URANIUM MINER EXPOSURES "UMEX"

Presented To:

ISOE
FORT LAUDERDALE
JANUARY 8-10, 2018

Presented By:

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Uranium Resource Development

Canada

Kazakhstan

Mongolia

Russia

Australia

United States

Africa

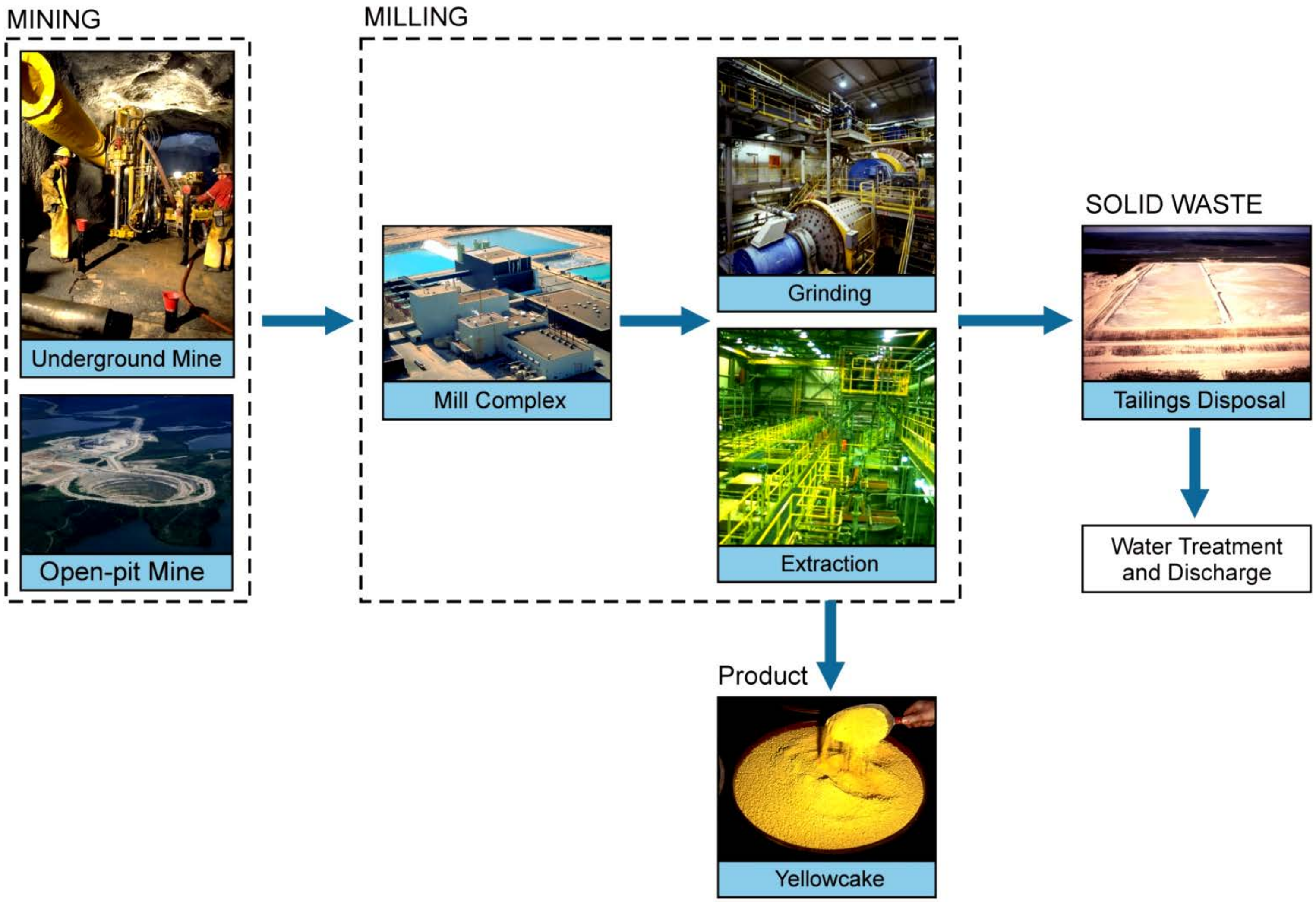
By- product (gold, phosphate fertilizer production,…)

Mining Methods

There are three main methods of producing uranium:

- underground mines,
- open pit mines, and
- in–situ-leach (ISL) (sometimes referred to as in-situ recovery or ISR).

