Quality Assurance Programs for Uptake Probes and Well Counters

Uptake probes and well counters are subject to various types of malfunctions that can lead to sudden or gradual changes in their performance characteristics. For example, electronic components and detectors can fail or experience a progressive deterioration of function leading to changes in detection efficiency, increased background, etc.

To ensure consistently accurate results quality assurance procedures should be employed on a regular basis for probe and well counter measurement systems. A good quality assurance program would include: Daily energy calibration, energy resolution/full-width at half-maximum (FWHM), daily measurement of background; and quarterly measurements of high voltage, chi-square and minimum detectable activity.

Energy calibration and High Voltage

An energy calibration evaluates an energy pulse height and calibrates it to gamma ray energy for a NaI (TI) detector. A calibration used in nuclear medicine is that a 100 keV gamma ray produces a photopeak centered at 1.00 V. This can be evaluated by using a radionuclide standard source which emits a single known energy gamma ray and is long lived. An example of such a source is Cs-137 which emits a single gamma ray of 662 keV. This source can be used to adjust and readjust the PM tube high voltage in such a manner that the Cs-137 photopeak is centered at 6.62 V. Because high voltage drifts with time, energy calibration should be checked daily before the equipment is used. The high voltage should be performed whenever the photopeak is moved outside of the peak energy window due to fluctuations in ambient temperature, line-voltage and equipment usage over time. At a minimum high voltage checks should be performed quarterly.

Energy resolution/FWHM

The energy resolution test evaluates the sharpness of a photopeak produced when a probe or well detector is exposed to a single energy radionuclide. A relatively sharp, bell-shaped peak indicates proper functioning equipment. Widening of the bell indicates a malfunction of some system component, such as inconsistent multiplication of electrons in the photomultiplier (PM) tubes; a breakdown of the crystal-to-PM tube seal or deterioration of the detector crystal.

In order to evaluate energy resolution, a long-lived, single energy radionuclide source, such as Cs-137 is used. Its gamma photopeak occurs at approximately 662 keV. An energy resolution/FWHM test should be performed each day the probe or well is used.
FWHM = \( \frac{\text{Right channel #} - \text{Left channel #}}{\text{Peak channel #}} \times 100 \)

a) Measure a Cs-137 source that is appropriate for a probe or well counter.

b) Observe the energy spectrum and note which channel the Cs-137 peak is in.

b) Divide Peak channel count by 2

c) Right channel is 1st channel # that has counts less than \( \frac{1}{2} \) Peak channel counts

d) Left channel is 1st channel # that has counts less than \( \frac{1}{2} \) Peak channel counts

e) Note channels and apply to formula

**Chi-Square Test**

Chi-Square (\( x^2 \)) test is a means for testing precision in counting instruments and whether random variations in a set of measurements are consistent with what should be expected for a Poisson distribution. A Chi-Square test should be performed quarterly.

1. Using a Cs-137 source for the probe or well, obtain a set of 10 counting measurements, 10 seconds each.

2. Compute the mean \( \bar{N} \)

\[
\bar{N} = \sum_{i=1}^{n} \frac{N_i}{n}
\]

\( n = \) number of sample
\( N_i = \) each measurement from 1 to 10

3. \( \chi^2 = \sum_{i=1}^{n} \left( \frac{N_i - \bar{N}}{\bar{N}} \right)^2 \)

4. The probability is that it should fail 20% of the time: 10% high and 10% low. The Chi-Square result should be between 4.168 and 14.684.
Minimal Detectable Activity (MDA)

A good definition of MDA as used in nuclear medicine is the smallest amount of activity distinguishable from background which can be quantified at a given confidence level of 95%. MDA is a calculation designed to give an indication of the basic capabilities of a counting system. MDA may be performed as often as an end-user would like however at a minimum it should be performed quarterly. Below is the formula commonly used for MDA:

\[
MDA = \sqrt{\frac{2.71}{T_S} + 3.29 \left( \frac{R_B}{T_B} + \frac{R_B}{T_S} \right)^{1/2}}
\]

\[
\text{Det efficiency} \times \text{Geometric efficiency} \times \text{area/100 cm}^2
\]

**NOTE:** System assumes a 100 cm\(^2\) wipe

RB = count rate of the natural background

TB = time of the background count

TS = time of the sample count

E = detection efficiency of the counter

A = area monitored or wiped

**NOTE:** E = Detector efficiency x Geometric efficiency

**NOTE:** Wipe area program assumes 100 cm\(^2\) / 100 cm\(^2\)