Health Hazards for Uranium Mine and Mill Workers - Science Issues

(last updated 5 Jul 2000)

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- Uranium Radiation Properties · Uranium Toxicity

Pulmonary fibrosis with uranium miners caused from inhalation of radon progeny

Abstract:

"Many uranium miners have been disabled by and died of pulmonary fibrosis that was not recognized as an occupational disease. A review of animal studies, complications from whole body irradiation, pulmonary function, and mortality studies of uranium miners led us to suspect radiation-induced chronic diffuse interstitial fibrosis in miners who had inhaled excessive radon progeny. A selected group of uranium miners (22) with severe respiratory disease (but no rounded nodules in chest films) were studied. Lung tissue from five disclosed severe diffuse interstitial fibrosis, with "honeycomb lung" in all. Some also had small anthrasilicotic nodules and birefringent crystals. Although quartz crystals probably contributed, we concluded that the predominant injurious agent in these cases was alpha particles from radon progeny. This disease, after a long latent period, usually results in pulmonary hypertension, shortness of breath, and death by cardiopulmonary failure."

Reference:
Native American uranium miners experience higher risk of nonmalignant respiratory disease

Native American miners have more nonmalignant respiratory disease from underground uranium mining, and less disease from smoking, than other miner groups, but are less likely to receive compensation for mining-related disease.

Uranium mining is more strongly associated with obstructive lung disease and radiographic pneumoconiosis in Native Americans than in Hispanics and non-Hispanic Whites. Obstructive lung disease in Hispanic and non-Hispanic White miners is mostly related to cigarette smoking. Current compensation criteria excluded 24% of Native Americans who, by ethnic-specific standards, had restrictive lung disease and 4.8% who had obstructive lung disease. Native Americans have the highest prevalence of radiographic pneumoconiosis, but are less likely to meet spirometry criteria for compensation.

Reference:

Chromosomal Aberrations With Namibian Uranium Mine Workers

Verification study finds no excess chromosomal aberrations in Namibian uranium miners

"On 22 June 2000 Drs Lloyd and Lucas, the two international experts appointed by Rössing Uranium Ltd and the branch executive of the Mineworkers Union of Namibia (MUN), announced in Windhoek the results of the Verification Study on the effects of long-term, low dose radiation exposure.

The purpose of the study was to confirm or refute the study findings on radiation exposure of Dr Reinhard Zaire, the retained expert of the MUN. Dr Zaire's findings suggested that there was a high incidence of chromosomal aberrations among Rössing employees due to long-term, low dose radiation exposure. The experts refuted Dr Zaire's findings and stated in the report: 'The overall conclusion is that the frequency of chromosomal damage in the miners did not exceed that in the control subjects. This verification study has therefore not confirmed the earlier report of Dr Zaire and his colleagues.' [...]"

To implement the study, blood samples were obtained from two groups, namely the study group and the control group. The study group consisted of ten Rössing employees with the highest accumulated radiation dose, and the control group of ten individuals from communities at the coast with no connection to Rössing. All participants were screened for suitability to participate in the study according to the selection criteria prescribed by the two experts and agreed by the Rössing and the MUN."

(from Rössing/MUN media release, June 30, 2000)
Excess chromosomal aberrations found in Namibian uranium miners

A new study found two-fold chromosomal aberrations with workers at the Rössing uranium mine and mill in Namibia, compared to a control group.

Analysis of white blood cells from uranium mineworkers in Namibia for chromosomal and phenotypic alterations

(excerpt from poster presented by R. Zaire et al. at the Congress of German and Austrian Oncologists in Hamburg, 8 Oct 1995)

Introduction

Workers of the open cast uranium mine in Namibia suffer from health problems including malignant diseases at a much higher prevalence compared to the general population. Exact epidemiological data on this subject do not exist.

Objectives

The objective of the study is to determine whether exposure of miners to uranium increases the risk of biological radiation damage which may lead to malignant diseases. An increase in chromosomal abnormalities represents a major risk factor for the development of a malignancy.

Material and Methods

Study population

The study group comprises 75 male uranium open cast miners who were employed in different sections of the mine. Annual exposure varied considerably and was highest (~6 mSv for 20 workers) in the Final Plant Recovery. All persons examined were healthy and no one had previously received radiation or cytostatic therapy. No virus infections were recorded for the 3 weeks prior to blood sampling. The 75 miners were compared to a control group of 31 individuals with no occupational history in mining living in Namibia remote from the uranium cast.

