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RADON IN MINING PAST, PRESENT AND FUTURE

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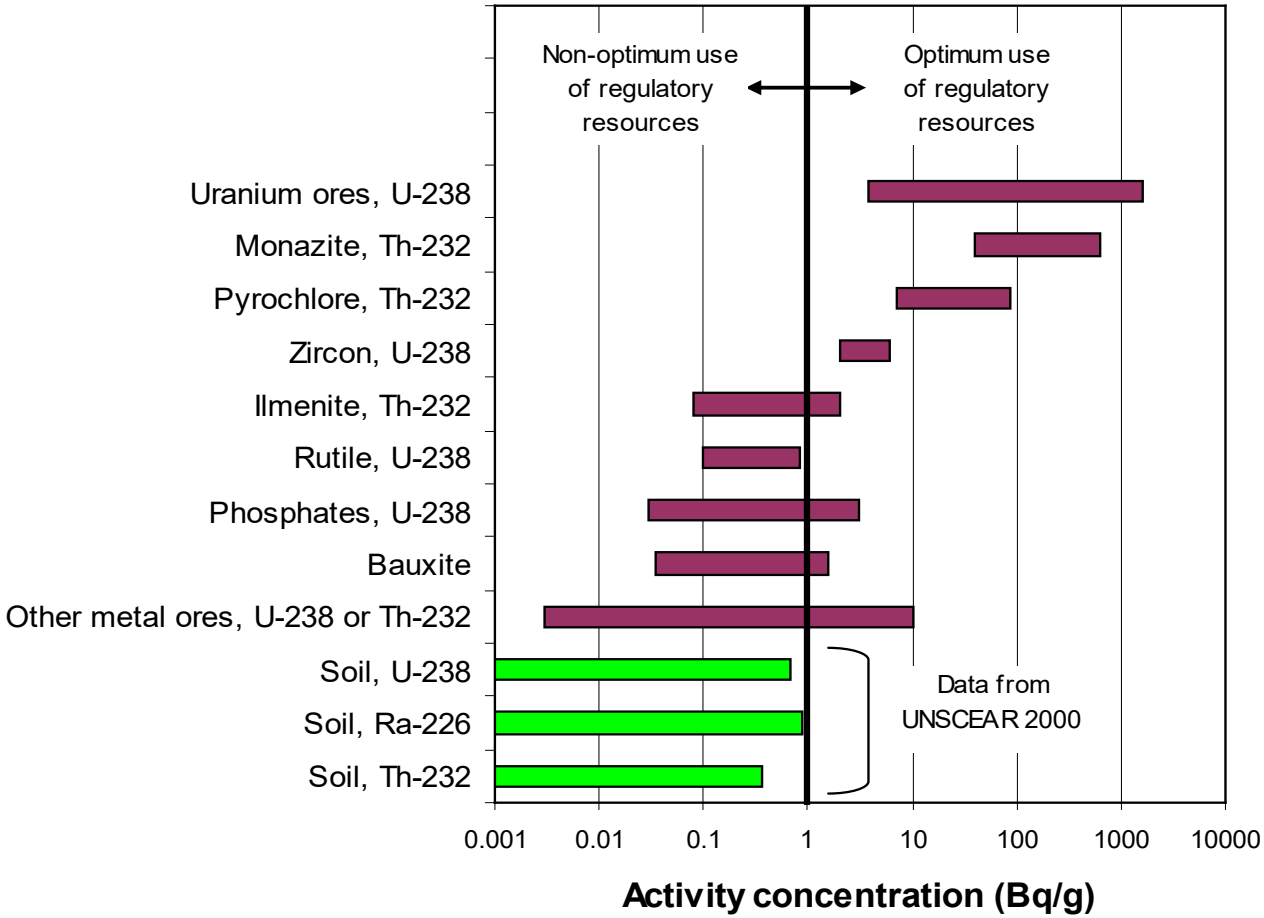
Every thing is naturally radioactive

