Contamination Monitoring

Radiation Safety Orientation Open Source Booklet 4 (June 1, 2018)

For more information, refer to the Radiation Safety Manual, 2017, RSP-3, Section 10 and the Quick Step Guide for Contamination Monitoring in Radiation Safety Records Binder

After work with radioactive material, it is important to confirm the work area is free of radioactive contamination….

Contamination Monitoring has been separated into three parts:

- **Part A: The Basics of Contamination Monitoring** What everyone needs to know!
- **Part B: Liquid Scintillation Counting** Everyone needs to know in order to complete the "Liquid Scintillation Counting Practical Activity" in your own lab with a local LRS or arranged with an EHS mentor.
- **Part C: Contamination Meter/Surveying for Radioactive Contamination** Read before attending in-lab Radiation Safety Workshop. During the radiation safety workshop, you will complete the "Contamination Meter/Surveying for Radioactive Contamination Practical Activity".

Part A: The Basics of Contamination monitoring

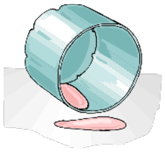
What everyone needs to know

Why is Contamination Monitoring required?

The purpose of contamination monitoring is to ensure that levels of radioactive contamination do not exceed legal limits in order to protect:

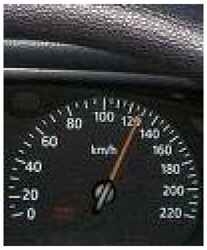
- Staff, students, the public and the environment and
- The reliability of experimental results

When you find contamination, you must take action! Decontamination and re-monitoring is required.



What is Radioactive Contamination?

Radioactive Contamination is the presence of radioactive materials in any place where it is not desired, in particular where its presence may be harmful. Contamination may present a risk to a person's health or the environment. Contamination has also been determined to be the cause of failed experiments. Control of contamination is one of the key concerns whenever radioactive materials are used.



Is there a 'Safe Limit' for Radioactive Contamination?

CNSC Surface Contamination Limit is the level of removable beta and gamma radioactive contamination on all normally accessible working surfaces in radioisotope laboratory that requires action and varies with the radioisotope.

- The CNSC numbers reflect safety for a human to work in the area.
- At The University of Manitoba, the University Decontamination level is 'twice background'.

Decontamination Level refers to the level of removable radioactive contamination that requires action (decontamination and re-monitoring) by the lab personnel. If you find removable contamination above twice the background, it is recommended that you take action.

The regulatory and University limits are listed in a table that can be found in Appendix D of the Radiation Safety Manual, 2017. Note that the table outlines the two distinctive levels/limits.

> *At the University of Manitoba, contamination results greater than 6 times background shall be reported to the Radiation Safety Officer as this may indicate removable contamination above the CNSC limit and may require further reporting.*
>
> *If in doubt call Radiation Safety!*

What do you need to know in order to monitor for radioactive contamination?

- What radioactive materials have been used or stored? Different radioisotopes emit different forms & different energies and may require different methods to make useful measurements.
- What is the 'decontamination level'? The method used to measure for radioactive contamination must be sensitive enough to demonstrate/detect the radioactive contamination is below the decontamination level.
- When is monitoring is required and where monitoring should be done
- How monitoring is documented
- When do you need to decontaminate

How do I Monitor for Contamination?

There are two methods

Direct Monitoring refers to measuring radioactive material with a contamination meter and not wiping the surface or item to differentiate the removable radioactive contamination. It is like measuring 'in situ'.

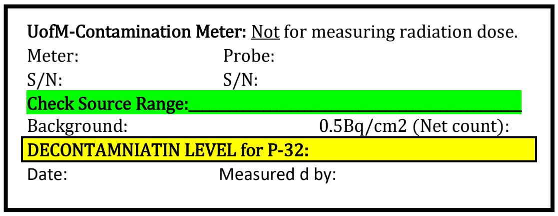
In-Direct Monitoring requires taking a sample, usually a wipe of the surface, and is used to estimate if the contamination if removable. The sample is then measured for radioactivity by using a liquid scintiallion counter, gamma counter or contamination meter.

What equipment may be used to measure radioactive contamination?

