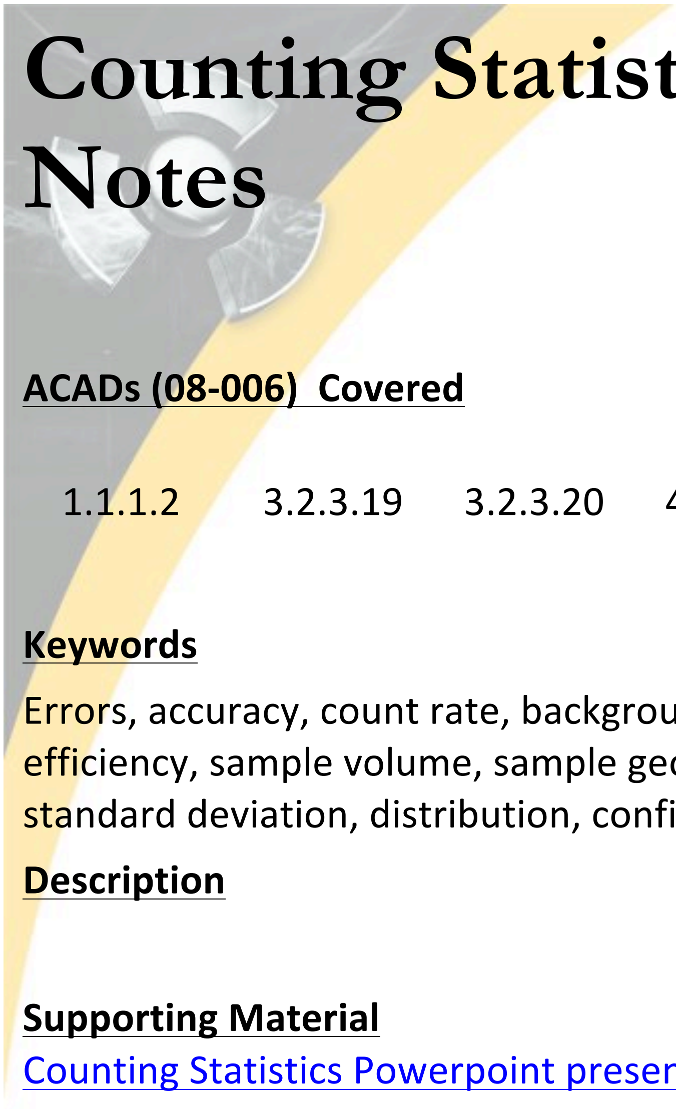

Counting Statistics Instructor Notes

ACADs (08-006) Covered

1.1.1.2 3.2.3.19 3.2.3.20 4.13.1 4.13.2 4.13.4

Keywords

Errors, accuracy, count rate, background, count time, equipment efficiency, sample volume, sample geometry, moisture absorption, standard deviation, distribution, confidence, chi square.

Description

Supporting Material

Counting Statistics Powerpoint presentation

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NUCLEAR TRAINING

TRAINING MATERIALS COVERSHEET

RADIOLOGICAL PROTECTION TECHNICIAN INITIAL TRAINING
PROGRAM

FUNDAMENTALS TRAINING	HPT001
COURSE	COURSE NO.
COUNTING STATISTICS	HPT001.011
LESSON TITLE	LESSON PLAN NO.

INPO ACCREDITED YES X NO ______

MULTIPLE SITES AFFECTED YES X NO ______

PREPARED BY Brian K. Fike	*Original signed* Signature / Date
PROCESS REVIEW E. G. Pugh	*Original signed* Signature / Date
LEAD INSTRUCTOR/PROGRAM MGR. REVIEW R. L. Coleman	*Original signed* Signature / Date
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NUCLEAR TRAINING

REVISION/USAGE LOG

REVISION NUMBER	DESCRIPTION OF CHANGES	DATE	PAGES AFFECTED	REVIEWED BY
0	Initial Issue		All	
1	Revised to comply with TCA 50A		All	
2	Program was inactive. Reviewed and revised to reactivate.	3/21/90	All (WTC)	
3	General revision to update material.	TBD	All	Brian K. Fike

I. PROGRAM: Radiological Protection Technician Initial Training

II. COURSE: Fundamentals Training

III. LESSON TITLE: Counting Statistics

IV. LENGTH OF LESSON/COURSE: 24 Hours

V. TRAINING OBJECTIVES:

A. Terminal Objective

Upon completion of this course, the participant will demonstrate knowledge of Counting Statistics as presented in this lesson plan by obtaining a score of ≥80% on a written examination.