Uranium-238, radium-226 and hence radon-222 are ubiquitous

Concentration Ranges of Uranium and Thorium Series Radionuclides



After Wymer, 2008

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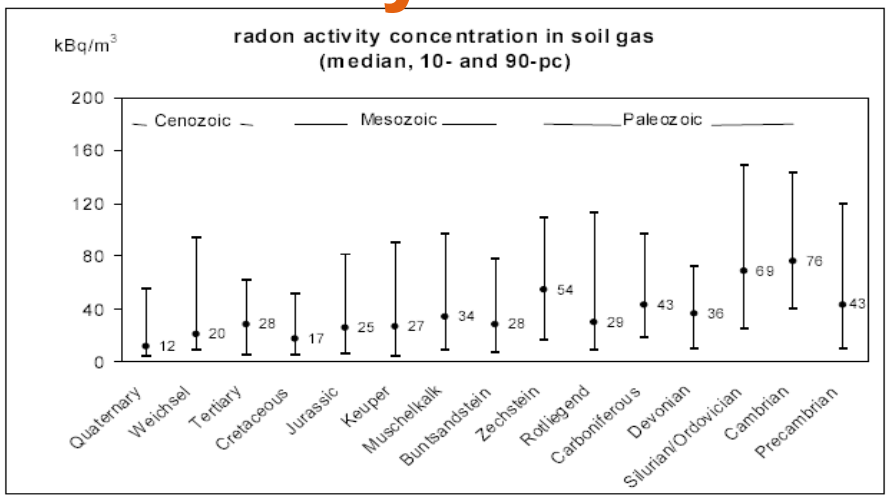
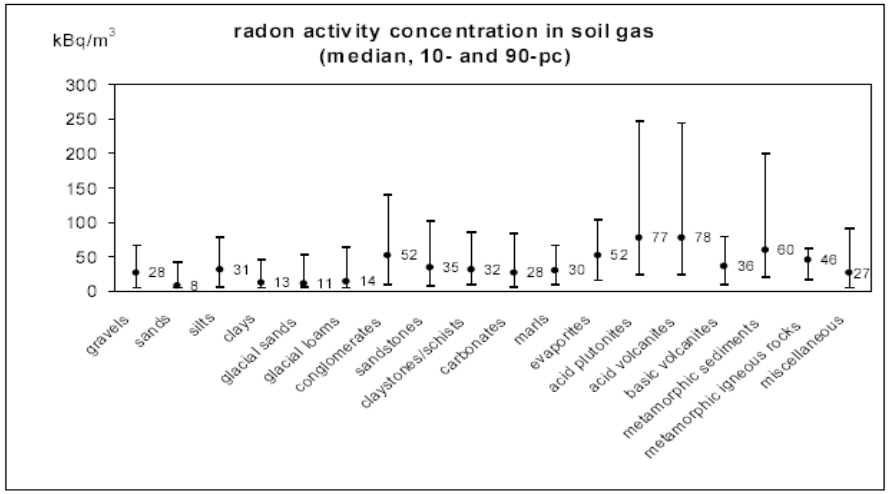
Radon Concentration in Soil Gas of Sedimentary Rocks



according to geological age



according to rock type

Jung

4

RECOGNITION OF LUNG CANCER AS A RISK TO MINERS

Mining of metals and minerals has been taking place for thousands of years

In the 15th century, a large silver deposit was discovered at Joachimsthal in Bohemia which was the basis for Agricola's treatise on mining *De Re Metallica*

As early as Agricola, there was a recognition of an unusually high incidence of a fatal lung disease in miners

- the unusual lung disease was eventually (500 years later) recognized as lung cancer
- The miners' disease was reported to have caused up to 70% of the miners' deaths
- radon levels in these medieval mines were thought to have had radon progeny levels ranging from 30 to 150 WL

MOTIVATION FOR OCCUPATIONAL RADON GUIDANCE

By the mid 1950's, there was a global awareness of the risk of lung cancer in miners.

This drove the development of radiation protection guidelines for radon and consequent parallel changes to mining methods and ventilation practices

The radon guidelines and standards evolved over time as our understanding of the radon hazard evolved through measurement and epidemiology studies of miners

These actions which resulted in substantial improvements in radon levels in uranium mines in Canada and elsewhere

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Evolution of Radon Standard in the USA -1

The United States uranium industry began after World War II when the government began to buy uranium.

Early mine operators knew nothing of the hazard of exposure to radon and no government agency had the authority to regulate the health and safety of miners.

In 1949, the U.S. Public Health Service became concerned about the potential hazard based on the experience of the Joachimsthal/ Schneeberg mines.

Measurements in about 40 mines in Utah and Colorado and confirmed high concentrations averaging over 92,000 Bq/m^3 (2,500 pCi/L).

Radon Concentrations Found in US Uranium Mines in 1949 to 1950*

Area	Number of Mines	Range of Radon Concentrations (pCi L^{-1})	Median Value (pCi L^{-1})
Navajo reservation	4	37 – 7,500	345
Utah	10	100 – 50,000	5,000
Colorado	24	135 – 22,300	2,540

*Holaday and Doyle, 1964

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Evolution of Radon Standard in the USA - 2

Beginning in 1954, the U.S. Atomic Energy Commission had regulatory authority over the uranium industry

- after the material was mined but had no authority to regulate the mining industry.
- There were no mining industry standards and no personnel experienced in assessing the hazard within the mining community.

In 1955, the Public Health Service developed the concept of expressing a tolerance level in terms of the potential alpha energy of radon decay products in air

In 1958, the Nuclear Standards Board of the American National Standards Association (later Institute), established a committee to develop a standard for uranium mines and mills.