At the University, the two methods (direct and indirect monitoring), measure radioactivity in counts per minute (CPM) or disintegrations per minute (DPM). The type of equipment used for contamination monitoring will be listed on the permit in section 6, Contamination Monitoring Equipment.

Contamination Meter When only P-32, F-18 or Tc-99m is in use, then monitoring may be done directly using a contamination meter. At the University of Manitoba, a survey meter is referred to as a 'contamination meter' if it meets the following:

- The meter must have an EHS "contamination meter" or HSC "calibration" sticker validating the decontamination level for the meter and probe combination for the isotope, and
- The sticker is valid for a maximum of 36 months.



UofM-Contamination Meter: Not for measuring radiation dose.
Meter: Probe:
S/N: S/N:
Check Source Range:________________
Background: 0.5Bq/cm2 (Net count):
DECONTAMNIATIN LEVEL for P-32:
Date: Measured d by:

Liquid Scintillation Counter For all other radioisotopes, wipe tests measured by liquid scintillation counting is required (this is the indirect method).

NOTE Other contamination meter and probe combinations or gamma counters or well counters require specific written approval from EHS to be considered acceptable. EHS will document approval in writing and the decontamination level should be copied onto the University Decontamination Levels table on the Quick Step Guide for Contamination Monitoring in the Radiation Safety Records binder.

How are CPM related to DPM?

It is important to keep in your mind, that the instrument (liquid scintillation counter or contamination meter) usually is not capable to measure 100% of the radioactivity.

CPM (counts per minute) This is the number of light flashes or counts the instrument registered per minute. The actual number of decays produced by the radioactivity is usually more than the number of counts registered. 'CPS' would represent counts per second.

DPM (disintegration per minute) The sample's activity in units of nuclear decays per minute. 'dps' would represent disintegrations per second.

Efficiency The ratio (CPM/DPM) of measured counts to the number of decays that occur during the measurement time.

$$\text{(DPM) disintegrations per minute} = \text{(CPM) counts per minute} \times \frac{100}{\text{Efficiency (\%)}}$$

When is monitoring for radioactive contamination required?

At The University of Manitoba, monitoring is required:

- Within seven (7) days of each use of radioactive material.
- Whenever possible contamination is suspected, such as after a spill (whoops!).
- After each use of more than 500uCi (18.5MBq) of any radioisotope with a half-life greater than two hours other than H-3 and C-14.
- Storage areas where radioisotopes are stored for longer than six months should be monitored at least annually.
- Prior to decommissioning or 'releasing' a room or equipment that has been used to work with or store radioactive material.

What is decommissioning?

It is the process of releasing equipment or a room used with radioactive material for non-radioactive use or for renovation or servicing. Decommissioning requires documentation to record that all radioactive material has been removed and no radioactive contamination is present in excess of legal limits.

At the University of Manitoba, see RSP-2, section 5.3 for Decommissioning procedure/process and Radiation Safety Forms on the Radiation Safety Program webpage for the Radioisotope Permit Decommissioning form (for releasing a room).

Where should I monitor for radioactive contamination?

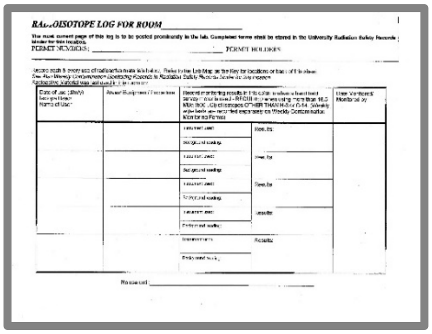
The number of locations monitored may be reduced, by limiting the number of locations used for radioactive work.

- In general, for an average sized lab, ten locations should be satisfactory.
- As a rule, increase the number of locations monitored whenever there are new workers, new procedures or new equipment until you have confidence that the contamination control strategies are effective.
- Include random locations to increase variation of areas monitored. These areas must be properly described on the Form if they are not included on the map.

How do I document monitoring for radioactive contamination?

At The University of Manitoba, if your lab is already permitted to use radioactive material, look for forms that have been prepared for your lab in the 'Radiation Safety Records' binder in the Quick Step Guide for Contamination Monitoring section.