Mining & Milling Components



Underground at Cluff Lake

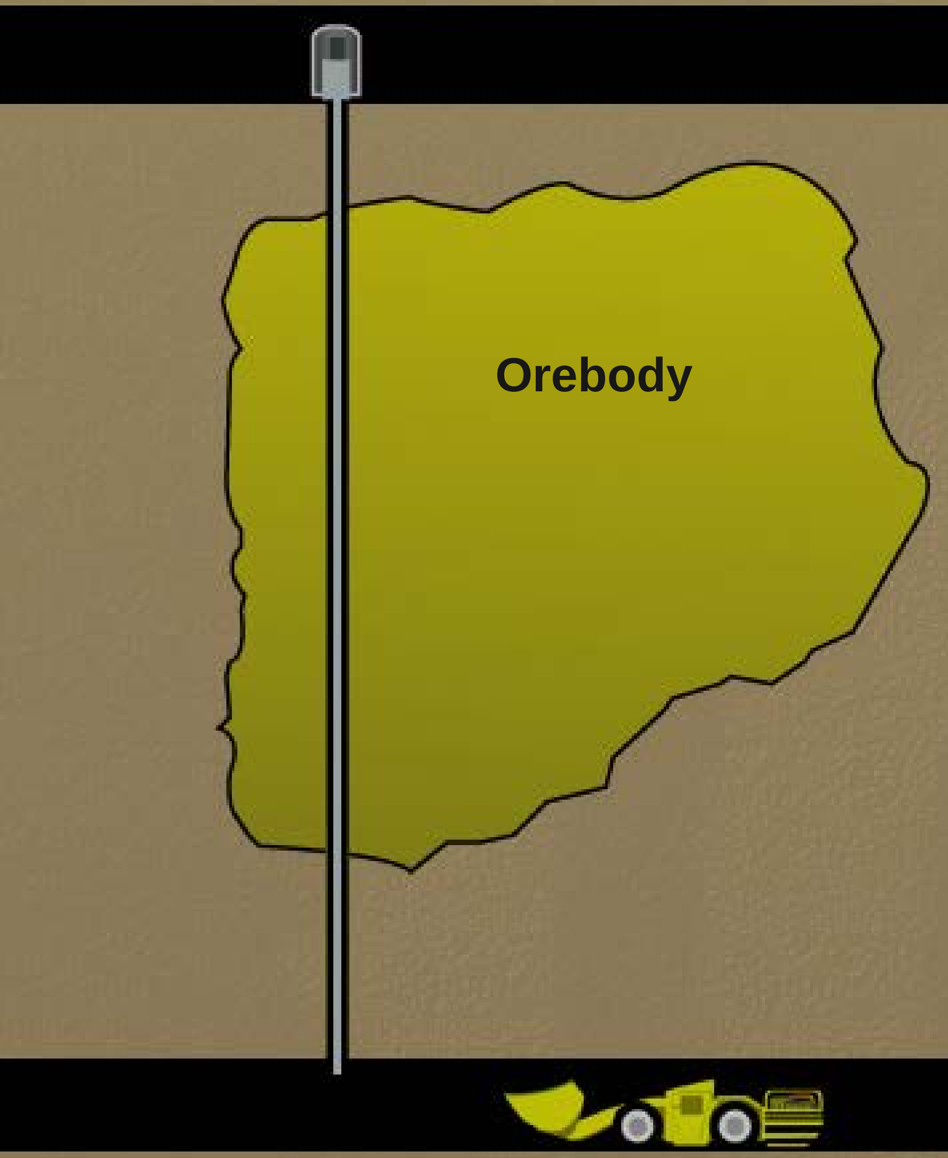
Underground at Rabbit Lake

McClean Lake Mine and Mill

Open Pit Mining at McClean Lake

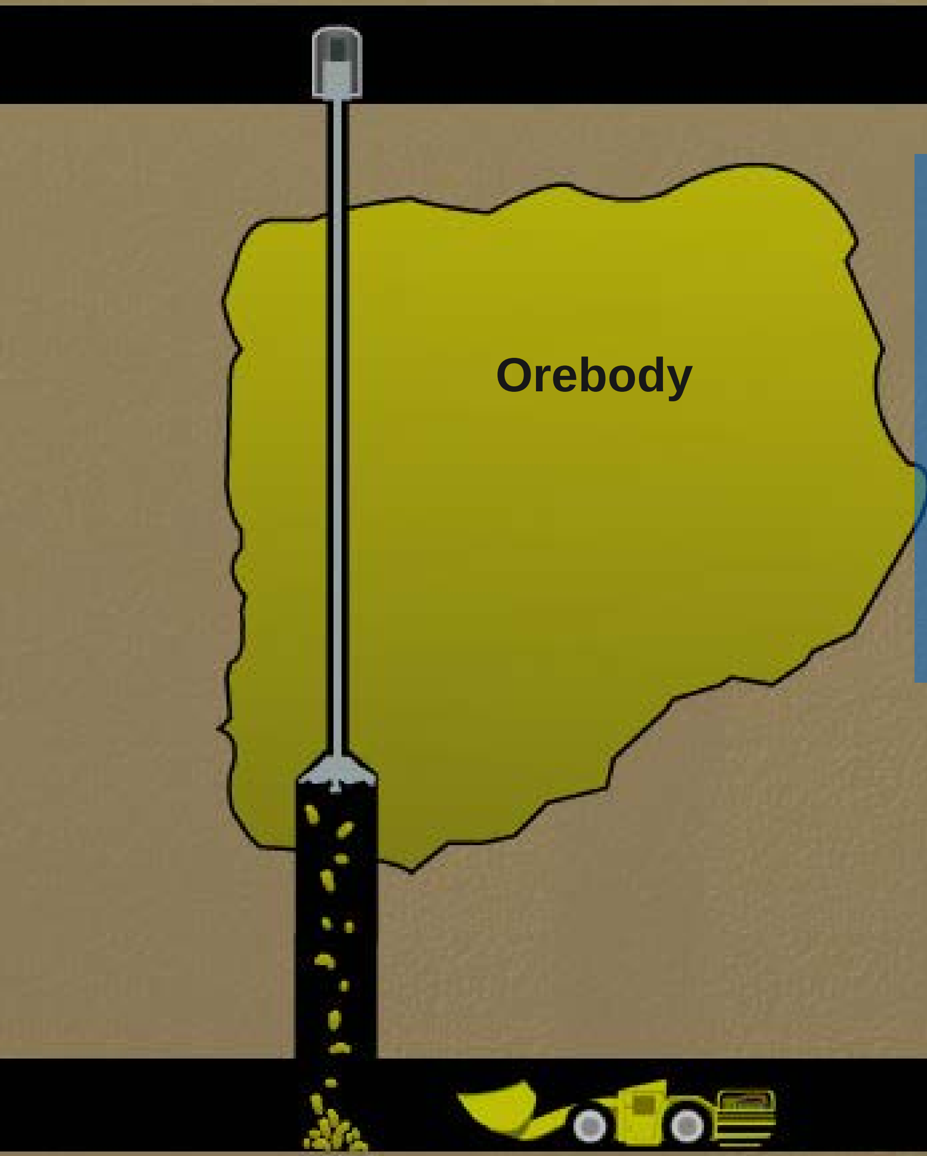
Freeze Plant at McArthur River

Raisebore Mining Method – Step 1



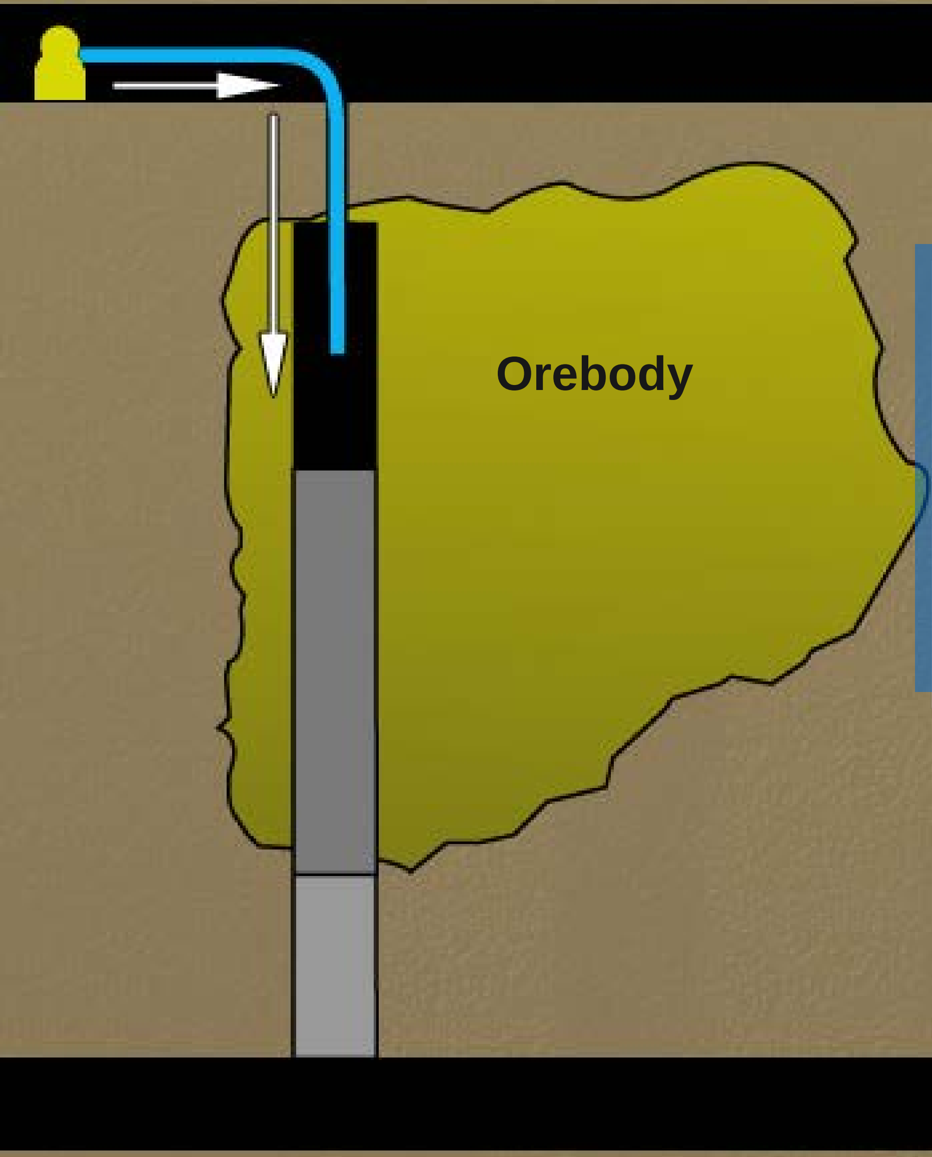
Pilot hole drilled from 530 m level to 640 m level

Raisebore Mining Method – Step 2



Reaming head installed at 640 m level and bores back up through orebody

Raisebore Mining Method – Step 3



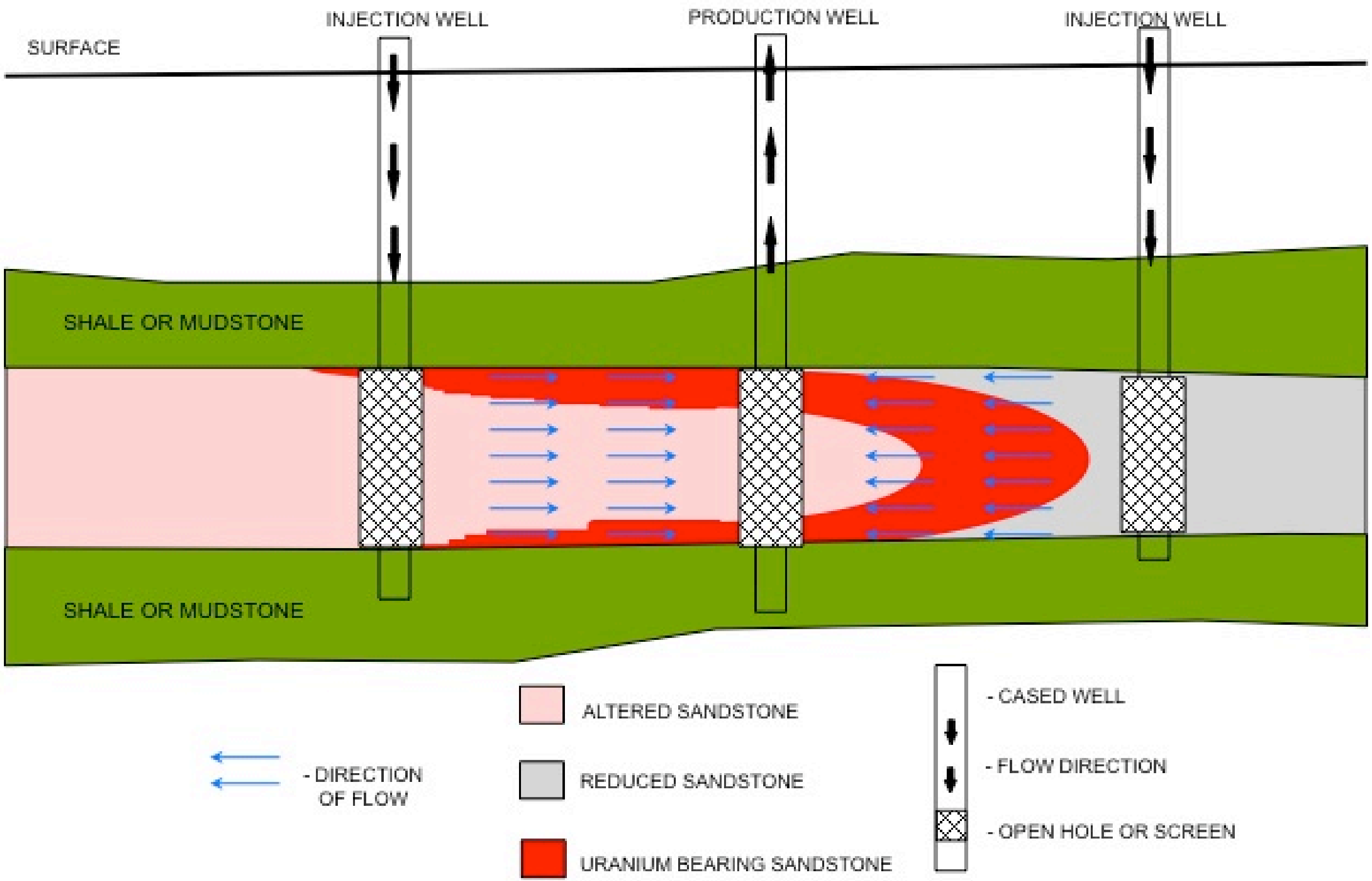
Back filling – Completed raise capped and filled with concrete