Neutrophil counts and immunophenotyping

[...]

Cytogenetic studies with FISH

[...]

Results

1. Neutrophil counts and immunophenotype

In the miners, n=75, the absolute neutrophil counts were significantly decreased compared to the control group (n=31), (2.4 +/- 0.94 / nl versus 3.1 +/- 1.43 / nl, x
mean +/- SD, p=0.0036).
CD4 and CD8 cell counts, as well as NK cell counts were in normal range.

2. Cytogenetics

Quantitative and qualitative genomic alterations were investigated in representative cohorts using the Fluorescence-in-situ-Hybridization (FISH) method. In the miner's group 0.81 +/- 0.20 (x mean +/- SD) chromosomal aberrations per 100 cells were recorded and compared to a control group, 0.45 +/- 0.15 (x mean +/- SD) (p=0.0031). This represents a two-fold increase of the total number of all chromosomal aberrations recorded in peripheral lymphocytes of mineworkers versus the unexposed individuals.

Discussion

While the determination of chromosome aberrations have been made using conventional staining of chromosome banding, the effort required has prevented wide-scale exploration and applications of this approach. The recent development of FISH for chromosome staining has significantly improved the situation. The main advantage of FISH-based translocation analysis is that the aberrations are made distinct so that they can be scored rapidly. In addition, discrimination between translocations and dicentrics can be done accurately using centrometric staining with a pan-centromere probe. This is particularly important when the translocation and dicentric frequencies are of similar magnitude (e.g. in analysis of cells at first division within a few weeks after radiation exposure). Chromosome alteration analysis also may be useful in studies of chronically exposed populations because stable aberrations such as translocations are expected to accumulate during exposure.

Conclusion

Here we conclude that:

- FISH-method is useful for detection of genomic alterations in white blood cells of radiation-exposed people
- $^{238}$U-exposed miners have a higher chromosomal aberrations in their lymphocytes which may be indicative for an increased risk for malignancy.

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References:
Zaire, R; Notter, M; Riedel, W; Thiel, E: Unexpected rates of chromosomal instabilities and alterations of hormone levels in Namibian uranium miners, in: Radiation Research Vol. 147, 1997, No. 5 (May); p.579-584
Zaire,R; Griffin,C S; Simpson,P J; et al.: Analysis of lymphocytes from uranium mineworkers in Namibia for chromosomal damage using Fluorescence in-situ Hybridization (FISH), in: Mutation Research-Genetic Toxicology Vol. 371, 1996, No.1-2, p.109-113

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Risk of Cancer Incidence other than Lung Cancer with Uranium Mine and Mill Workers

Two studies performed by Prof. W. Jacobi quantify the risk of contracting cancer other than lung cancer for uranium mine and mill workers, and provide data to determine whether an cancer incidence observed is related to earlier occupational exposure.

Summary

"After the reunification of Germany the so-called Hauptverband der gewerblichen Berufsgenossenschaften (HVBG) is the responsible German institution for the acknowledgement of occupational diseases and the compensation of workers at the previous WISMUT uranium mining company in East Germany. On behalf of the HVBG in an earlier study already an analysis of the possible lung cancer risk of these uranium miners due to their exposure to radon progeny has been carried out (Jacobi et al., GSF Report S-14, 1992). In the last years an increasing number of other cancer cases among these miners have been submitted for compensation. The HVBG, therefore, has requested a similar expertise for the possible radiation risk and probability of causation of extrapulmonary cancers among the WISMUT uranium workers. In the following report the methods and main results of this risk analysis are discribed.

For the evaluation of the lung cancer risk from inhaled radon progeny direct epidemiological data from other groups of uranium miners are available. These data yield, however, no quantitative evidence for extrapulmonary cancers. Therefore, in this study an indirect dosimetric approach for the evaluation of the possible excess relative risk (ERR) of extrapulmonary cancers among the WISMUT workers was applied. In this approach the following exposure pathways are taken into account: (1) The inhalation of radon and its short-lived progeny; (2) the inhalation of uranium (U-238, U-235) and its decay products with the ore dust; and (3) the tissue doses from external gamma and beta radiation. Tissue doses from inhaled radionuclides were calculated applying the new respiratory tract model recommended in ICRP Publication 68 (1994). The evaluation of the attributed ERR proceeds from the recently published data of the Life Span Study on the excess cancer incidence in the atomic bomb survivors, taking into account a DDREF of 2 and a radiation weighting factor of 20 for alpha radiation. For solid cancers a time-constant relative risk model was used, whereas for leukemias, lymphomas and myelomas the variation of the ERR with time since exposure was taken into regard.