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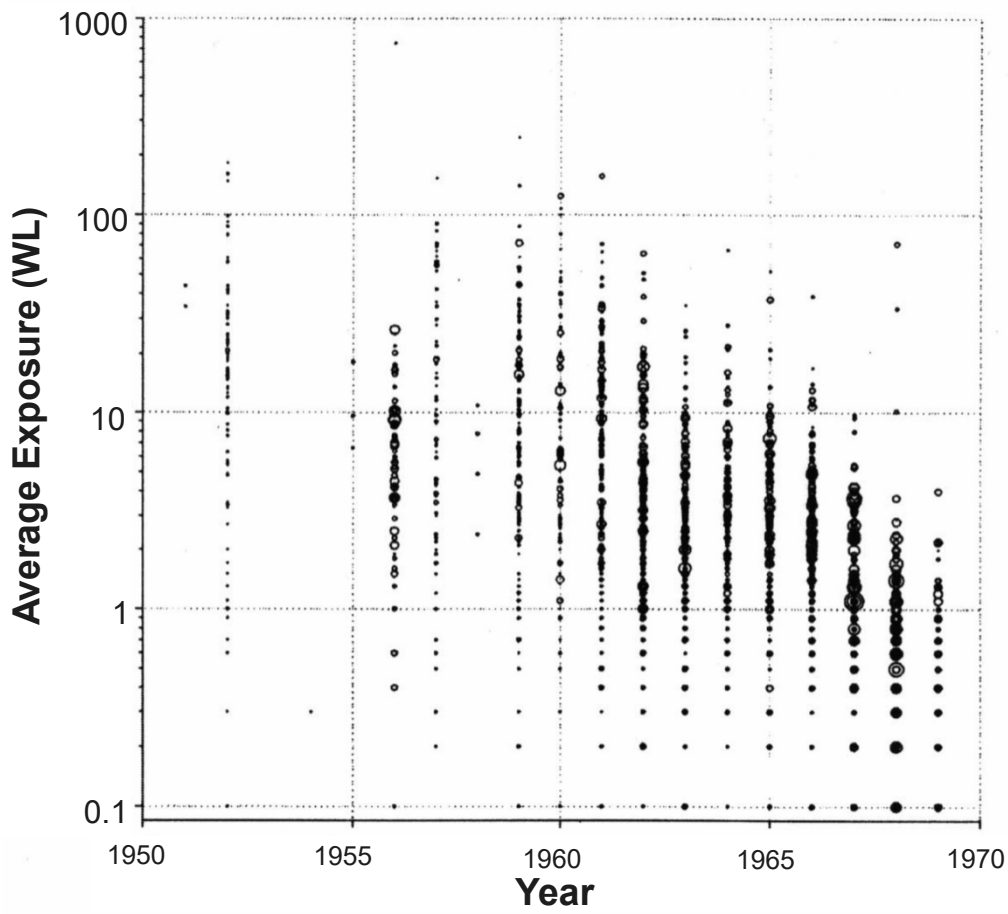
Evolution of Radon Standard in the USA - 3

- The adoption of 1 WL standard was adopted in 1960 (12 working level months per year)
- Its utility was in that it was thought to be directly related to lung dose
- The standard was the impetus for a significant decrease in miner exposures beginning in 1960, as states and mining companies began implementing control through mine planning and increased ventilation.
- The standard was reduced to 4 WLM per year in 1971 as the emerging picture of lung cancer developed.
- This standard is still in effect in mines in the United States.

MEASURED EXPOSURES FOR UNDERGROUND URANIUM MINES IN COLORADO



Epidemiological Studies of Miners Considered in UNSCEAR 2006 – Annex E

- Colorado Plateau
- Ontario
- Czech
- Swedish Iron
- Beaverlodge
- Wismut
- Port Radium
- French Uranium
- **Chinese (uranium and tin)**
- **Newfoundland (fluorspar)**