B. Enabling Objectives

Upon completion of the training the participant should be able to correctly:

1. Identify factors that affect statistical accuracy of radioactivity measurements, to include count rate, background, count time, equipment efficiency, sample volume, and sample geometry.

2. Explain how the statistical accuracy of measurements can be improved, to include error prevention techniques where applicable.

3. Distinguish between accuracy and precision.

4. Define and apply the terms standard deviation, mean, percent error, and confidence level.

5. Distinguish between the following distribution functions: Frequency Distribution, Poisson Distribution, and Gaussian Distribution.

6. Given a set of data, calculate the standard deviation, the mean and the values of ± two sigma values that could be utilized to construct a control chart.

7. State what percent of data would be expected to be contained within each of the following sigma values on a control chart: ± one sigma, ± two sigma, ± three sigma.

8. Distinguish between Minimum Detectable Count Rate (MDCR) and Lower Limit of Detection (LLD), and perform calculations for various radioactivity measurements.

9. Calculate a Chi-Squared from collected data and indicate if the data falls within acceptable limits.

Note: Conditions and Standards for enabling objectives unless otherwise specified are implied. Conditions are "as presented in this lesson plan" and Standards are "as evaluated by written examination."

VI. TRAINING AIDS:

A. Dryboard, Dry Erasable Markers

B. Overhead Projector

C. Computer Controlled Projection Equipment (if desired)

VII. TRAINING MATERIALS:

A. Appendices:

1. Handouts

a. HO-1 Student Objectives
b. HO-2 Terms and Definitions
c. HO-3 Counting Statistics Introduction
d. HO-4 Statistical Accuracy
e. HO-5 Error Reduction
f. HO-6 Accuracy and Precision
g. HO-7 Standard Deviation
h. HO-8 Frequency Distribution
i. HO-9 Poisson Distribution
j. HO-10 Gaussian Distribution
k. HO-11 Confidence Level
l. HO-12 Minimum Detectable Count Rate
m. HO-13 MDCR Application
n. HO-14 MDCR Application (cont'd)
o. HO-15 Lower Limit of Detection
p. HO-16 Chi-Square Test
q. HO-17 Chi-Square Test (cont'd)

2. Transparencies

a. TP-1 Counting Statistics Introduction
b. TP-2 Statistical Accuracy
c. TP-3 Error Reduction
d. TP-4 Accuracy and Precision
e. TP-5 Standard Deviation
f. TP-6 Frequency Distribution
g. TP-7 Poisson Distribution
h. TP-8 Gaussian Distribution
i. TP-9 Confidence Level
j. TP-10 Minimum Detectable Count Rate
k. TP-11 MDCR Application
l. TP-12 MDCR Application (cont'd)
m. TP-13 Lower Limit of Detection
n. TP-14 Chi-Square Test
o. TP-15 Chi-Square Test (cont'd)

VIII. REFERENCES:

A. INPO ACAD 93-008, Guidelines for Training and Qualification of Radiological Protection Technicians, August 1993.

B. Introductions to Nuclear Radiation Detectors, Volume 2, P. J. Ouseph, Plenum Press, New York, 1975.

C. Radiation Detection and Measurement, Second Edition, Knoll, John Wiley and Sons, 1989.

D. Basic Radiation Protection Technology, Second Edition, Gollnick, Daniel A., Pacific Radiation Corporation, 1988.

IX. INTRODUCTION:

The following items are to be incorporated as

Since radioactive decay is a random process, two counts of the same sample may differ slightly. In addition, environmental background, electronic noise, and data collection processes are all random processes that add errors to the counting results. Statistical analysis is used to evaluate the error associated with the measurement.