The forms that could be in use are:



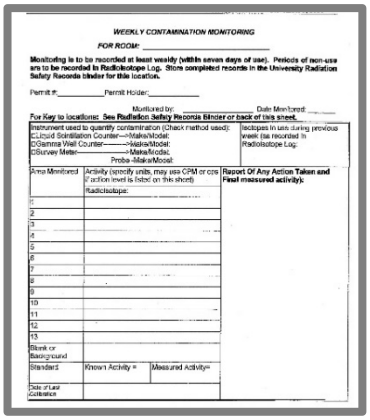
RADIOISOTOPE LOG FOR ROOM ____________

The most current page of this log is to be posted prominently in the lab. Completed forms shall be stored in the University Radiation Safety Records binder for this location.

PERMIT NUMBERS: ____________ PERMIT HOLDERS

Radioisotope Log is the form used to provide a single ongoing written history to record each use of radioactive material in a particular room.

- The Radioisotope Log is no longer required, however, it is very useful for multi-use or shared spaces using a variety of radioisotopes.
- The form provides space to record the results of direct monitoring done immediately after an experiment with a hand held contamination meter that is calibrated for the radioisotope in use.



WEEKLY CONTAMINATION MONITORING

FOR ROOM: ______________________

Monitoring is to be recorded at least weekly (within seven days of use). Periods of non-use are to be recorded in Radioisotope Log. Store completed records in the University Radiation Safety Records binder for this location.

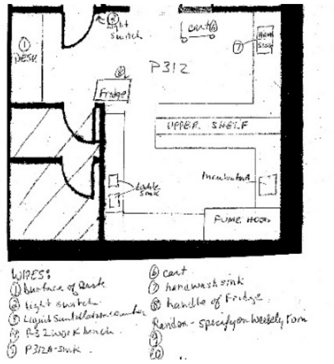
Permit #:__________Permit Holder:__________

Monitored by: ______________ Date Monitored: ______

For Key to locations: See Radiation Safety Records Binder or back of this sheet.

Instrument used to quantify contamination (Check method used): ☐Liquid Scintillation Counter—>Make/Model: ☐Gamma Well Counter———>Make/Model: ☐Survey Meter————>Make/Model: Probe -Make/Model:			Isotopes in use during previous week (as recorded in Radioisotope Log:
Area Monitored	Activity (specify units, may use CPM or cps if action level is listed on this sheet) Radioisotope:		**Report Of Any Action Taken and Final measured activity):**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
Blank or Background			
Standard	Known Activity =	Measured Activity=	
Date of Last Calibration			

Weekly Contamination Monitoring Form is used to document contamination monitoring results. If using an indirect method, attach (if available) the printout from the contamination monitoring equipment (LSC) used to measure the wipes. If using a calibrated CM meter, record the results on the form.



A Laboratory Map is useful to clearly communicate where wipes or measurements are taken. Make sure the map is current!

University of Manitoba

When do I clean up radioactive contamination?

For most radioactive material the decontamination level is 0.5 Becquerel per square centimeter (to keep our experimental areas clean), which is equal to 300 (DPM) disintegrations per minute over the background.

Different Decontamination Levels for certain radioisotopes may be required and will be listed as an Approved Alternate Method of Detection (AAMD) in the Approved Usage section of the Internal Radioisotope Permit.

To protect experiments and to save yourself from calculating ‘Becquerel per square centimeter’ –it is recommended that you act (decontaminate and re-monitor) whenever you measure contamination above twice your background reading!

Part B: Liquid Scintillation Counting

What everyone needs to know in order to complete the "Liquid Scintillation Counting Practical Activity" in your own lab with a local LRS or arranged with an EHS mentor

What is Liquid Scintillation Counting?

Liquid Scintillation Counting is an analytical technique which is defined by the incorporation of the sample into uniform distribution with a liquid chemical medium (cocktail or liquid scintillation fluid) capable of converting the kinetic energy of nuclear emissions into light energy. The liquid scintillation counter (LSC) is a sophisticated laboratory counting system used to quantify radioactivity. Liquid scintillation counters designed to measure particulate emitting radioactive samples (H-3 & S-35), can also detect the auger electrons emitted from gamma/X-ray emitters (Cr-51& I-125).

What is Cocktail or Liquid Scintillation Fluid?