Raise Boring at McArthur River

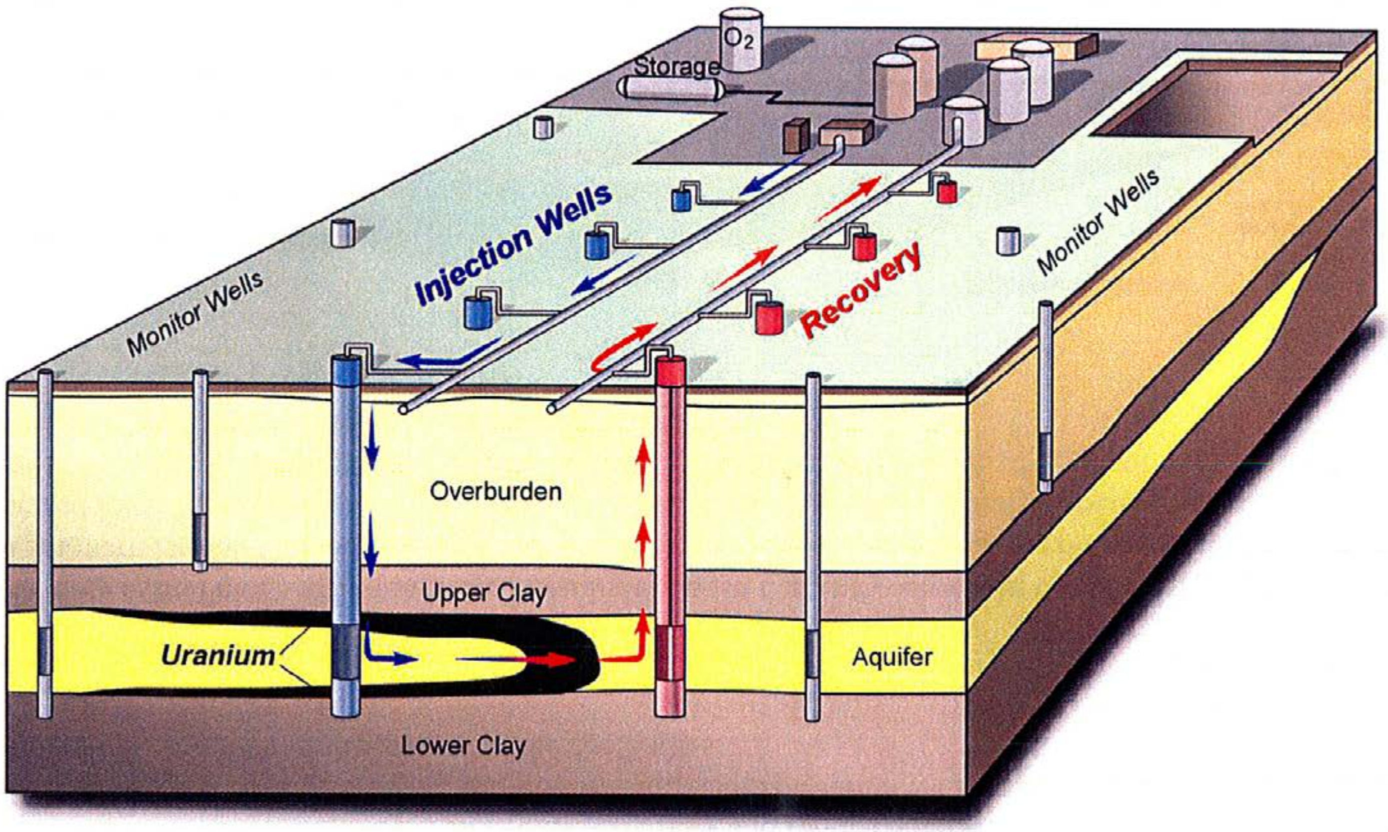
Remote Scooptram Operating at McArthur River

Air Sampling at McArthur River

Basic ISR Mining Method



IN-SITU LEACH (ISL)



ISL Central Processing Plant and Portion of Well field - Wyoming

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

UMEX – The Design - Requirements

Important requirements and information to collect:

- capture as many of the uranium workers as possible across a wide number of jurisdictions
- need to know the type of operation and nature of the work being performed
- Need to understand the key assumptions used to monitor and calculate exposure and dose
- Collect dose information based on individual pathways
- Ideally wish to know the underlying dose distribution
- Record primary control mechanisms to optimise dose

UMEX – The Design
- Current Systems

Current System of uranium mining doses:

- Some countries have central dose registers
- Some mines regulated at local (State, Region, Province)
- Dose data may be held by multiple bodies (mine, State regulator, national database) across different jurisdictions
- High variability in how doses are monitored and calculated
- High variability in how workers are classified

UMEX – The Design
- Limitations and Solutions

PRIVACY – A critical limitation so only amalgamated information received to prevent with no personal identifiers

EASE of USE – To enable the widest possible response needed to make the data entry easy and quick (otherwise it would not happen)

Multiple Dose Databases – Used national regulator to determine which is the official dose register

Variability – Combination of drop down menus, information tabs and free form fields to structure data entry

Different Dose Methodologies – Capture as much information about monitoring and dose calculation methodologies

UMEX – The Design - The Questionnaire

The final questionnaire developed was EXCEL based (to ease data merging and structure data entry) and covered the following key areas:

- Background information
- Operations information
- Monitoring approach
- Dose calculation
- Radiation controls
- Auxiliary controls
- Workgroup dose data

UMEX- The Questionnaire - Workgroup Dose Data

Workers divided into workgroups (freeform) under defined work categories and the number of personnel recorded

For each workgroup average, maximum and conversion factor is given for each pathway and total

Where possible, the standard deviation, assumed distribution and basis for the conversion factor is requested

The number of personnel in each 0.5mSv/y bracket is also requested to enable a dose histogram to be developed

UMEX – The Response

The survey provided a snapshot of the doses in the 2012 calendar year

Occupational data from 36 operating facilities were received

This covered a production of 58,344 t of uranium or approximately 85% of global uranium production in 2012

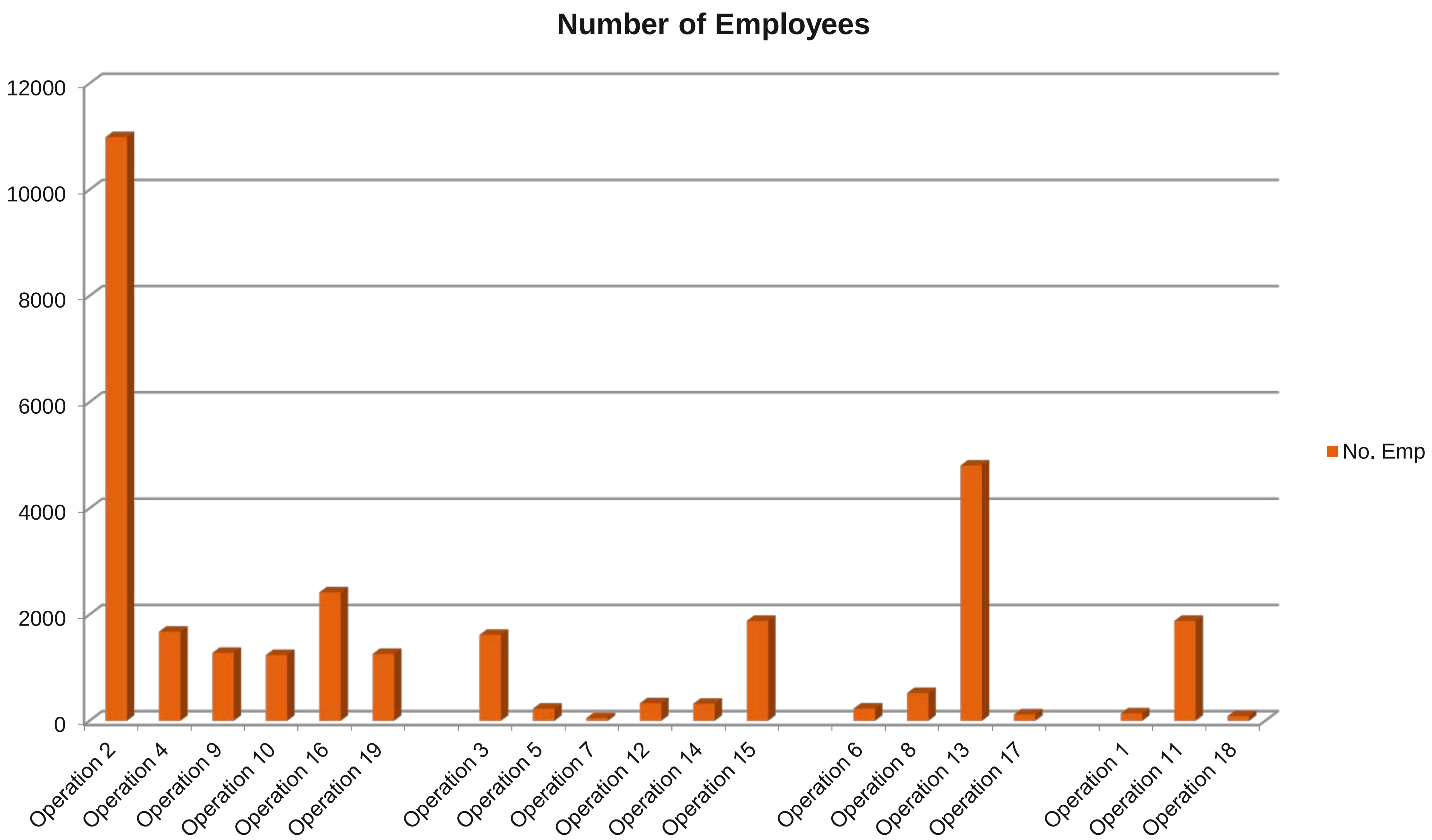
Amalgamated dose data was received from in excess of 30,000 workers

UMEX – The Response (Cont'd)

The data received covered open cut mines, underground mines, in situ leach mines, toll processing operations and by-product recovery

Data on 15 Individual operations using similar mining and processing techniques were amalgamated and reported as a single operation