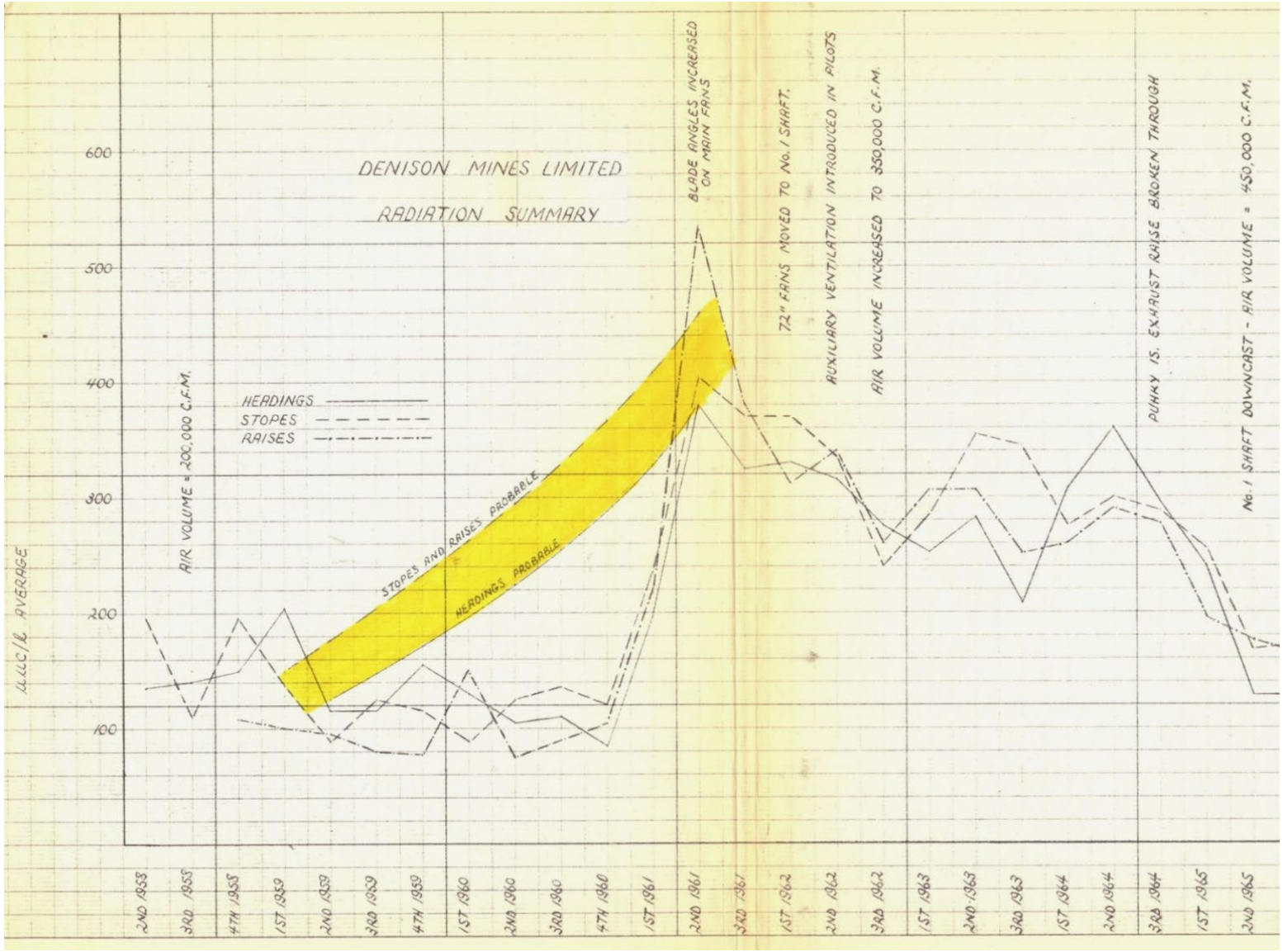
URANIUM MINING IN CANADA

- Underground mining, initially for radium, later for uranium started in 1932 at Port Radium in the Northwest Territory
- By 1951 Beaverlodge mine in northern Saskatchewan was in operation (later many satellite mines)
- By the early 1950's uranium was mined in Ontario at Elliot Lake (some 23 companies), Agnew lake and Bancroft
- Since the mid 1970's uranium mining has focussed in northern Saskatchewan
- Several new developments planned for Saskatchewan and elsewhere in Canada