Radioactive decay can be described by the laws of probability. The probability that a single atom will decay in a given time period is not predictable; however, the number of decays from a million atoms of the same type is predictable just as the number of "heads" from a million coin tosses is predictable. The predictability increases with the number of individuals involved. It follows that if the number of decaying atoms in a time period can be determined from the total number, then the reverse is also true. Since the radiation emitted from decaying atoms make the disintegration events detectable, this is the procedure used. The instruments used for radiation detection must operate normally to give accurate results from which a knowledge of plant conditions can be determined. The standard method for checking detectors is to check the results for conformance to statistical laws. Radiation protection technicians will apply these concepts routinely.

much as possible, when applicable:

- Operating Experience
- Work Expectations
- Human Performance Improvement Principles
- Warning Flags

Show TP-1 and use it and HO-3 to demonstrate the randomness of radioactive decay, and to provide a prelude for instrument efficiency.

After prelude, use HO-1 to facilitate an overview of the Terminal and Enabling Objectives.

INSTRUCTOR NOTES

X. TERMS AND DEFINITIONS:

A. Arithmetic mean--The average value. HO-2

B. Absolute error--The deviation of the determined value from the theoretical value (true value).

C. Relative error--The ratio of the absolute error to the theoretical value (or true value).

D. Accuracy--A measure of how close the measured value is to the true value.

E. Precision--A measure of how close consecutive measurements are to each other.

F. Bias--The deviation of the mean value from the true value.

G. Determinant error--A human error.

H. Indeterminant error--One that results from unknown causes.

K. Efficiency--The ratio of the determined activity to the actual activity.

L. Range--The simplest measure of dispersion, the difference between the lowest and highest values.

M. Deviation--The amount each number varies from the mean.

N. Histogram--A graph of bars where the height of a bar represents the frequency of an occurrence (data).

INSTRUCTOR NOTES

XI. LESSON BODY:

A. Quality assurance programs are needed for the following reasons:

1. To identify deficiencies in sampling and measurement processes so that corrective action can be taken.

2. To provide a means of relating the results of a particular monitoring program to the National Bureau of Standards (Now called the National Institute of Standards and Technology (NIST)).

Standard sources normally used are Th-230 (alpha), Tc-99 (beta), and Ba-133 (radioiodine-gamma)

3. To obtain some measures of confidence in monitoring programs to assure regulatory agencies and the public that the results are valid.

4. Quality assurance should be applied to all facets of radiation protection processes that may include:

   a. Surveys

   b. Shipments of radioactive material

   c. Receipt of radioactive material

   d. Preparation of samples

   e. Measurement of radioactivity (counting)

   f. Data evaluation

   g. Reporting of monitoring results

INSTRUCTOR NOTES

B. Quality control in the Radcon arena

1. Reference standards are used to determine counting efficiencies for specific radionuclides or, in the case of gamma-ray spectrometry systems, to determine counting efficiency as a function of gamma-ray energy.

2. Radionuclide standards that have been certified by the NIST, or standards that have been standardized using a measurement system that is traceable to the NIST, should be used when such standards are available.

   a. The details of the preparation of working standards from certified standard solutions should be recorded.

   b. The working standard should be prepared in the same form as the unknown samples, or close approximations.

Compare source check of scaler system to air sample analysis - geometry must match.

3. Efficiency calibrations should be checked periodically with standard sources.

   These checks should be performed whenever a change in the operating system is suspected as indicated by the use of a check source.

4. Determination of the background counting rate and the response of each radiation detection system are performed on a scheduled basis for systems in routine use.

   a. The results of these measurements are recorded in a log and/or plotted on a control chart.

   b. Appropriate investigative and corrective action should be taken when the measurement value falls outside the predetermined control value.

INSTRUCTOR NOTES

c. The check source used for determining changes in counting rate or counting efficiency should be of sufficient radiochemical purity to allow correction for decay but does not need to be a standard source.

C. Planned and periodic audits are made to verify implementation of the quality assurance program.

D. Factors that affect the statistical accuracy of Radioactivity Measurements

Obj 1
TP-2/HO-4

1. Count rate

2. Background

3. Count time

4. Equipment efficiency

5. Sample volume

6. Sample geometry

7. Moisture absorption

8. Errors Relating to Arithmetic Calculations

Stress HU tools that reduce the likelihood of these type errors, in particular, Peer Check, Procedure Use and Adherence, and Self-Checking.

a. Human errors such as incorrect mathematical manipulations or incorrect decimal positions.