Central best estimates of the resulting ERR and the attributed probability of causation of extrapulmonary cancers are given for typical exposure conditions of the WISMUT uranium miners, particularly for the critical years 1946-55. For most extrapulmonary cancer types the ERR values are more than a factor of 10 lower than the corresponding value for lung or bronchial cancer, respectively. The only exemption concerns cancers in the extrathoracic region (mouth region, pharynx and larynx) for which the ERR is only about a factor of 5 lower than the ERR for lung cancer.
Finally, general conclusions and recommendations for the decision making in the individual acknowledgement procedure are outlined." [Jacobi1995]

Expected excess relative risk (ERR) and probability of causation (PoC) for solid cancers due to one year of underground work in the period 1946-55, central best estimates for WISMUT-hewers, for an age at exposure of 25 years and a time after exposure of 30-60 years (excerpt of Table 6.1 [Jacobi1995]):

<table>
<thead>
<tr>
<th>cancer location</th>
<th>ERR</th>
<th>PoC</th>
</tr>
</thead>
<tbody>
<tr>
<td>lung, total</td>
<td>4.0</td>
<td>80%</td>
</tr>
<tr>
<td>lung, bronchial epithelium</td>
<td>5.8</td>
<td>85%</td>
</tr>
<tr>
<td>mouth region, pharynx, larynx</td>
<td>0.8</td>
<td>45%</td>
</tr>
<tr>
<td>bone, connective tissue</td>
<td>0.3</td>
<td>25%</td>
</tr>
<tr>
<td>liver</td>
<td>0.10</td>
<td>9%</td>
</tr>
<tr>
<td>kidney</td>
<td>0.06</td>
<td>6%</td>
</tr>
</tbody>
</table>

For leukemia, the excess relative risk is highly depending on the time since exposure. For the miners who worked in the period 1946-55, a significant increase of leukemia incidence is expected for the period 10-20 years after exposure, but there is no epidemiologic data available for that period. In our days, i.e. 40-50 years after exposure, the expected ERR after one year of work is around 0.12, the probability of causation around 10%.

The conclusion of the analysis is that

- an observed cancer of the mouth region, pharynx, and larynx has a probability of causation from the occupational exposure at WISMUT of 50% already after slightly more than one year of underground work;
- for bone and connective tissue cancers, the same probability of causation is expected after 4-8 years of underground work;
- for leukemia, liver and kidney cancer, a probability of causation of 25-50% can be expected after many years of underground work.

In a second study [Jacobi1997], Jacobi et al. performed a more detailed assessment of bone and liver cancers.

from the Summary:

"In the latter report (Jacobi et al. 1995) the risk coefficients resulting from the Life Span Study of the atomic bomb survivors have been applied, taking into account a radiation weighting factor of 20 for the alpha ray exposure of the WISMUT miners. In the conclusions of this report it was recommended to consider in the case of bone and liver cancer in addition also the available direct epidemiological data from internal alpha emitters. This is the objective of the now submitted report.

In the first part the relevant data from epidemiological studies on bone cancer (radium-224 patients, radium workers) and on liver cancer (Thorotrast patients) are summarized. On the basis of these findings empirical models for the evaluation of the excess absolute risk rate as function of activity intake and time since exposure or the attained age, respectively, are developed for the relevant radionuclides. In this procedure the new biokinetic and dosimetric models proposed by ICRP Committee 2 are taken into account. For the calculation of the excess relative risk and the corresponding probability of causation the incidence data on bone and liver cancer from the DDR Cancer Registry are used as normal background rate.
The application of these risk models to the exposure conditions of WISMUT workers takes into regard the inhalation of radon-222 and its progeny (including lead-210), the inhalation of U-containing ore dust with large particle sizes and the external gamma radiation at the workplace." [Jacobi1997]

The critical group are the employees who were exposed at the age of around 20 years. For this group, the excess relative risk (ERR) of contracting liver cancer from one year of work at WISMUT during the period 1946 - 1955 reaches values of 2 - 7 at the age of 35 - 55, corresponding to a probability of causation (PoC) of 65 - 87%. For bone cancer, the ERR is much lower and reaches 0.4 - 0.8 at the age of 30 - 50, corresponding to a PoC of 28 - 45%.