Number of Employees per Operation



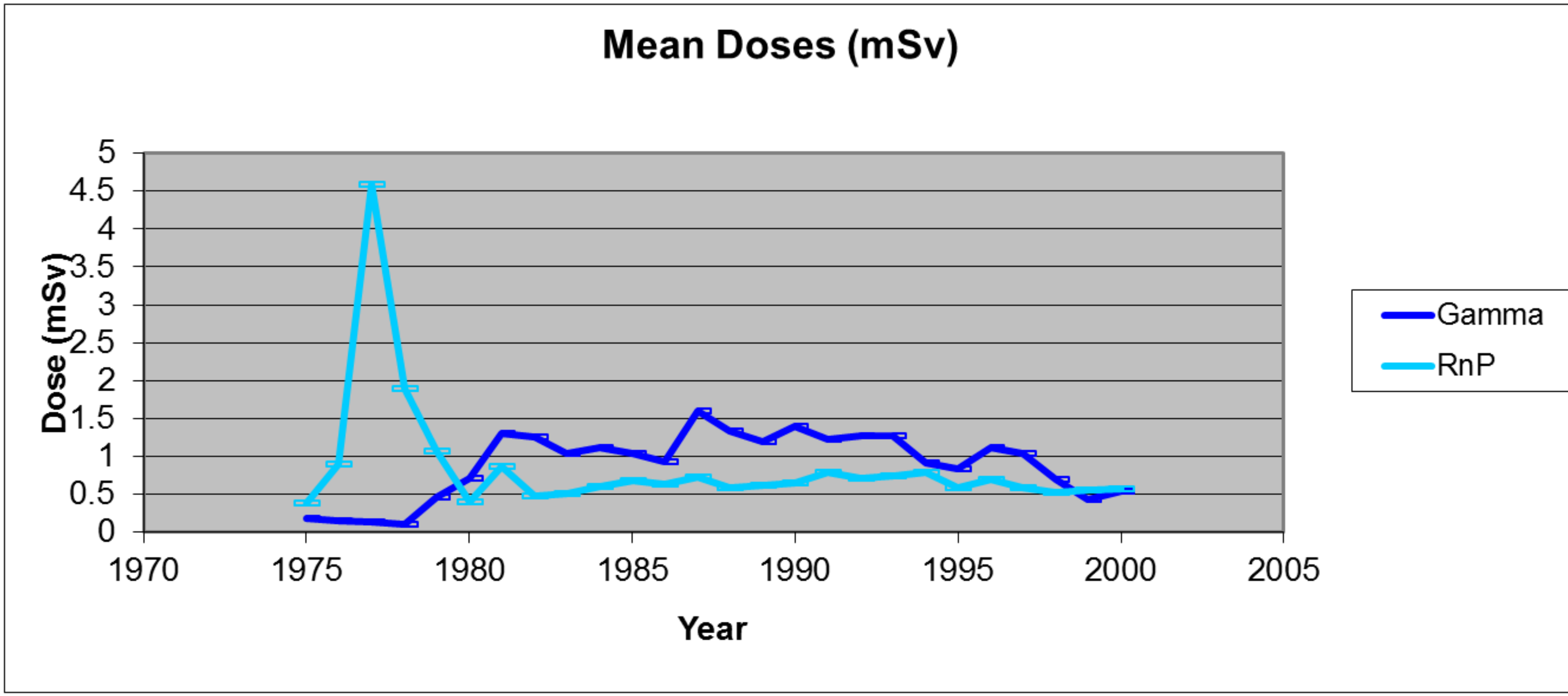
UMEX – The Results

The survey data characterise an industry where occupational exposures are well controlled and doses remain within applicable limits

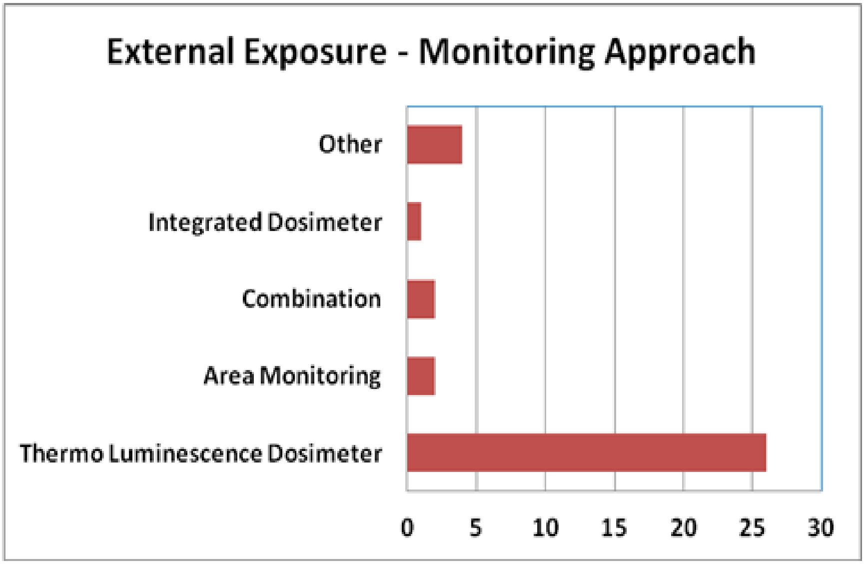
Average doses were typically less 5 mSv/y and the maximum individual dose was 16.5 mSv/y

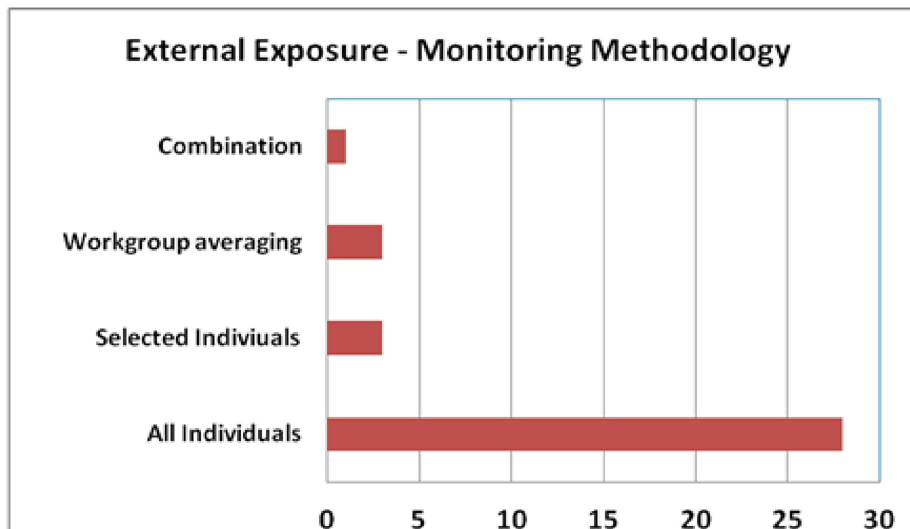
Majority of doses to personnel are below 2 mSv/y

Mean Doses for Current Mining (Northern Saskatchewan)



External Exposure Monitoring Methodology





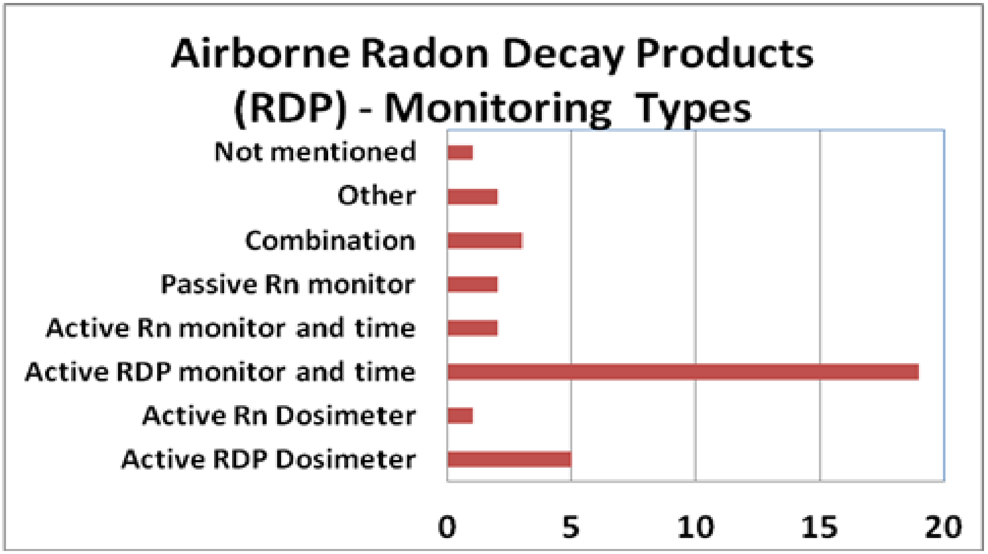
Individual Monitoring Methods

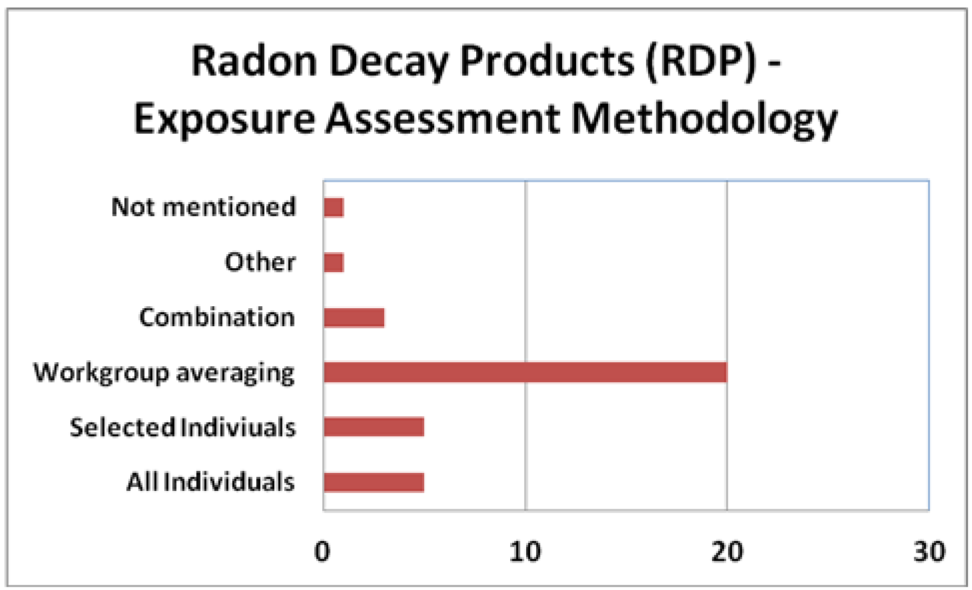
External dosimetry

Personal Alpha Dosimeters
(Radon progeny and uranium ore dust)