TP-3/HO-5/Obj 2

b. Errors due to variations in individual measurements carried and increased by the mathematical manipulations.

Error can be carried forward to another tech/shift (e.g. - alpha air samples).

9. Errors Relating to Radioactivity Measurements

    a. Random disintegration for radioactive atoms.

    b. Random emission of radiations when an atom decays.

    c. Detector related errors

        (1) Every radiation emitted will not reach the detector.

        Relate to efficiency.

        (2) Every radiation entering the detector will not be counted.

            (a) This is especially true at high counting rates.

            (b) A certain amount of time is needed for the electronics to recover from one count before it can count another disintegration event.

        (3) There will be electronic and detector variations due to changes in temperature and applied voltage.

        (4) In detectors that use counting gases, the sealed gases break down gradually, and the flow of non-sealed gases can vary.

INSTRUCTOR NOTES

d. Radiation Measurement Technique Errors

(1) The absorption of beta radiation by windows or walls of the detector, and by a cover over the source, and even by air reduces the number of beta particles reaching the detector.

(2) When gamma rays are absorbed by materials outside the detector, secondary radiations are produced that can enter the detector.

Note: If the sample is placed in the identical geometry, has similar mass, and is counted under similar conditions, this type of error is minimal. Stress the need for consistency from technician to technician.
Relate to interactions with matter and the term specific ionization.
Draw on board.

(3) Self-absorption of the radiation by other atoms in the source.

(4) Scattering and backscattering can occur when radiation interacts with matter both in and out of the detector with part, but not all of the energy being deposited in the detector, i.e., part escapes and is not detected or recorded.

E. Classification of Errors:

1. Systematic or Determinate Errors

a. This type of error results from the way the system operates; it is inherent in the system.

b. The error is always the same (or proportionately the same) for each determination.

c. Such an error can be allowed for in the calculations, i.e., the derived answer can be corrected by calculation.

d. The efficiency of a radiation detector is a good example.

(1) For a given energy of a beta particle, the detector can detect only a specific percent of particles actually emitted.

(2) If samples with known emissions are counted, a correction factor can be calculated.

e. Even when allowances are made for all systematic errors, variations still exist.

(1) The known sample determinations were subject to "accidental" errors.

(2) The correction factors are thus subject to accidental errors.

2. Accidental or Indeterminate Errors (Random Errors)

a. This type of error cannot be accounted for and is present even when careful technique and systematic error correction factors are used.

b. Accidental errors can be treated in accordance with probability considerations, i.e., it is possible to express an experimental result with an error which fits probability calculations.

c. With radioactive decay, the number of decays is never exactly known since each decay is itself a probability.

d. As a result of this basic phenomenon, there is no true value with which to compare each determination (with respect to radioactivity, this means the count).

e. With only accidental errors assumed, the best approximation to the true value is the arithmetic mean.

INSTRUCTOR NOTES

$\surd = (\Sigma x_i)/n$

3. Precision and Accuracy

Obj 3
TP-4/HO-7

a. Precision refers to the ability to repeat a measurement.

(1) A radioactive source, when counted a number of times, shows precision if the separate counts are relatively close to each other.

(2) percent error is a common way to measure precision. The experimental value is subtracted from the true value; and the result divided by the true value; then multiplied by 100. This gives a percent deviation from the true value. The sign, + or -, gives the direction of the deviation.

Obj 4

(3) A survey meter that gives precise measurements may or may not be accurate.

b. Accuracy refers to the closeness of the measurements to the true value.

(1) Since in counting, the true value is assumed to be the mean, <u>a measure of accuracy is the amount that each determined value deviates from the mean.</u>

(2) If there are many determinations, there are equally as many deviations from the mean.

(3) It would be convenient to have just one figure that would be a measure of the deviations.

F. Standard Deviation

TP-5/HO-7

INSTRUCTOR NOTES

1. Once the "middle" of a set of values has been determined and assumed to be the "true" value, some measure of "precision," and along with it "accuracy," is needed.

    a. Since precision is the closeness of the determinations to each other, some measure of the "spread" of values could give such information.

    b. Range measures the distance between the highest value and the lowest value.

    c. Variance and standard deviation are measures of dispersion with respect to the mean.

Values that deviate from the mean only slightly are both accurate and precise.

