Personal Alpha Dosimetry Service – Quality Assurance Matters

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Quality Assurance

The Radiation Safety Institute of Canada is committed to the highest quality of its licenced Personal Alpha Dosimetry Service.

Through the development and implementation of a comprehensive quality assurance program, the Institute strives to ensure it provides the most accurate radiation exposures possible to its clients.

The Institute extensively utilizes statistical control charts and process capability analysis as important tools to monitor and trend key operational and performance indicators. In this poster we will present an introduction to our dosimetry service and the use of control charts and process capability analysis in our quality assurance program.

Worker at Cameco Corporation's Rabbit Lake uranium mine wears a PAD while operating a remote control scoop tram.
Photo courtesy of Cameco

Quality Assurance Program Elements

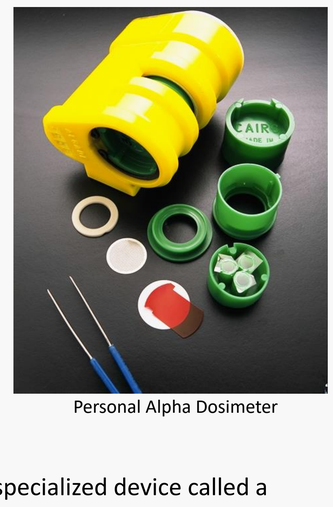
Key elements of the Institute's quality assurance program include:

- Management commitment and support
- Physical and financial resources necessary to administer the program
- Documented quality assurance objectives
- Documented operating procedures for all key processes
- Worker training and competence verification
- Dosimetry materials and supplies procurement quality control
- Dosimeter preparation and processing quality control measures and metrics
- Dosimetry reporting and records management quality control
- Internal and independent device performance testing
- Non-conformance reporting and investigation framework
- Contingency planning
- Client complaint mechanisms
- Program reviews – internal and independent

PAD performance testing in the Institute's National Radon Chamber

Personal Alpha Dosimetry

The Radiation Safety Institute of Canada operates a Personal Alpha Dosimetry Service licenced through the Canadian Nuclear Safety Commission (CNSC). The Personal Alpha Dosimetry Service is also an approved dosimetry service through the South Australia Environment Protection Authority.



Personal Alpha Dosimeter

Personal alpha dosimetry, primarily used in the uranium mining and milling industry, involves the measurement of occupational inhalation exposures to radon and thoron progeny and long-lived uranium radioactive dust (LLRD).

Worker exposures are measured utilizing a specialized device called a Personal Alpha Dosimeter (PAD).

The PAD consists of a solid state nuclear track detector (dosimeter head) mounted in a battery operated sampling pump which is worn by the worker during normal work shifts for a monitoring period of one month.

PAD Principles of Operation

During operation, the PAD continuously samples the air in the work environment collecting attached and unattached aerosols and dust on a filter membrane located inside the PAD dosimeter head.

Radon and thoron progeny collected on the filter will undergo radioactive decay emitting alpha radiation. The alpha radiation registers tracks on a cellulose nitrate film located inside the dosimeter head.

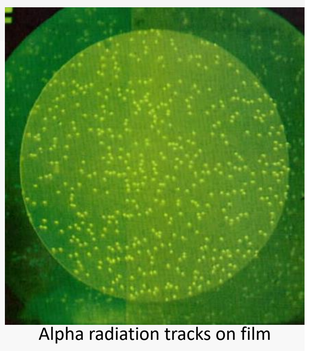
The number of tracks registered on the dosimeter head film is proportional to the radon and thoron progeny exposure received by a worker during the monitoring period.

PAD Processing

At the end of a dosimetry monitoring period, dosimeter heads are returned to the Radiation Safety Institute of Canada National Laboratories for processing.

The primary processing steps include:

- Etching the dosimeter head film in a caustic solution to enlarge alpha tracks present on the film.
- Counting the number of tracks on the dosimeter head films using a specialized image analysis system.
- Counting the alpha activity from LLRD on the dosimeter head filter.



Alpha radiation tracks on film

From the data collected, worker inhalation exposures are computed and reported to the client and to the Canadian National Dose Registry (for Canadian clients).

Statistical Control Charts

When dealing with a quality characteristic (measurement) that is variable, it is usually necessary to monitor both the mean value of the quality characteristic and its variability. Control of process average or quality level is typically done with a control chart for means, the $\overline{x}$ Control Chart. Process variability can be monitored with the $\overline{R}$ Control Chart.

A control chart always has a central line for the average, an upper line for the upper control limit (UCL), and a lower line for the lower control limit (LCL). These lines are determined from historical data (baseline data) where the process is believed to be "in control".

The formulas used for constructing control chart limits are summarized below for *m* process samples.

Process average:

$$\overline{x} = \frac{\overline{x}_1 + \overline{x}_2 + \overline{x}_3 + \cdots + \overline{x}_m}{m}$$

Observation range:

$$R = x_{max} - x_{min}$$

Average range:

$$\overline{R} = \frac{R_1 + R_2 + R_3 + \cdots + R_m}{m}$$

$\overline{x}$ Chart Control Limits:

$$UCL = \overline{x} + A_2\overline{R}$$

$$Centre\ Line = \overline{x}$$

$$LCL = \overline{x} - A_2\overline{R}$$

$\overline{R}$ Chart Control Limits:

$$UCL = D_4\overline{R}$$

$$Centre\ Line = \overline{R}$$

$$LCL = D_3\overline{R}$$

The factors A and D may be calculated or drawn from statistical tables based on the number of process samples (*m*).