Detector Charging Station

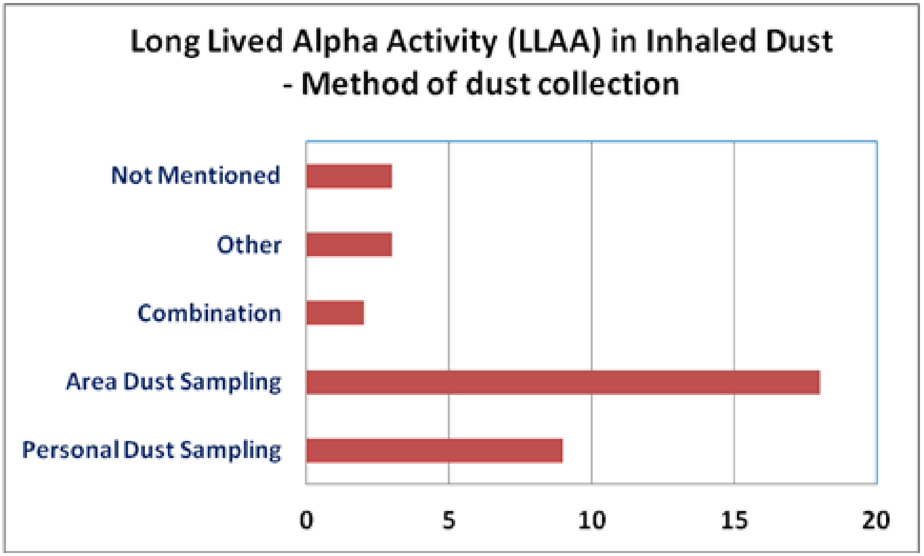
Radon Decay Product Monitoring Methodology