2. Deviation from the Mean

    a. The location of an individual value with respect to the mean is determined by subtracting the mean value from it.

        $x - \surd$

        (1) If x is larger than the mean, the deviation will have a positive value.

        (2) If x is smaller than the mean, the deviation will be negative.

        $x = 6, 4, 8, 4, 3: \surd = 5$
        $x - \surd = 1, -1, 3, -1, -2$

        (3) If one attempts to add these deviations to obtain a single measure of dispersion with respect to the mean, zero is obtained for the answer.

b. A mean deviation can be obtained if the absolute values of the individual deviations are averaged.

mean deviation = $\Sigma (x - \surd)\ /n$

c. If the individual deviations are squared, the canceling effect of the negative values are eliminated.

(1) The sum of the squares of the deviations from the mean are used to describe the variance.

(2) Sample variance is defined as the sum of the squares of the deviations from the mean divided by one less than the number of items in the sampling. It is the average value of the squared deviations of the data points:

(n - 1) is used because this is the number of variations about the mean. If only one figure, there is no mean and no variation.

sample variance $= (\Sigma (x_i - \surd)^2)/(n - 1)$

(3) Sample variance is a measure of the internal scatter of data and won't be much different if numbers of data are increased.

d. The standard deviation is the positive square root of the variance and is the most often used of the measurements for accuracy and precision.

Obj 4
Standard deviation can be defined as the arithmetic measure of a probability density around its mean.

G. Graphical Displays of Distribution

1. A Frequency Distribution

Obj 5
TP-6/HO-8

a. Data is plotted on a graph called a histogram.

INSTRUCTOR NOTES

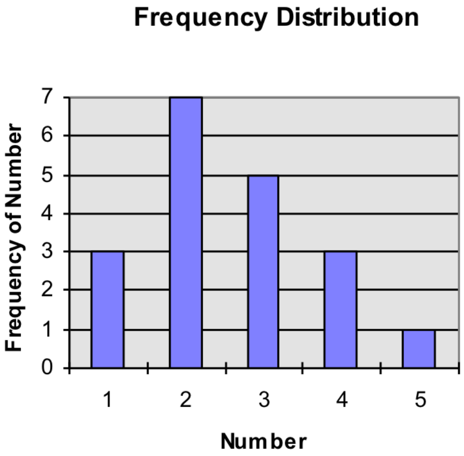
b. The histogram is a series of bars where the height of each bar represents the frequency of an occurrence, such as a number.

c.

3	2	2	3	2
4	4	1	2	2
4	3	2	5	2
2	1	3	3	1

Prepare a frequency distribution of this data.

One occurs three times; therefore, the frequency for x = 1 is 3, etc.



3. The Poisson Distribution

TP-7/HO-9

a. This distribution occurs when there is a low probability of success with one trial, and there are at least 100 possibilities.

After Simeon Poisson, a French statistician, 1840.

INSTRUCTOR NOTES

(1) In radioactive counting, the number of atoms present is easily more than 100 in a sample.

Ask if this could apply to counting radioactive samples.

(2) The probability of one individual atom's decaying is low.

example: $P = 1 - e^{-\lambda t}$

λt = the probability of a single atom decaying in time t.

P = probability of success in one trial

λ = decay constant

t = time of observation

$e^{-\lambda t}$ = the probability of a single atom remaining after time t.

A radionuclide has a half-life of 5 days. What is the probability that any atom will decay in a 2-minute counting time?

Have students work problem; show solution on board.

$\lambda = .693/T_{½} = .693/5d = 0.1386/d$

Internalize this concept!

$P = 1 - e^{-(0.1386/d)(1.39E\text{-}3d)}$

$P = 0.0002$

b. In most radioactive counting, the size of the sample (number of radionuclides) is not known.

c. In radioactive counting, the probability of an individual decay is rarely known.

d. The probability for “x” successes in the Poisson Distribution fits the radioactive counting situation:

$$p(x) = \frac{(\surd)^x e^{-\surd}}{x!}$$

$\surd$ = the average number of successes in “n” trials (in counting, the avg count).