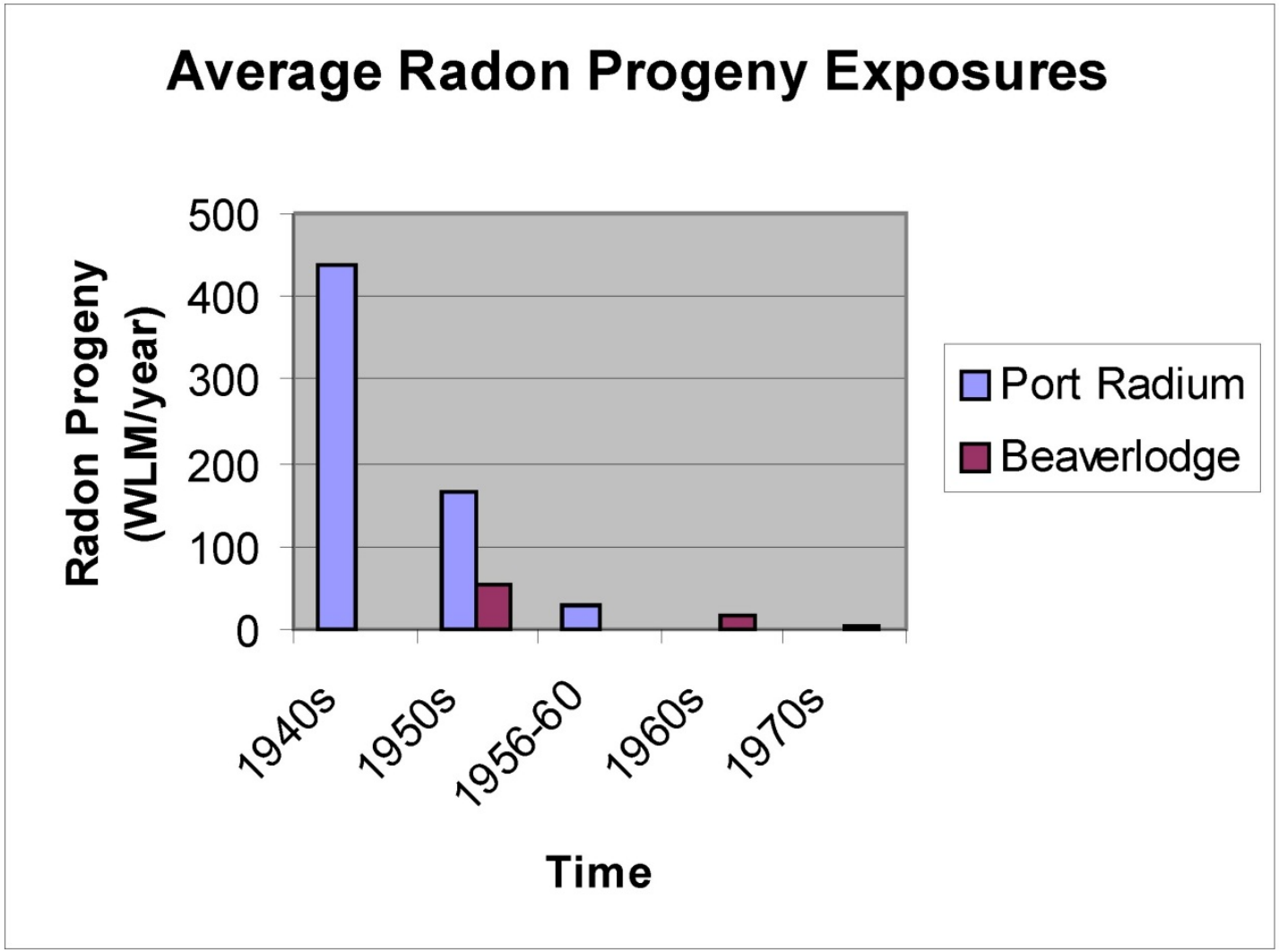
PORT RADIUM, 1940

Port Radium Hand Sorting

Denison UG 1950's



RADON 1940 TO 1970



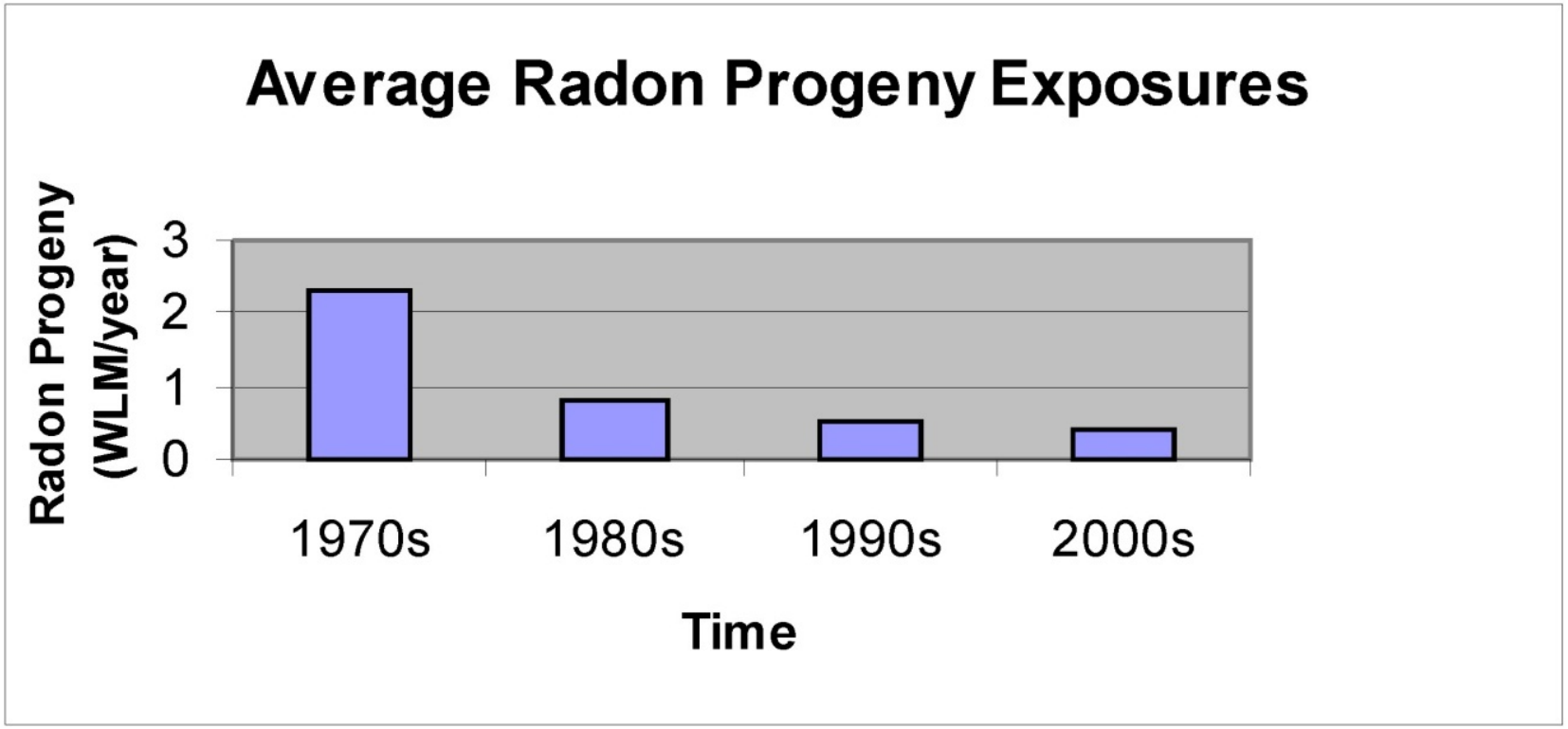
ELLIOT LAKE MINES 1980s

Underground at Rabbit Lake

Underground at Cluff Lake

Remote Scooptram Operating at McArthur River

RADON 1970 TO PRESENT



Uranium Resource Development

Canada

Kazakhstan

Mongolia

Russia

Australia

United States

Africa

By- product (gold, phosphate fertilizer production,…)

UMEX – The Idea

For nuclear industry workers there are a number of databases of occupational doses at both international and national level (IAEA Information System on Occupational Exposure {ISOE}, Canada's national dose registry…)

Similar systems are in place or being developed for medical exposures and industrial workers

The Information System for Uranium Mining Exposures (UMEX) was designed to examine global occupational exposures in uranium mining and processing

UMEX – Objectives

To develop an information system for occupational exposure in uranium mining and milling

To obtain a global picture of the occupational radiation protection experiences in uranium mining and processing industry worldwide

To identify leading practices and opportunities and to derive actions to be implemented for assisting in optimising radiation protection