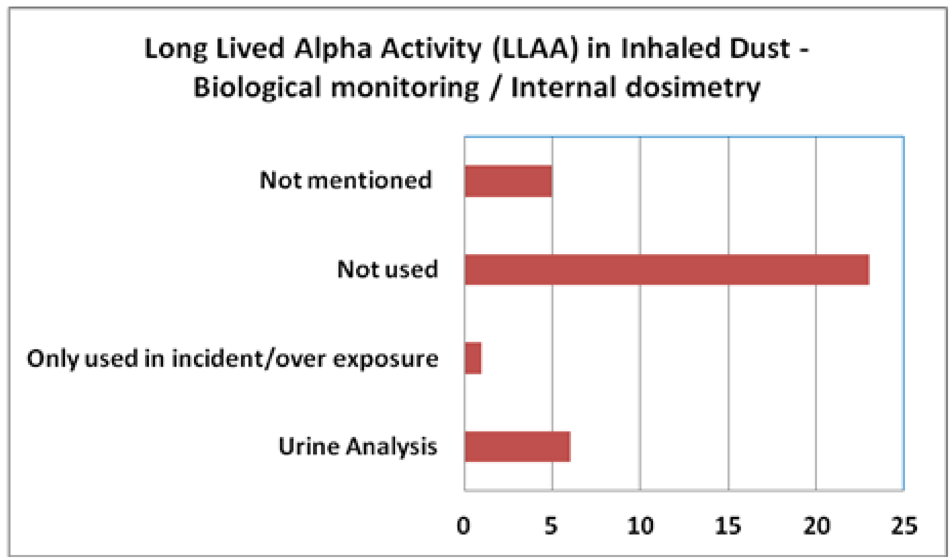




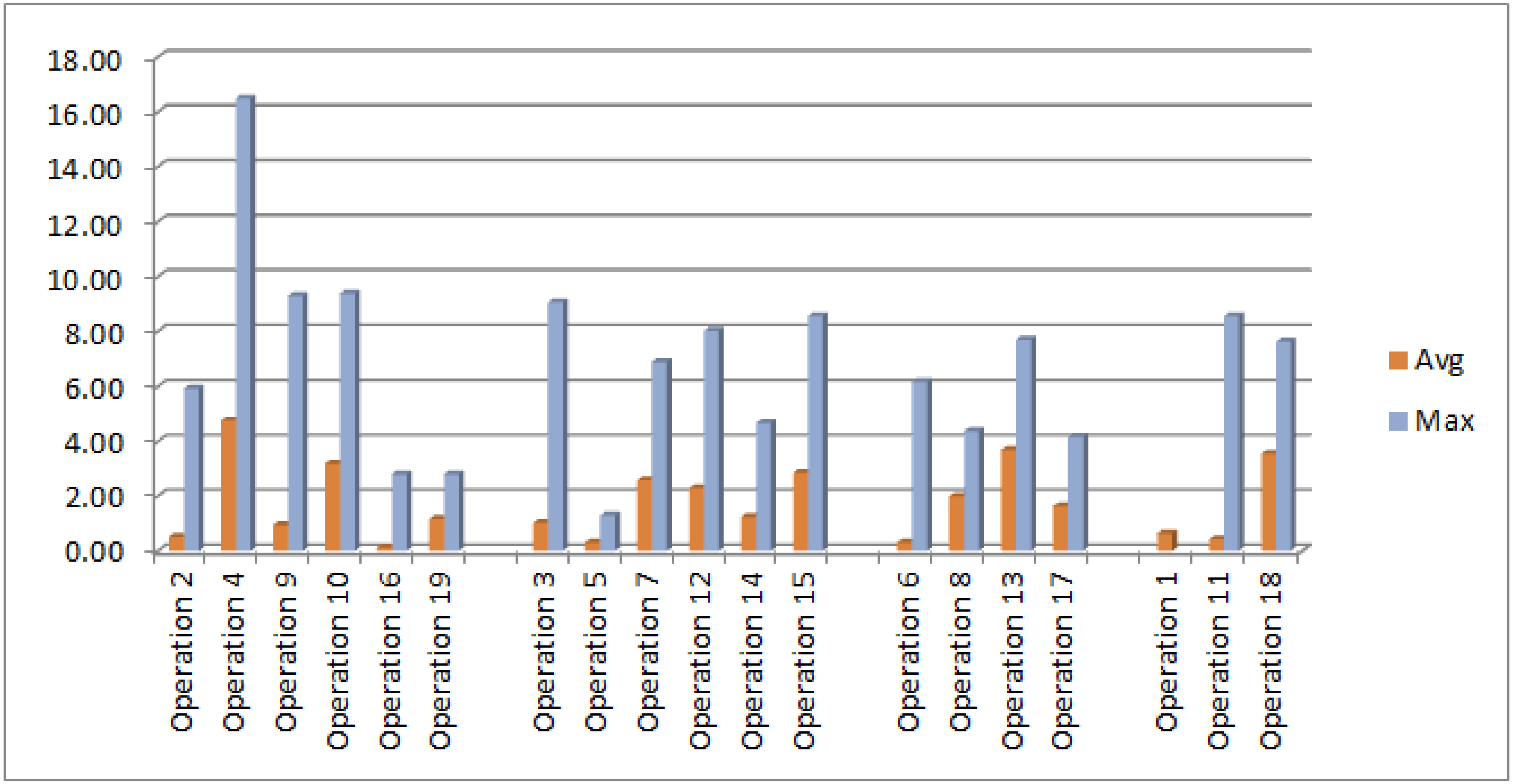
Area Radon Detector

Inhaled Dust Monitoring Methodology

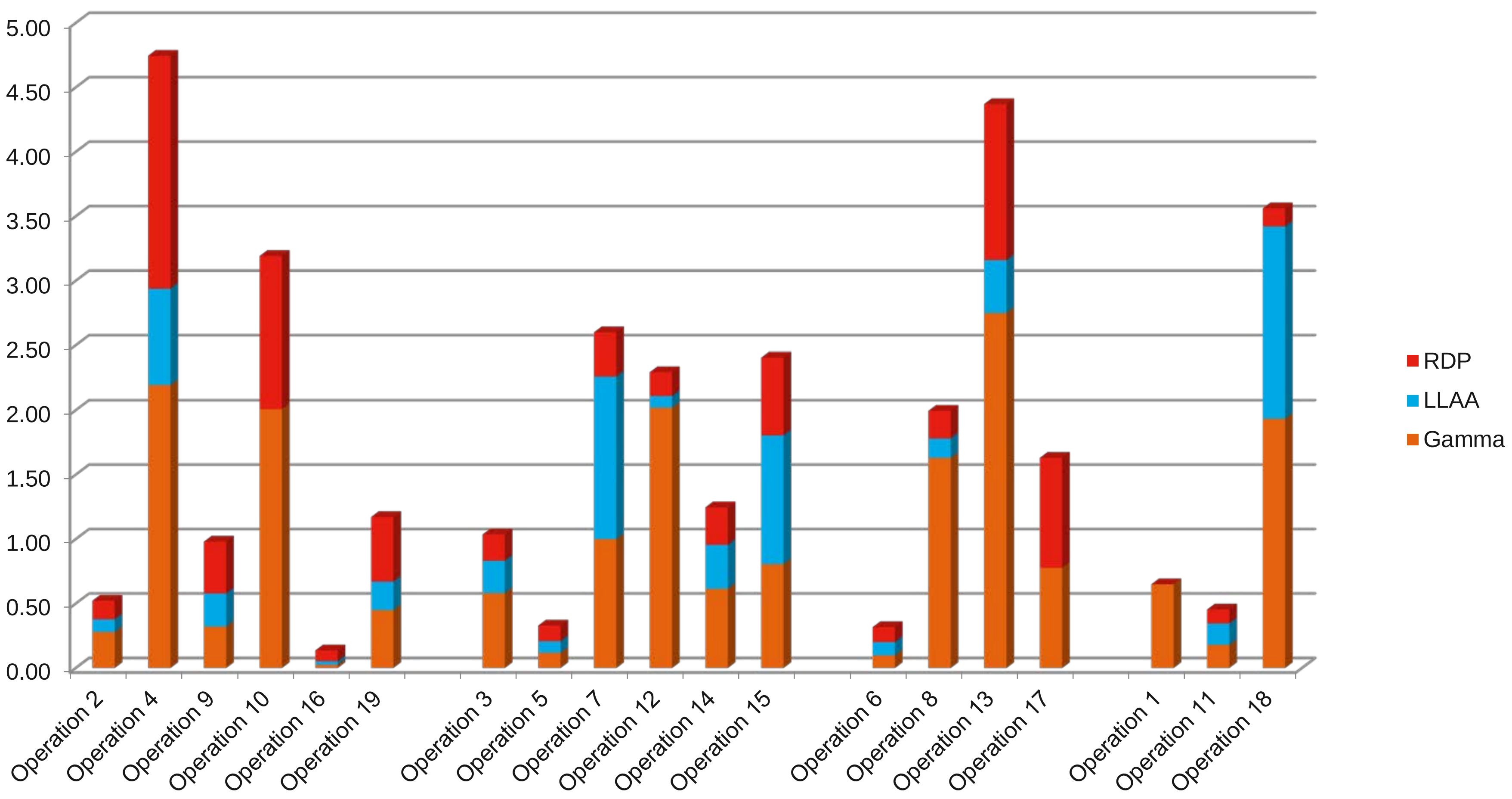




Average and Maximum Doses by Operation



Breakdown of Average Doses by Pathway and Operation



UMEX
– Observations and Learnings

Potential Changes in Radon (Decay Products) Dose Conversion Factors

High Dose and Corrective Actions

Background Subtraction

Different Dose Distributions

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
- which 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

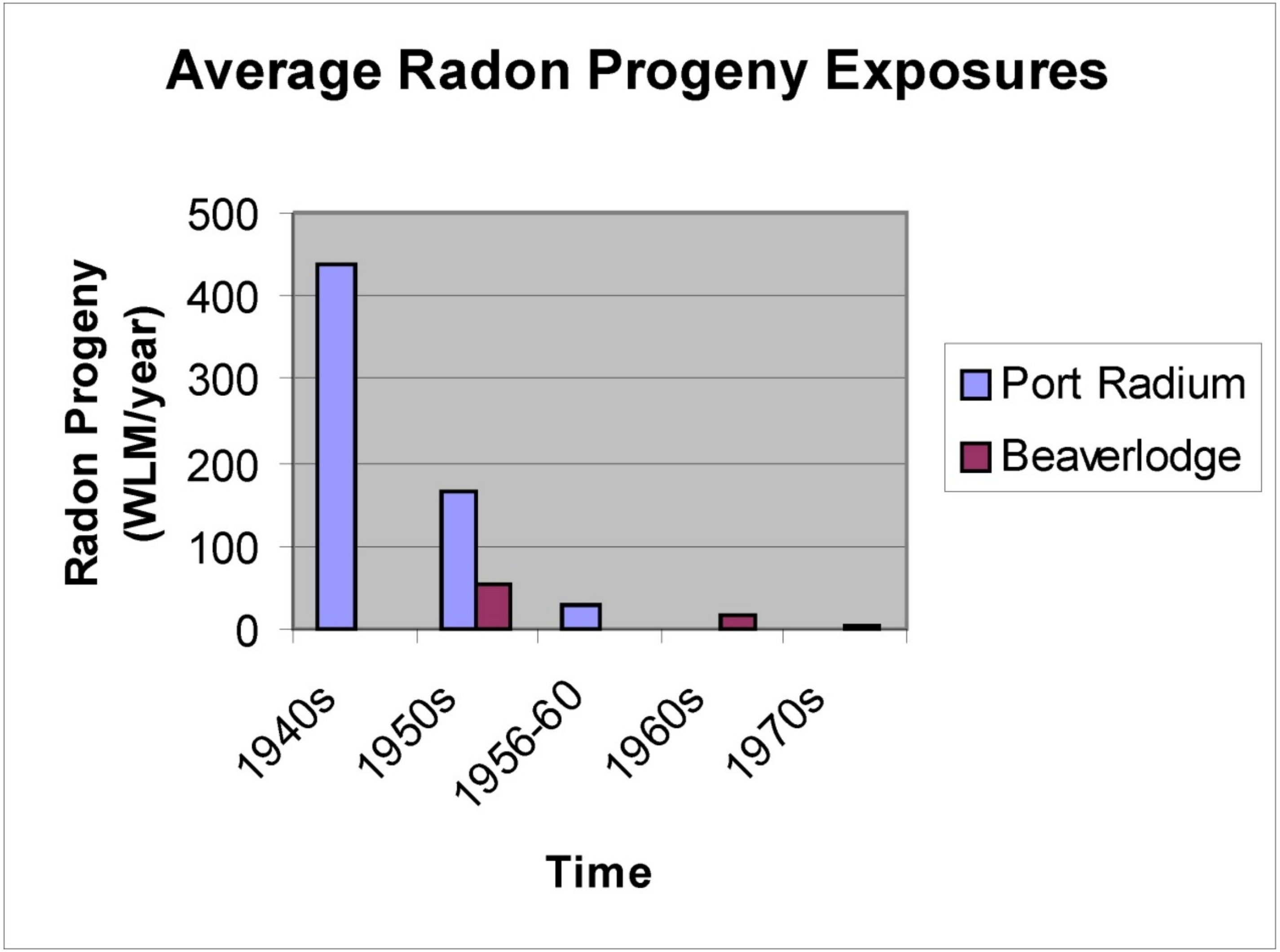
By the mid 1950's, there was a global awareness of the risk of lung cancer in miners

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

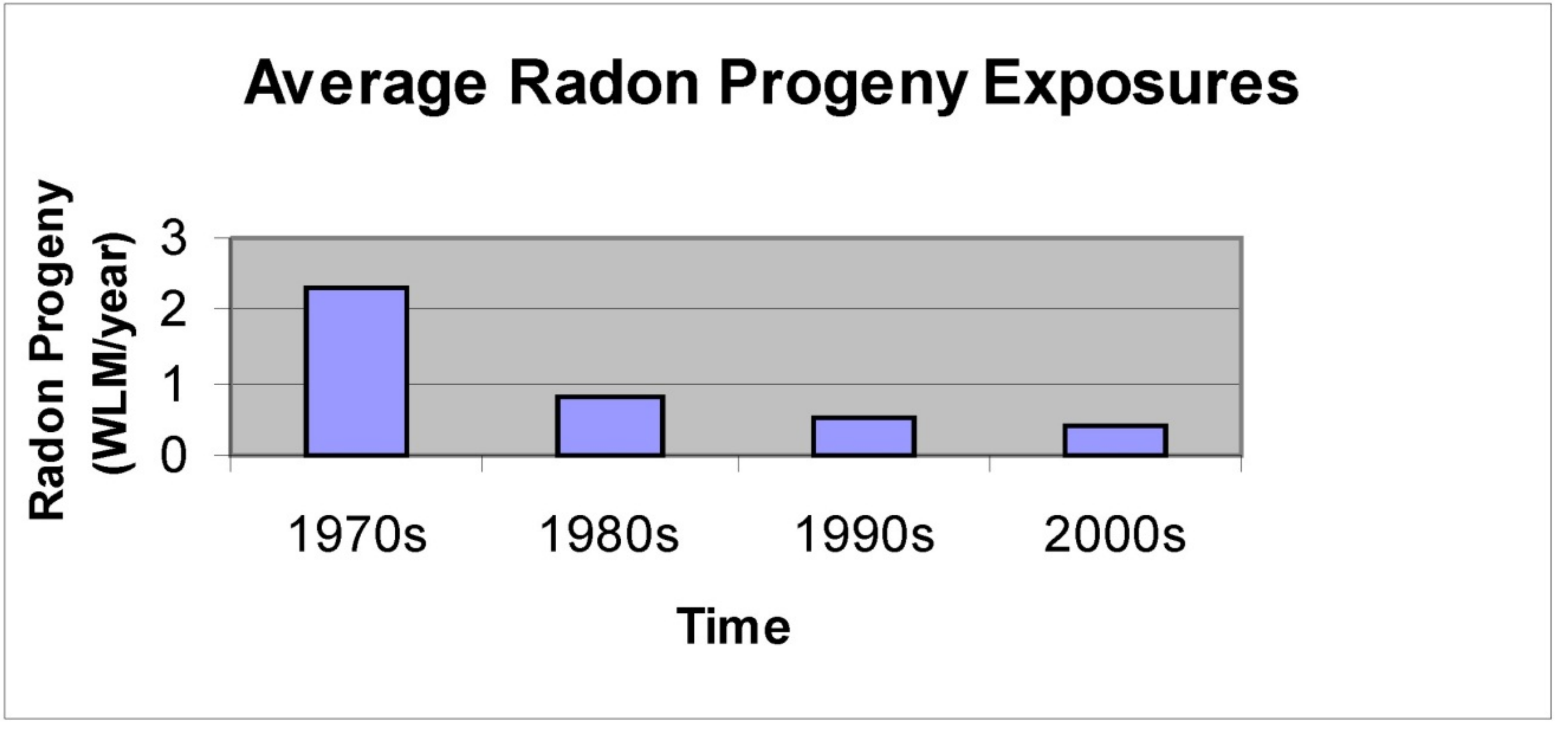
The radon guidelines and standards evolved over time as our understanding of the radon hazard evolved through measurement and epidemiology studies of miners