$\surd$ = pn

p = the probability of success in a single trial.

e. Variance and standard deviation are:

$$\sigma^2 = x$$

$$\sigma = (\surd)^{1/2}$$

f. Example:

Out of 1000 people selected at random, how many are apt to have today's date as a birthday?

p = probability of a single success, 1/365.

p is small; therefore, a Poisson Distribution can be used.

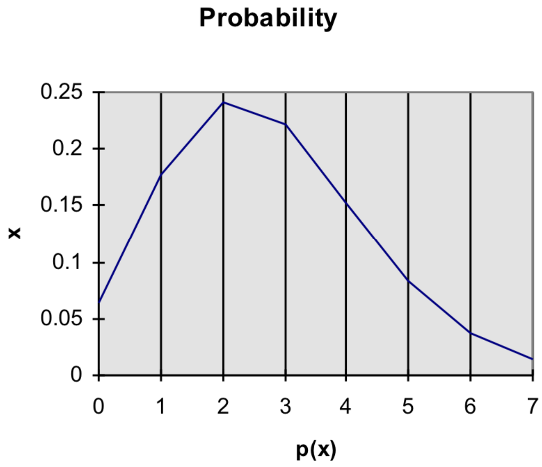
$\surd = pn = 1/365 * 1000 = 2.74$ (round to 3)

$\sigma = (\surd)^{1/2} = 1.66$

p(x) = the probability that x birthdays will be today from a random sampling of 1000 people.

Note: In radioactive counting, only the number of successes is known by the emission of the radiation.

$$p(x) = (\surd)^{x}e^{-x}/x!$$



x	p(x)
0	0.064
1	0.177
2	0.242
3	0.221
4	0.152
5	0.083
6	0.038
7	0.014

g. Distribution is around a mean value, but the mean value is not the peak value.

4. The Gaussian or Normal Distribution

TP-8/HO-10

a. This distribution is another special situation where the probability of a single success is small and the mean value is large (greater than 20).

b. The probability equation reduces to:

$$p(x) = 1/(2\pi x)^{1/2}\left(e - \frac{x-\surd^{2}}{2x}\right)$$

c. The mean value is again pn.

d. The variance and standard deviation are:

$\sigma^2 = \surd$

$\sigma = (\surd)^{1/2}$

e. Example: The number of birthdays today from sampling of 10,000 people.

$\surd = pn = 1/365 * 10{,}000 = 27.4$

$\sigma = 5.23$

f. The Gaussian Distribution is symmetrical about the mean.

g. One standard deviation on either side of the mean will include 68.3 percent of all the area under the curve.

(1) This means that in a random sampling, 68.3 percent of all samples will be no more than the standard deviation away from the mean. Obj 6

(2) It is now convenient to consider how many standard deviations a measurement is from the mean.

No. of Std. Deviations	Probability of Occurrence
0	0
0.674σ	0.50
σ	0.683
1.64σ	0.900
1.96σ	0.950
2.58σ	0.990
3.00σ	0.997

INSTRUCTOR NOTES

h. Two standard deviations from the mean will include 95.5 percent of all samples.

i. Three standard deviations from the mean will include 99.7 percent of all samples.

j. The standard deviation is equivalent to the random error.

k. The standard deviation is also known as the confidence level.

TP-9/HO-11
Obj 4

   (1) We can be 68 percent confident that the true value of the mean is within ±1 standard deviation.

   Obj 7

   (2) We can be 95 percent confident that the true value of the mean is within ±2 standard deviations.

   (3) We can be 99 percent confident that the true value of the mean is within ±3 standard deviations.

5. Limits of Detection

Obj 8

a. Is a count rate of 45 ± 3 cpm significant when the background is 40 ± 2 cpm?

b. Statistical equations calculate the minimum activity that can be detected in the presence of background.

MDA

c. The minimum detectable count rate (MDCR) is the count rate which indicates the presence of activity with a probability of p and only a (1 - p) probability of a false conclusion of its presence.

INSTRUCTOR NOTES

d. Calculate the minimum detectable counts and minimum detectable count rate using the following equations.

NRC recommends the 95% confidence level.