The UMEX project commenced in 2012

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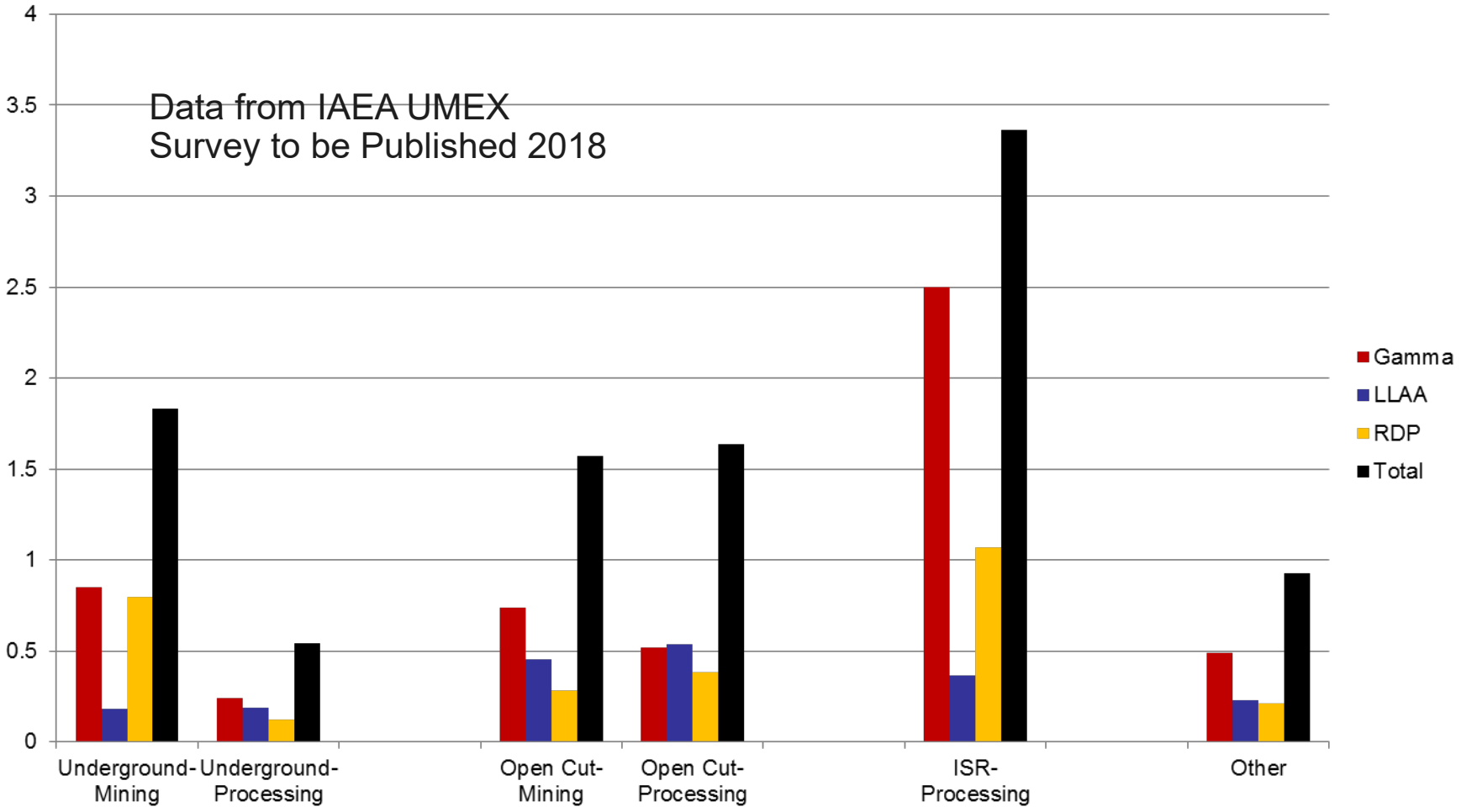
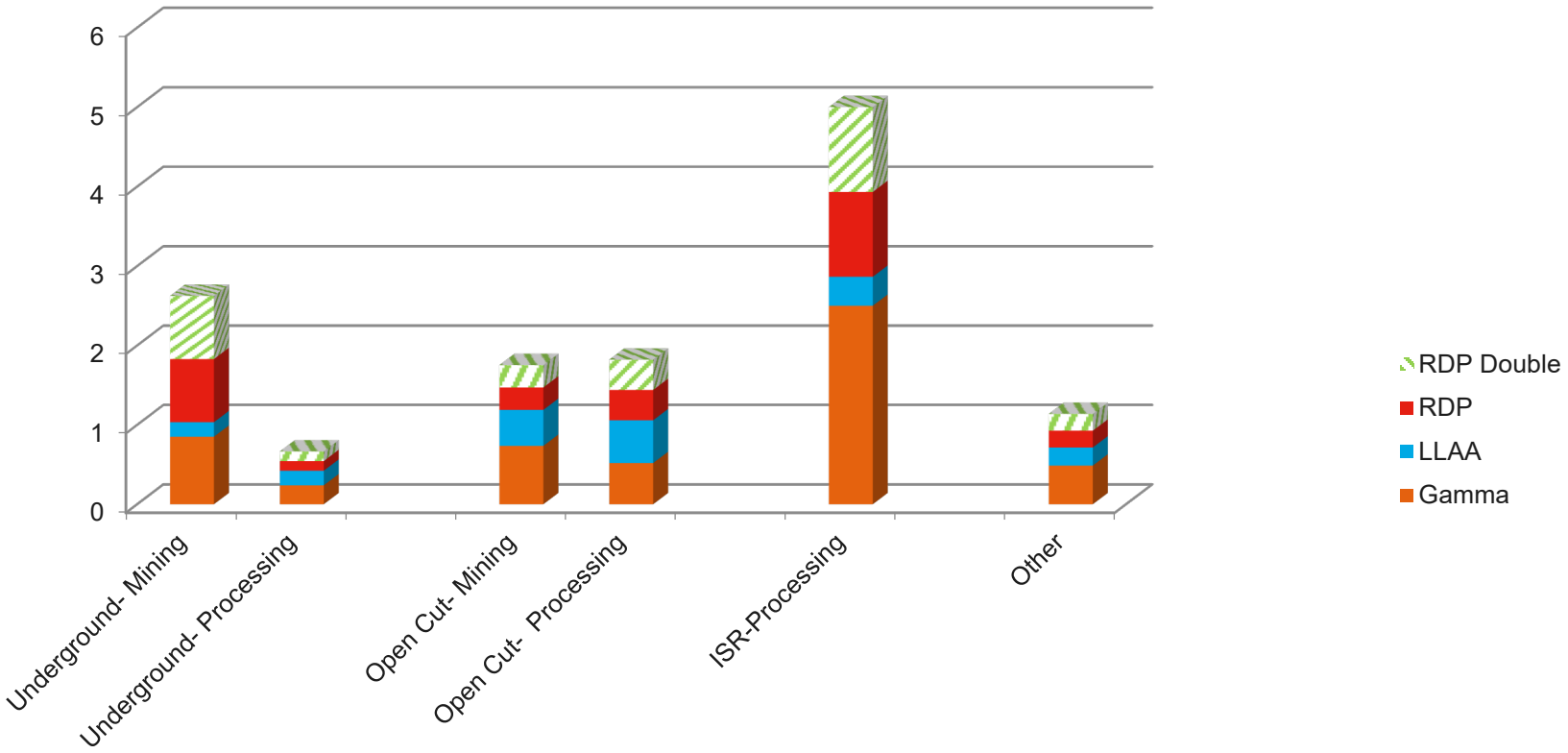
Exposures in Modern Uranium Mines



