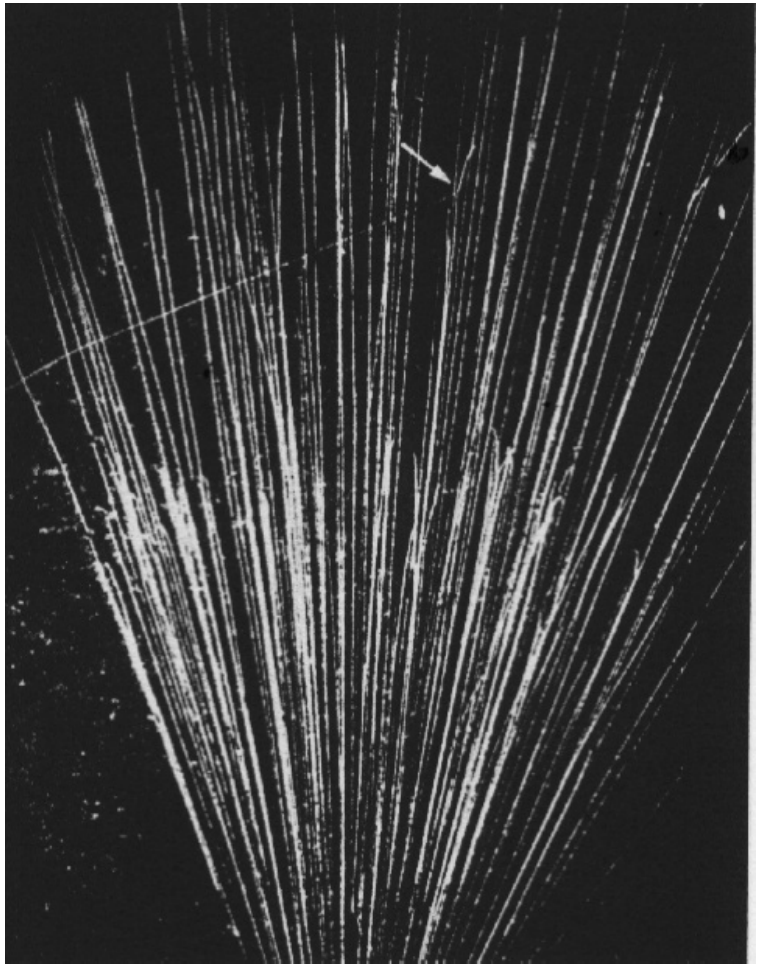
- Dosimetry
- Implausible high cancer rate in “unexposed”
- Mortality instead of morbidity

Leukemia risk among German uranium miners Case-control study, Möhner et al. 2010

Relative Risk 2,64 in the highest dose category (bone marrow dose >105 mGy)

Excess relative risk : 2.06 per Gy

Radon in houses
and other contaminations by Wismut activities:
no published data about health effects in the population



α-particles emitted by a radium sample in a cloud chamber

The relation Bq/g is called **specific activity**.

Specific activity of uranium isotopes

1 mg U-238	1 mg U-234	1 mg U-235
12.4 Bq	231,000 Bq	80 Bq

Specific activity of natural uranium

0.99 mg U-238	0.05 µg U-234	7 µg U-235	1 mg U_{nat}
12.3 Bq	12.3 Bq	0.6 Bq	25 Bq