TP-10/HO-12

$$MDC = 2.71 + 3.3\ [B(t_b+t_s)/t_b]^{1/2}$$

where:

MDC is the minimum dectectable counts;
B is the background counts;
t_b is the background counting time, minutes;
t_s is the sample counting time, minutes.

$$MDCR = MDC/t_s$$

Note: MDC taken from NUREG/CR-4007, Sept. 1984, Equation 21, page 92.

e. In some cases, it may be necessary to determine the amount of radioactivity present on a sample containing very small quantities at or just slightly above minimum detectable activity (e.g., service air system sampling). MDA is a function of both MDCR and sample volume and assumes that the background is constant or changing slowly.

f. For all samples if the gross sample count rate is ≥ (BKG + MDCR) it may be concluded with 95 percent confidence that radioactivity is present above natural background. Calculate results using normal processes. If the gross sample count rate is < (BKG + MDCR) then record "< MDA".

TP-11/HO-13

TP-12/HO-14

Example:

Calculate the MDCR at 95 percent confidence level when using a counter with a background of 35 cpm. Background was counted for 20 minutes, sample for 5 minutes.

Work example on board after students have calculated results.

g. Lower Limit of Detection

TP-13/HO-15

(1) LLD is the lowest activity in a sample that may be detected by a counter.

Obj 8

(2) With a 95 percent confidence, the equation is:

$$\text{LLD } (\mu\text{Ci/cc}) = \frac{4.66\sigma_b}{(2.22E^6)(E)(V)(Y)(D)}$$

σ_b = standard deviation of background count rate (cpm)

E = counter efficiency (cts/dis)

V = volume of sample in cc

Y = chemical yield (if applicable)

D = Decay correction for delayed count on sample

$2.22E^6$ = dpm per µCi

R. Statistical Tests

1. Statistical tests are performed to determine whether the results from counting samples reflect the random nature of radioactive decay.

2. Chi-Square Test

   TP-14/HO-16

   a. This test is performed when the counting system is calibrated, after repairs or changes to the system, and after identified-problems have been corrected.

   b. Some labs may routinely perform the Chi-Square test on a periodic basis.

   c. Problems that could cause a failure of the Chi-Square Test:

      (1) An instrument malfunction

      (2) Fluctuating power supply

      (3) Malfunctioning timer

      (4) Preset counts selected instead of preset counting time

      (5) Fluctuating background

      (6) Improperly positioned source

      (7) Temperature or humidity changes.

   d. A series of individual counts are taken (usually 21) and Chi-Square calculated according to the formula:

$$x^2 = \frac{\Sigma(n-\bullet)^2}{\bullet}$$

n = the data for each count

⬣ = the average of the individual counts

$$⬣ = \frac{\Sigma n}{N}$$

N = the number of observations (usually 21)

e. A long half-life material should be chosen with a count time that will produce 50,000 counts or more.

f. For the Chi-Square test, background is not subtracted.

g. The Chi-Square value is calculated and compared to the values in a table with the same number of degrees of freedom.

h. If the value is in the satisfactory area of the graph, a control chart may be prepared.

i. If the value is lower than satisfactory, the counting system is not producing the randomness that it should.

j. If the value is "marginal," the test should be repeated.

k. If the value is higher than the satisfactory area, there is a problem in the instrument that should be corrected.

INSTRUCTOR NOTES

l. An easy way to calculate x^2 is by the use of a 3-column table as follows:

TP-15/HO-17

Counts (n)	$(n-\bullet)$	$(n-\bullet)^2$
52377	+116	13456
52202	-59	3481
52102	-159	25281
52385	+124	15376
52427	+166	27556
52133	-128	16384
52460	+199	39601
52040	-221	48841
52188	-73	5329
52003	-258	66564
52680	+419	175561
51972	-289	83521
52441	+180	32400
52153	-108	11664
52388	+127	16129
52287	+26	676
52108	-153	23409
52399	+138	19044
52290	+29	841
52185	-76	5776

$\Sigma n = 1{,}045{,}220 \qquad \Sigma(n - \bullet)^2 = 630{,}890$

Objective 9

$$\bullet = \frac{\Sigma n}{N} = \frac{1{,}045{,}200}{20} = 52261$$

$$x^2 = \frac{\Sigma(n - \bullet)^2}{\bullet} = \frac{630{,}890}{52261} = 12.07$$

Have students calculate; then show results on board.

m. If a 90 percent confidence level is desired, x^2 should fall between 11 and 26 to be satisfactory.