Liquid scintillation fluid is a mixture of at least 3 chemicals (solvent, emulsifier, and fluor) which produces light flashes when it absorbs the energy of particulate radioactive decay.

Emulsifiers are usually detergents to keep water based samples in solution with the organic solvent.

Solvent A chemical component of the liquid scintillation cocktail that dissolves the sample, absorbs excitation energy and emits UV light which is absorbed by the fluor. Phosphor A luminescent substance or material capable of emitting light when stimulated by radiation.

Fluor A chemical component of the liquid scintillation cocktail that absorbs the UV light emitted by the solvent and emits a flash of blue light.

Are Fluorescence and Luminescence the same thing?

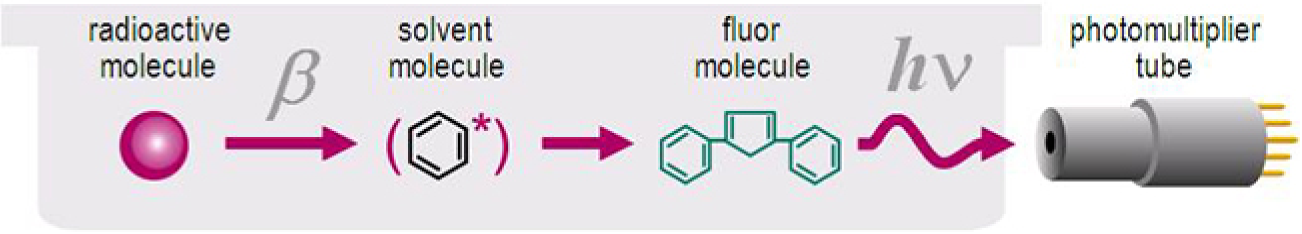
Fluorescence The emission of light resulting from the absorption of incident radiation and persisting only as long as the stimulating radiation is continued.

Luminescence A general term applied to the emission of light by causes other than high temperature.

How does a Liquid Scintillation Counter work?

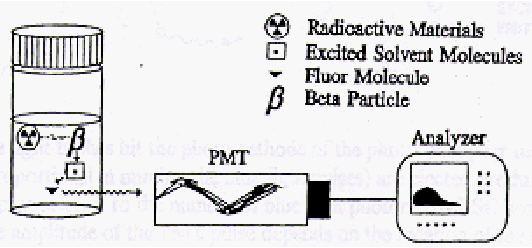
Review this section to help you understand how to use a LSC - you are not expected to memorize it!

Photo-Multiplier Tube (PMT) is an electron tube that detects the blue light flashes (photon) from the fluor and converts them into an electrical pulse. The size of the electrical signal from the PMT is proportional to the radiation energy absorbed by the cocktail.



The figure above provides a graphic illustration of the way (the steps) the emitted radiation from the radioactive sample interacts with the liquid scintillation fluid to produce a light flash (photon) leading to a count (pulse) being recorded by the system.

Step 1 Beta particles are emitted in a radioactive decay from the sample. In the relatively dense fluid, the beta particle travels only short distances before all of its kinetic energy is dissipated. Some of the beta energy is absorbed by solvent molecules making them excited (but not ionized).



Step 2 The energized solvent molecules transfer the captured energy to each other until the energy is emitted as ultraviolet light and is absorbed by a fluor molecule. The solvent molecule returns to ground state and the fluor molecules emit blue light (photon) flashes upon absorption of the transferred energy. The total number of photons from the excited fluor molecules constitutes the scintillation. The intensity of the light is proportional to the beta particle's initial energy.

Step 3 The photons hit the photo multiplier tube (PMT) and electrons are ejected producing an electrical pulse that is proportional to the number of photons. A liquid scintillation counter (LSC) normally has two PMT's. The signal from each PMT is fed into a circuit which produces an output only if the photon reaches both PMT. The output obtained is proportional to the total intensity of the scintillation.

Step 4 The amplitude of the electrical pulse is converted into a digital value and the digital value, which represents the beta particle energy, passes into the analyzer where it is compared to digital values for each of the LSC's channels with an energy range from 0-2000 keV.