By comparing current and future data to these control limits, one can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

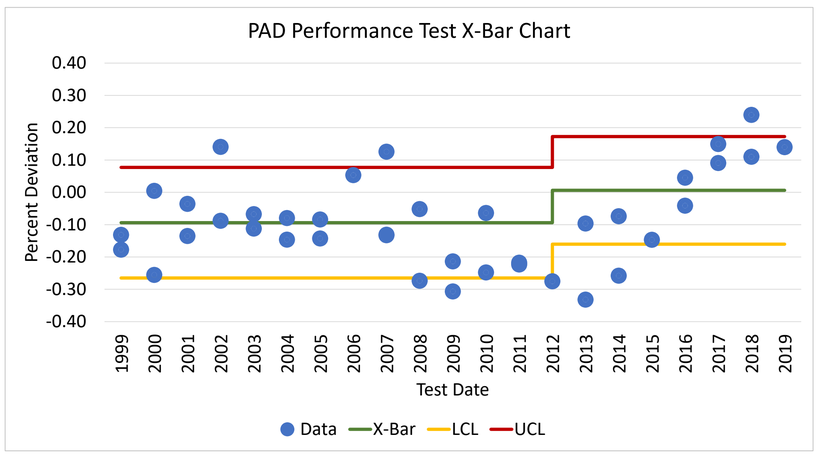
Data point trends above or below the average (centre line) or points falling outside the control limits is a possible indication of a process issue rather than simply random statistical variation.

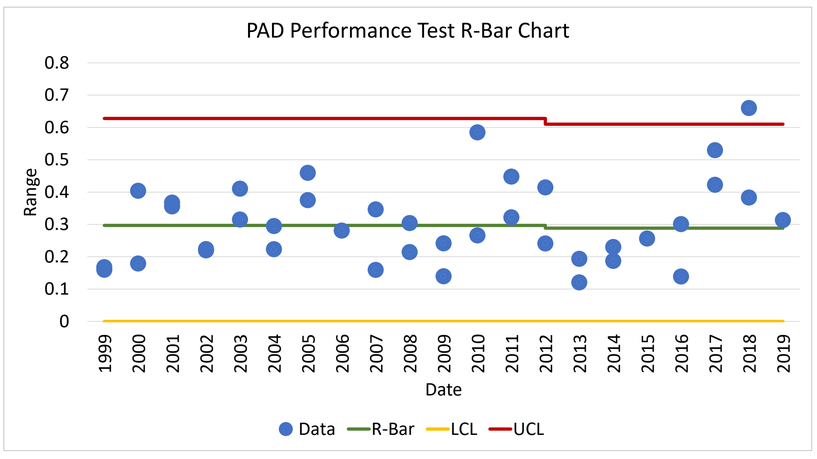
PAD Testing Control Charts

Shown in the charts below are examples of statistical control charts for routine blind PAD radon progeny testing at the Bowser-Morner Radon Chamber in Dayton Ohio, USA. The data points represent the average relative percent error between the PAD and the radon chamber measured radon progeny potential alpha energy concentrations.

As seen on the X-Bar chart, in 2013 PAD performance results fell below the control chart LCL. Upon further investigation, it was determined that there was an issue with the film counting image analysis system. The issue was corrected resulting in a return of PAD performance results to within control chart limits.

Control levels limits were adjusted in 2013 to reflect the commissioning of a new image analysis system and improved performance of the PAD.





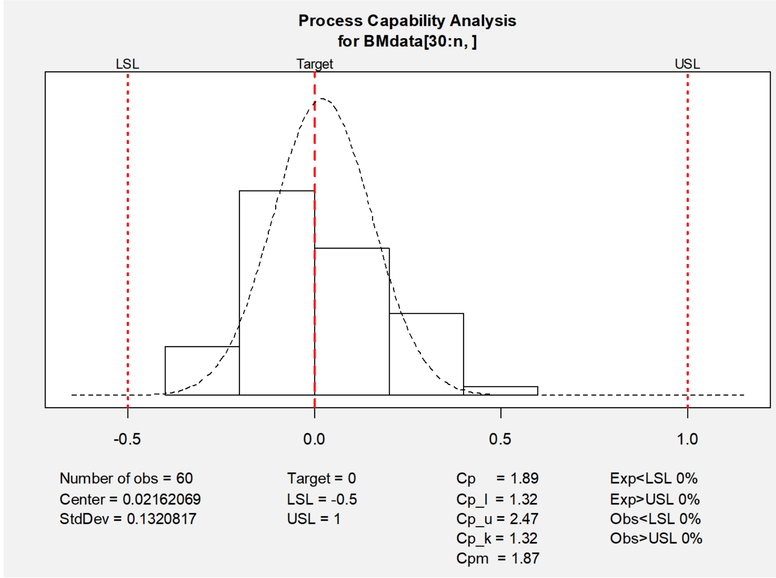
Process Capability Analysis

In process improvement, the process capability ratio is a statistical measure of process capability, a measurable property of a process to defined specification limits. Process capability indices measure how much natural variation a process experiences relative to its specification limits. The concept of process capability only holds meaning for processes that are in a state of statistical control.

The process capability ratio (PCR), Cp is defined as:

$$C_p = \frac{USL - LSL}{6\sigma}$$

The PCR is a measure of the ability of the process to fall within a defined upper specification limit (USL) and lower specification limit (LSL). The CNSC has defined the USL and LSL to be +100% (1.0) and -50% (-0.5) respectively for the required measurement accuracy for radon progeny in the range of 0.05-0.10 WLM.



Shown in the above figure is the capability chart for blind PAD radon progeny testing at the Bowser-Morner Radon Chamber from 2013-2019. The mean relative percent error (Center) is 2.2% with a standard deviation of 13.2%.

The PCR for the these data points is determined to be Cp=1.89. For a capable process Cp > 1.33 is an acceptable value. From the blind test data collected to-date, one can conclude the PAD is operating properly and providing accurate exposure results.

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