The excess relative risk of contracting liver cancer from the occupational exposure at WISMUT thus is 20 - 70 times higher than estimated in the previous study.

The models are available online in the [Uranium Miner Health Risk Calculator](#).

Sources:


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**New Model for Assessment of Lung Cancer Incidence with Uranium Miners**

by Peter Diehl

Prof. Wolfgang Jacobi, former director of the Institut für Strahlenschutz of the GSF - Forschungszentrum für Umwelt und Gesundheit GmbH (Institute for Radiation Protection of the GSF - Research Center for Environment and Health Ltd.) in Neuherberg, Germany, has analysed radiation exposure data of East Germany's uranium mining company Wismut, to find criteria for the recognition of lung cancers as occupationally caused or not. He developed a model that relates a lung cancer incidence to the work at Wismut for much lower doses than previously thought.

Since there is no personal data available on radon decay product exposure for the Wismut workers, general guidelines have to be found for the recognition of lung cancers as occupation related. During Wismut's early years 1946-1955, average annual exposure to radon daughters for miners is estimated at around 100-250 WLM (Working Level Month). This average exposure corresponds to radon concentrations in air of around 100,000 Bq/m³, while maximum radon concentrations reached 2 million Bq/m³. Between 1956 and 1970, radon daughter exposure strongly decreased, and since 1970 average annual exposure is around 4 WLM.

Based on epidemiological data from uranium miner studies published in literature, Jacobi developed a ZSE (time since exposure)-model to determine the lung cancer rate depending on exposure, age at exposure and age at lung cancer incidence. Due to insufficient data, the model makes no difference between smokers and non-smokers.

The results of the model are discussed for the following cases:
1. For miners who worked at least one year between 1946 and 1955 (and thus at least received around 200 WLM), the probability of causation for a lung cancer as occupation related is greater than 50%, independent of the age at lung cancer incidence.

2. For miners who worked during five years between 1956 and 1960 and thus accumulated around 190 WLM, the probability of causation for a lung cancer as occupation related is greater than 50%, independent of the age at exposure and at lung cancer incidence.

3. For those who worked during five years between 1961 and 1965 and thus accumulated around 90 WLM, the probability of causation for a lung cancer as occupation related is greater than 50% only, if lung cancer incidence was around 7-20 years after exposure.

4. For those who worked during five years between 1966 and 1970 and thus accumulated around 30 WLM, the probability of causation for a lung cancer as occupation related is greater than 50% only, if the age at exposure was 20-40 and if lung cancer incidence was around 10-20 years after exposure.

5. For those who worked since 1970 and thus accumulated around 4 WLM per year, the probability of causation for a lung cancer as occupation related is dependant on period of exposure, age at exposure and age at lung cancer incidence. For example:
   - After ten years of exposure and accumulation of 40 WLM, the probability of causation is only greater than 50%, if the age at exposure was 20 and the age at lung cancer incidence was 33-43, or if the age at exposure was 30 and the age at lung cancer incidence was 44-51.
   - After 30 years of exposure and accumulation of 120 WLM, the probability of causation is greater than 50%, if the age at exposure was 20 and the age at lung cancer incidence was 33-70, or if the age at exposure was 30 and the age at lung cancer incidence was 44-76.

With this model, the employers' liability insurance association, who has to pay for the compensation of occupationally caused diseases, has a first guideline for the assessment of lung cancers with Wismut miners.

A comparison of Jacobi's model with the BEIR IV model of 1988 is presented in [2].

It is worth noting that, according to this model, already an exposure of 30 WLM may be regarded as a cause of a lung cancer incidence, depending on age at exposure and age at cancer incidence. According to recognition practice under the GDR-era, at least 150 WLM of exposure were necessary for recognition (during the early years, the limit even was at 450 WLM). With this limit, no worker had a chance for recognition, if he had worked for example only after 1970. With the new model, all cases of lung cancer that were not recognized, have to be reassessed.

It's also interesting to compare the results of this model to the regulations met in the US Radiation Exposure Compensation Act of 1990. According to this act, only those miners who worked between 1947 and 1971 and received at least 200 WLM (non-smokers), 300 WLM (smokers with incidence before age 45), 500 WLM (other smokers) and developed lung cancer or a nonmalignant respiratory disease, shall receive compensation.

> Compensation of Navajo Uranium Miners

The model is available online in the [Uranium Miner Health Risk Calculator](http://www.uranium-miner-health-risk-calculator.com).

Sources:

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