Step 5 The number of pulses in each channel is printed out or displayed on the monitor. In this manner, the sample is analyzed and the spectrum can be plotted to provide information about the energy of the radiation or the amount of radioactive material dissolved in the cocktail.

What can interfere when measuring radioactive contamination by 'liquid scintillation counting'?

Low Counts - Counts may be lower than actual radioactivity when the sample volume is too small, the sample has two phases or there is quenching.

Sample Volume As the sample volume decreases, light output falls on less efficient areas of the PMT, so energy detection becomes less efficient with low volumes.

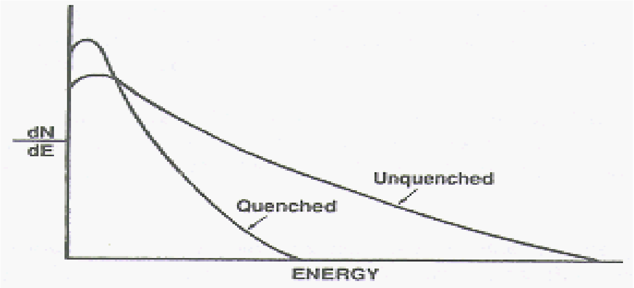
Dual Phase Samples When 2 phases are present, each phase will have its own counting efficiency.

Quench You are expected to know this section to complete the assignments.

What is Quench?

In liquid scintillation counting, quenching is a reduction in the scintillation intensity seen by the photomultiplier tubes due to absorption of the scintillation light that usually creates a reduction in counting efficiency.

Quench is a reduction in system efficiency as a result of energy loss in the liquid scintillation solution. The energy emitted by a radioisotope is not transferred completely into light and therefore is not detected by the PMT. Because of quench, the energy spectrum detected from the radioisotope appears to shift toward a lower energy.



Quench is important. You must understand the impact of quench and how the system you are using represents it if you want to obtain viable results. Quench calibration delimits the valid ranges for quantifying a sample. Quenching may be measured as QIP (Quenching Index Parameter) or "H" number.

Samples with quench numbers outside the calibration range will raise a flag which indicates the value is out of range. The conversion to dpm will be made, but will be an extrapolation from the highest/lowest recorded quench value.

Types of Quench

The three major types of quench, which interfere with the conversion of decay energy emitted from the sample vial into blue light photons resulting in a reduction of counting efficiency, are photon, chemical, and optical quench.

Photon Quenching occurs with the incomplete transfer of beta particle energy to solvent molecules.

Chemical Quenching sometimes called impurity, quenching causes energy losses in the transfer from solvent to solute. Is due to materials present in the scintillation solution that interfere with the processes leading to the production of light. The result is fewer photons per keV of beta particle energy seen by the PMT and usually a reduction in counting efficiency.

Optical Quenching or colour quenching causes a partial blocking of photons produced in fluor from reaching the PMT.

High Counts

Counts may be higher than actual radioactivity when there is Static, Chemiluminence or Photoluminescence.

Static Electricity on liquid scintillation vials is a single photon event with pulse height limited to about 10 keV. Many items used in the liquid scintillation counter environment are conducive to the development of static charges. In general, glass vials have less problems with static than plastic vials; small vials in adapters are particularly prone to static charge build up. Most systems offer an option which employs a static charge device or an electrostatic controller.

Luminescence is a single photon event and is registered as a count due to the probability of having coincidence events at high luminescence activity. Although LSCs employ a coincidence circuit, luminescence events stimulate each PMT within the resolving time of the coincidence circuits.

Chemiluminescence are random single photon events which are generated as a result of the chemical interaction of the sample components. Light is produced as a result of a chemical reaction between components of the scintillation sample in the absence of radioactive material. This most typically occurs when samples of alkaline pH and/or samples containing peroxides are mixed with emulsifier-type scintillation cocktails, when alkaline tissue solubilizers are added to emulsifier type scintillation cocktails, or when oxidizing agents are present in the sample. Reactions are usually exothermic and result in the production of a large number of single photons.
Photoluminescence results in the excitation of the cocktail and/or vial by UV light (e.g., exposure to sunlight or UV lights). UV activation causes delayed and persistent emission of single photons of light following activation of the fluor by ambient ultraviolet radiation.