S. Additional Studies On The Web

1. www.blackcatsystems.com/GM/experiments/ex4.html
2. http://hps.org/publicinformation/ate/q807.html

Statistics from another perspective.

Health Physics Society.

XII. SUMMARY:

Errors associated with radioactive counting are statistical in nature. Even when determinate errors are corrected by calculation such as detector efficiency, random type errors still exist. When dealing with radioactive decays the number of disintegration events is never exactly known; therefore, there is no true value. The mean value substitutes for the true value as the best approximation. Once the mean is assumed to be the true value, accuracy and precision in radioactive counting become synonymous.

The degree with which the values vary from the mean, or "true" value, is measured by the standard deviation. How the standard deviation is computed varies depending on the type of graph (curve) depicted by the distribution of the data. For the distributions relating to radioactivity, each trial has two possible outcomes, success or failure (decay or no decay). The Poisson and Gaussian distributions are special cases of the general distribution, more typical of radioactive data, and easier to calculate. These special cases require a low probability of success with one trial (low probability of decay for one atom), and at least 100 atoms in the sample. For the Gaussian distribution to apply, there is an added requirement of at least 20 for a mean value.

Using the Gaussian distribution, error calculations can be determined for radiation counting. One standard deviation from the mean is guaranteed for 68 percent of all data errors. Ninety-five percent of all errors should fall within two standard deviations of the mean.

Because mathematical calculations must be performed with counting data, the errors associated with each must be carried through the calculations to a final error associated with the mathematical result. Other calculations include the minimum sample activity that can be detected by a counter, and the minimum count rate that is due to activity, not system "noise."

Chi-Square and Control Charts are tests that check on the statistical nature of the counting data. If the data does not fit, it follows that something in the system is producing the error(s). Criteria exist for rejecting individual bits of data if they deviate too decidedly from the mean value.

Questions to assess student achievement of objectives:

Ask whether it’s possible to know the exact number of disintegration events over a specific time period.

Ask what error prevention techniques can be used to improve the statistical accuracy of measurements.

Ask how to discern between accuracy and precision.

Ask for the percent of data expected to be contained within one and two standard deviations.

Ask participants to describe the application of MDCR.

Ask participants to describe the application of Chi-Square and Control Charts.

Terminal Objective: Upon completion of this course, the participant will demonstrate knowledge of Counting Statistics as presented in this lesson plan by obtaining a score of ≥80% on a written examination.

Enabling Objectives: correctly: Upon completion of the training the participant should be able to

1. Identify factors that affect statistical accuracy of radioactivity measurements, to include count rate, background, count time, equipment efficiency, sample volume, and sample geometry.

2. Explain how the statistical accuracy of measurements can be improved, to include error prevention techniques where applicable.

3. Distinguish between accuracy and precision.

4. Define and apply the terms standard deviation, mean, percent error, and confidence level.

5. Distinguish between the following distribution functions: Frequency Distribution, Poisson Distribution, and Gaussian Distribution.

6. Given a set of data, calculate the standard deviation, the mean and the values of ± two sigma values that could be utilized to construct a control chart.

7. State what percent of data would be expected to be contained within each of the following sigma values on a control chart: ± one sigma, ± two sigma, ± three sigma.

10. Distinguish between Minimum Detectable Count Rate (MDCR) and Lower Limit of Detection (LLD), and perform calculations for various radioactivity measurements.

11. Calculate a Chi-Squared from collected data and indicate if the data falls within acceptable limits.

HO 1 - Student Objectives

TERMS AND DEFINITIONS:

A. Arithmetic mean--The average value.

B. Absolute error--The deviation of the determined value from the theoretical value (true value).

C. Relative error--The ratio of the absolute error to the theoretical value (or true value).

D. Accuracy--A measure of how close the measured value is to the true value.

E. Precision--A measure of how close consecutive measurements are to each other.

F. Bias--The deviation of the mean value from the true value.

G. Determinant error--A human error.

H. Indeterminant error--One that results from unknown causes.

K. Efficiency--The ratio of the determined activity to the actual activity.

L. Range--The simplest measure of dispersion, the difference between the lowest and highest values.

M. Deviation--The amount each number varies from the mean.

N. Histogram--A graph of bars where the height of a bar represents the frequency of an occurrence (data).

HO 2 - Terms and Definitions