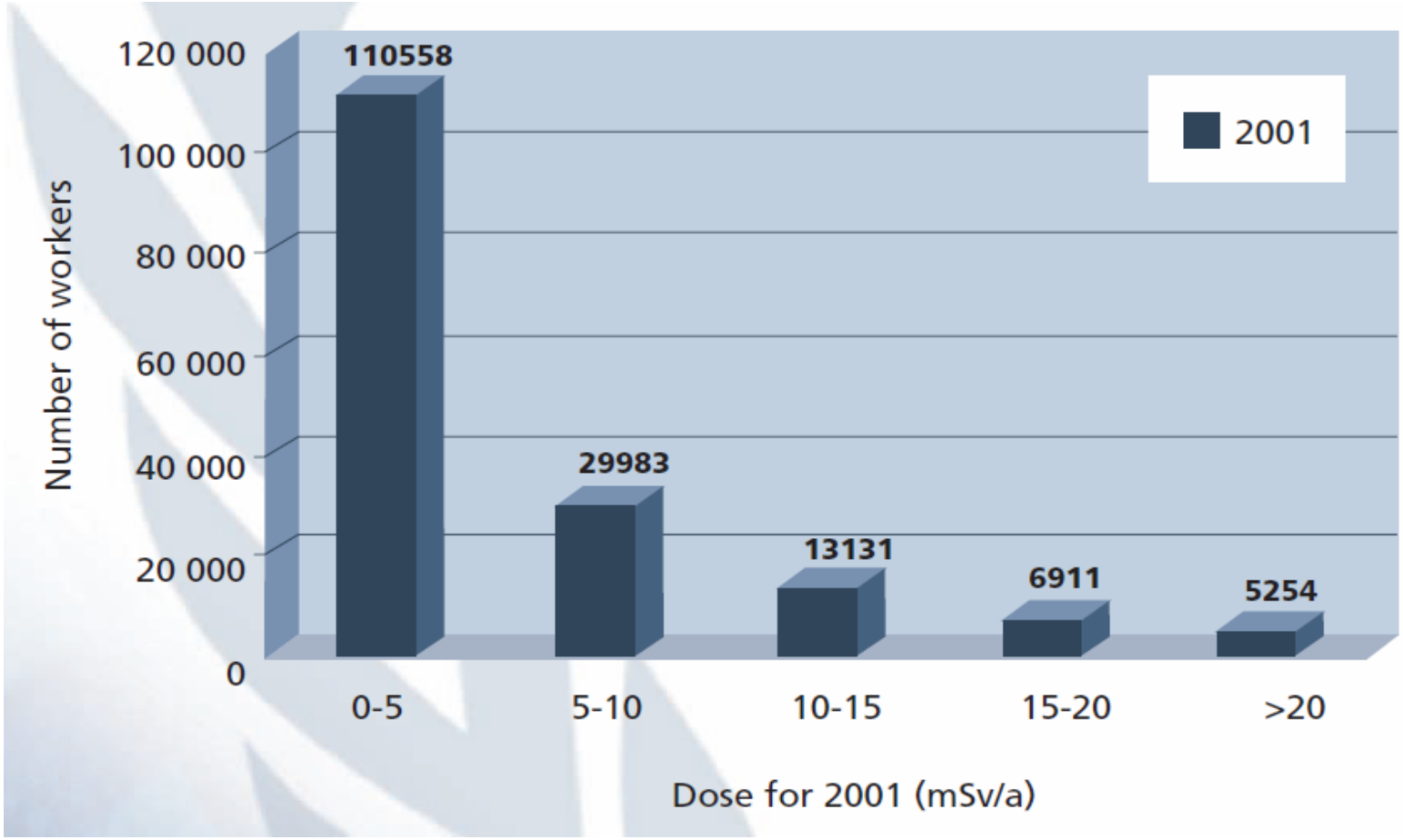
Changes in ICRPs Radon Dose Conversion Factor

- ICRP have recommended a new DCC for radon and radon decay products,
- An increase by a factor of 2,
- The UMEX data allows determination of potential impacts on the uranium mining industry, but
- Not limited to uranium mining industry.

Effect of Change in Radon Dose Conversion Factor



South Africa Underground Miners: Annual Exposures: 2001



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But!
Smoking is Main Cause of Lung Cancer

Darby *et al*. (2005) in a study of 13 European residential case control studies looked at combined effect of smoking and residential radon on the absolute risk of lung cancer and found that for lifetime (75 y) of exposure to 100 Bq m^{-3} and using the same relative risk factor of 0.16 per 100 Bq m^{-3}:

- **0.47% risk from radon to never smokers**
- **11.6% risk from radon to smokers**

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Overview

Radon levels in modern uranium mines are very low, typically well below the current limit of 4 WLM per year

- the continued application of ALARA and good work practice will continue to ensure safe levels of workplace radon in uranium mines
- but expect challenges in new mines, especially where work in ore is required
- it will be important in the future to ensure that the same radiation protection principles are applied to none-uranium mines and workplaces