Chemiluminescence has a relatively slow decay time (from 0.5 hr to > 1 day depending on the temperature) while photoluminescence decays more rapidly (usually < 0.1 hr). The luminescence spectrum has a pulse height distribution which overlaps the H-3 spectrum.

How do I set up the program on a Liquid Scintillation Counter?

Liquid Scintillation Counters (LSCs) come in a variety of shapes and types and manufacturers may use different terminology, however all LSCs operate in the same manner. Check with the owner of the LSC which parameters you are allowed to change. If you have any question, check with your mentor (departmental or EHS) before making any changes. Read the instruments operating manual to gain familiarity with the controls and operating characteristics.

LSC EXTERNAL SETTINGS

The following basic external controls are commonly found on most systems. A particular LSC may have other external controls, beyond the ones described below, depending on the counter type and model.

Gain A control used to adjust the height of the signal received by the detecting system.
The gain control for newer LSC's is often automatically set for the particular radionuclide selected.

LLD The lower level discriminator setting is used to discriminate against (i.e., not count) betas with energy below that setting. This setting is also used to decrease system noise which often occurs in the region below 3 keV.

ULD The upper level discriminator setting is used to discriminate against any beta energy higher than that setting.

How do different brands of Liquid Scintillation Counters compare?

Different manufacturers may offer more options than others. Some systems allow the user to select the regions of interest by selecting a keV range. Others offer several options (channel or keV).

If you are using a Beckman counting system, usually the channel option is the default option for the window setting. Beckman counting systems have 1000 channels and the energy is related to the equation:
Channel # = 72 + 280 log10 (Emax) where Emax is in keV.

Thus the ULD channel settings on a Beckman LSC to detect the maximum possible beta energy for H-3, C-14/S-35 and P-32 would be approximately 400, 670 and 1000 respectively.

Does a Liquid Scintillation Counter need to be calibrated to use for contamination monitoring?

YES – The calibration should be verified periodically! Calibration should be verified using a standard sample of known activity. Check with the manual or with the manufacturer for the machine specifics. To report the results in DPM or Bq/cm2, the liquid scintillation counter should be calibrated for the radioisotope being measured.

Remember: Using DPM is only possible when you know the specific radioisotope(s) you are monitoring for and the LSC is programmed to calculate for that radioisotope or you have a quench curve for it. DPM are preferred because you have taken into account the challenges to measure radioactivity accurately (energy/efficiency and quench).

CPM is used when either:

- you don't know for sure which radioisotopes may have been used or
- you don't have a calibrated source to determine the efficiency of the measuring equipment.

How is a Liquid Scintillation Counter calibrated?

LSC efficiency depends on the degree of quenching, the nature of the sample, the scintillator used and the preparation method. Not all particulate (a, ß) radiations are detected equally well by the LSC. Usually, the higher the beta particle energy equals higher the efficiency of the counter. To use the system's efficiencies for dpm calculation, a particular LSC must first be calibrated for the type of sample that it will analyze. Although there are several methods by which LSCs can be calibrated, the external standard method described below is the most widely used method of efficiency calibration.

EXTERNAL STANDARD METHOD

Use a 10 vial standard set each containing the same amount of radioactivity (i.e., dpm) but mixed with increasing amounts of a quenching agent (e.g., nitromethane, $C\text{-}Cl_4$) is used. Quenching agents absorb the radiation energy and, instead of emitting a pulse of UV light, they radiate infrared so the fluors do not get excited. Thus, the more quenched the sample, the fewer the counts detected in the desired channel. The reduced amount of light emitted per radiation energy absorbed usually results in a shifting of the spectrum to lower channels. A graph is drawn of the results and is the CALIBRATION CURVE.

How do I know if the LSC has been calibrated/programmed for my sample?

Check the manual, look for the manufacturer’s calibration certificate. Check the entered programs.

How is a Liquid Scintillation Counter used to measure radioactivity?

Review the instruments operating manual to become familiar with the controls and operating characteristics of the machine.

- Program instrument to report counts in DPM whenever available.
- Follow manufacturer's instruction count for the radioisotopes in use.
- Include a standard of known activity or calibrate with a standard if suggested by manufacturer. At The University of Manitoba:
- RECOMMENDED: Count each sample for a minimum of 5 minutes.