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

RADON 1940 TO 1970



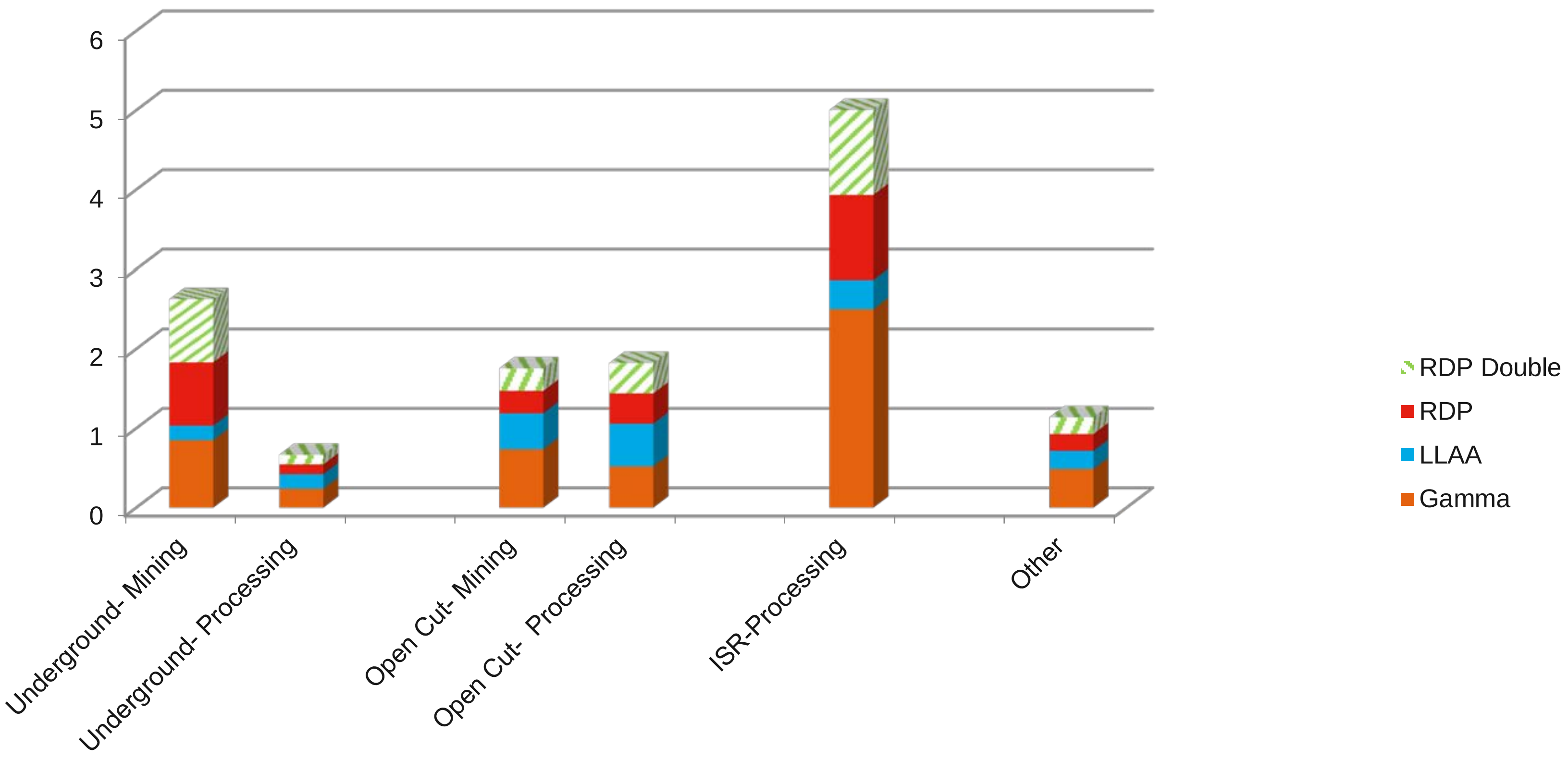
RADON 1970 TO PRESENT



Potential Changes in Radon Dose Conversion Factors

- 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.

Potential Changes in Radon Dose Conversion Factors



Radiation Safety Issues in South Africa Gold

The radiation issues in underground gold mines in South Africa producing uranium were investigated in the late 1950's/early 1960's by the mining industry

Radiation exposures occurred underground from radon daughters

In certain gold mines and areas of mines exposures could be multiples of the annual dose limit

There was little regulation or control

Assessing Underground Exposures

Most underground workers in South Africa receive doses well below 6 mSv per annum

In some work areas there are problems with compliance with dose limits (in older, shallower mines),

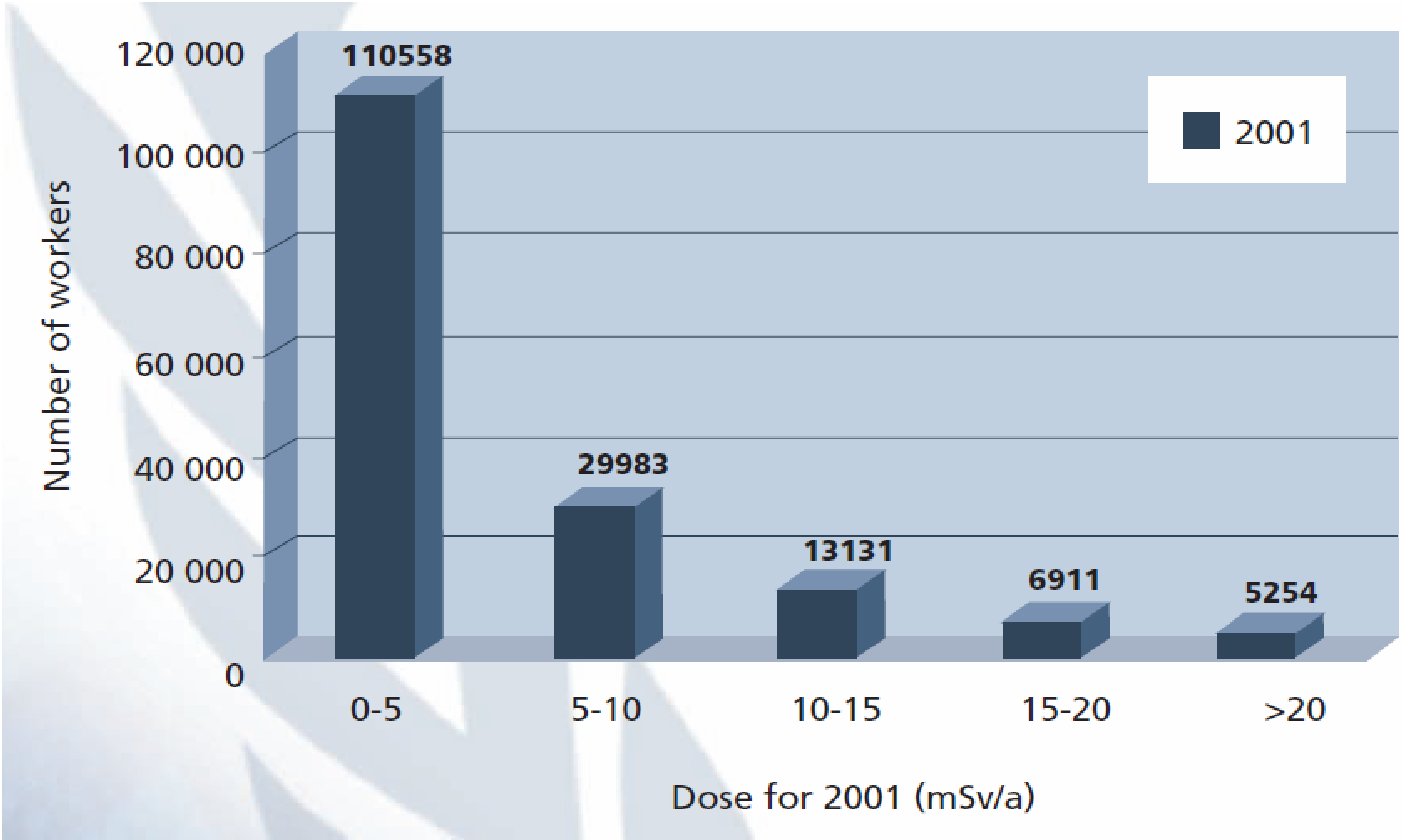
If ventilation improvements are not possible, workers can be rotated from underground work to surface when annual exposures exceed 15 mSv over 12 month period, or

Classify as a special case mine, with a 50 mSv annual limit and 100 mSv over 5 years,

Monthly individual dose reports are required,

Dose limitation approach must be agreed with unions, regulator and operator.

South Africa Underground Miners: Annual Exposures: 2001



High Dose and Corrective Actions

In the initial survey results one operation recorded a maximum dose of 31 mSv/y

Examination of the data showed 30 mSv was from gamma exposure

The UMEX team believed the dose was incorrect and subsequent investigation by the regulator and operator confirmed that the data was both suspect and impossible for the individual to have received

The individuals doses was corrected to reflect the workgroup average for gamma by the regulator

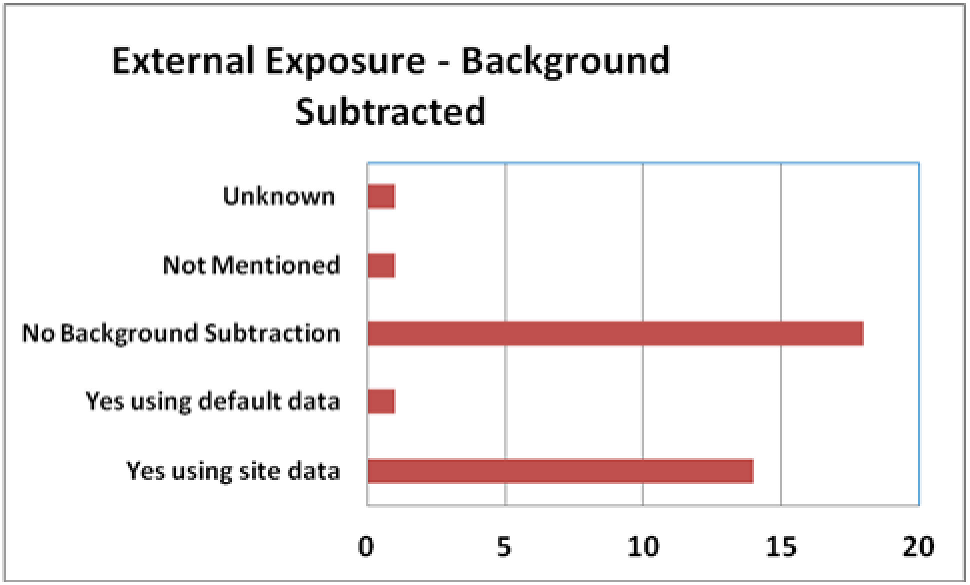
Background Dose Subtraction

For gamma exposure the majority of operations used TLD's (or equivalent)but a high proportion did not subtract background

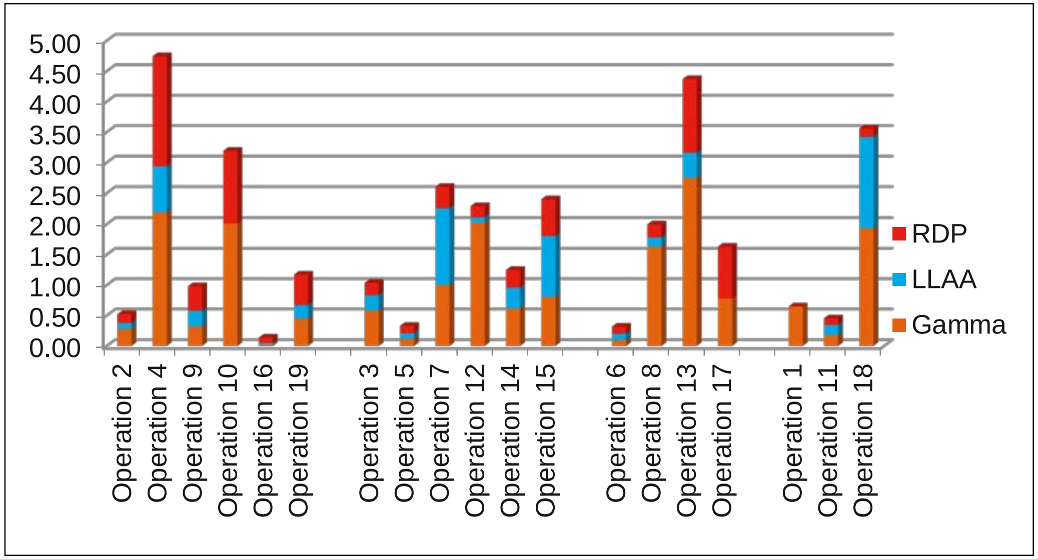
This was particularly apparent in the ISL mines where gamma was by far the dominant pathway

By not subtracting background the operational derived worker dose was likely over-estimated by between 0.5 and 1 mSv/y

Recommendations on appropriate methodology for the use of control and traveller badges were provided to assist in removing the natural background component



External Exposure – background subtracted



Different Dose Distributions

Distributions of doses heavily influenced by the choice of workgroup and who is included

This distribution variability raises questions about the use of normal statistical methods for interpreting doses

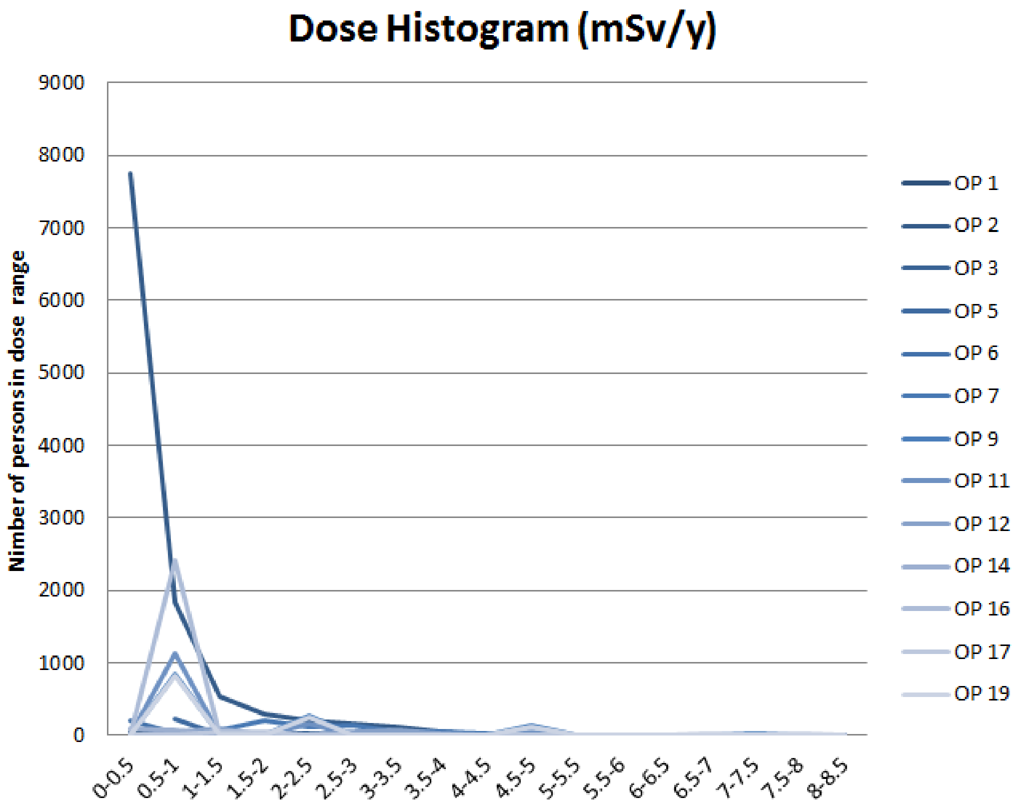
Also may call into question the use of average dose and how workgroups are defined

Lots of (non) Radiation Workers

Some operations have a high majority of workers in the 0-0.5 mSv/y range

Are these true radiation workers or are they made up of people not exposed to uranium or short term workers

In one operation this was very apparent and the regulator and operator are currently addressing this

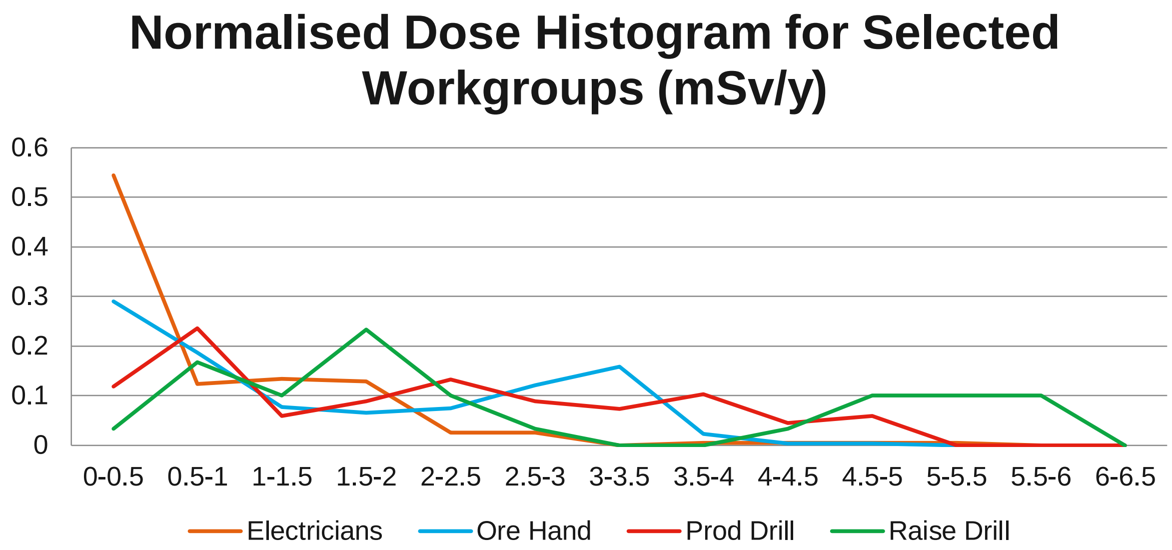


Multiple Distributions in a Workgroup

A workgroup is expected to be homogeneous with similar exposures

Often see multiple clumps of doses

Likely to be people with different work practices (supervisor vs face worker)



Conclusion

The UMEX provided a snapshot of occupational doses in the uranium industry

The response covered approximately 85% of global uranium production

The doses show compliance with international recommendations and represent good practice globally

The importance of the data collected was high and there were a number of improvement approaches identified upon analysing the data

The findings of the project will be incorporated in the upcoming IAEA Safety Report