To prepare a wipe to measure removable radioactive contamination:

1. Select an absorbent grade of filter paper with a diameter of about 5 centimetres (qualitative analytical grade is suitable) or another suitable material.
2. Consider wetting the paper with water or 50% alcohol.
3. Hold the (moistened) filter paper on the edge with thumb and index finger and rub lightly but firmly over the surface, using the pads of the other fingers to apply light pressure, try to obtain the contamination on centre of the paper. Wipe an area of approximately 100 cm^2. A larger area can be wiped but the counts obtained cannot be averaged over more than 100 cm^2. A zigzag pattern may be used to sample a large area.
4. Remember to include a blank or background count using an unused wipe.
5. Allow the paper to dry (as required by capabilities of scintillation fluid).
6. Place samples into LSC vials and add the correct amount of liquid scintillation cocktail (e.g., 5, 10, 15 or 20 ml, as appropriate).
7. It is best it the final volume is half the total volume of the vial.
8. Be aware of the sample solubility of the sample in the brand of scintillation fluid used.
9. If you do not add scintillation fluid then you are using an Alternate Method and that is to be pre-approved by EHS.
10. WAIT: Due to the activation of many scintillation fluids by exposure to light, it is recommended to store vials in the dark overnight after sealing and shaking them. This is usually enough time to allow chemiluminescence and ultraviolet activation to dissipate.
11. Place your sample vials with blank vial into the LSC tray (or rack) and place into the LSC.
12. Set count time, noting that shorter count times give poor counting statistics.
    At The University of Manitoba, we recommend 5 minute counting times.
13. Review the LLD, ULD, and Gain to ensure they are appropriate and begin counting.
14. Record results in contamination monitoring records or attach the print out with the locations indicated on it for each measurement. Compare results to the decontamination level for radioisotope in use with the lowest counting efficiency.
15. Decontamination and re-monitoring is required when results exceed the decontamination level for the radioisotope in use and recommended when results are more than twice background.

HINT: You can save yourself the calculations by using 300 DPM corresponds to 0.5Bq/cm^2 decontamination level or CPM if you practice the twice background action level.

> *At The University of Manitoba, contamination in excess of 6 x background must be reported promptly to the Radiation Safety Officer.*

CPM is acceptable if you act (decontaminate and re-monitor) whenever you measure more than twice your background reading.

DPM are better! as long as you act (decontaminate and re-monitor) whenever you measure more than 300 DPM over your blank/background reading.

Becquerel/ centimeter squared is best! as this can be compared to the CNSC surface contamination limits and The University of Manitoba 0.5Bq/cm^2. However, you need to know the specific radioisotope you are checking for, the efficiency of the detector, the impacts of the geometry of the measurement and the quenching in each sample.

How is DPM calculated from CPM when using a Liquid Scintillation Counter?

Many liquid scintillation counters can be programmed to use internally stored quench curves for commonly used radioisotopes. If not you can use the CALIBRATION CURVE described above in EXTERNAL STANDARD METHOD and:

- Count your samples, the counts per minute and the quench level are printed out for each sample.
- Look up the efficiency for each sample at its quench level from the calibration curve.
- To determine the activity (dpm) from the reported counts per minute (cpm), divide the number of counts by the efficiency (i.e., dpm = cpm/eff).

Most new LSCs (if set up properly) will perform this calculation for you, for 1 or 2 radioisotopes. If dual label dpm calculation is required, a quenched standard set for each radioisotope must be run and that data stored in the counter.

How is 'Becquerel per centimeter squared' calculated when using a Liquid Scintillation Counter?

For indirect monitoring – wipe testing

(Liquid Scintillation and Gamma Counters)

$$\underset{\text{(counts/second)}}{\text{*Net Count}} = \underset{\text{(cps)}}{\text{Measured Count}} - \underset{\text{(cps)}}{\text{Background Count}}$$

$$\underset{(\text{Bq/cm}^2)}{\text{Surface Contamination}} = \underset{\text{(cps)}}{\text{Net Count*}} \times \frac{100}{\underset{(\%)}{\text{detector efficiency}}} \times \frac{100}{\underset{(\text{cm}^2)}{\text{area wiped x wipe efficiency**}}}$$

** When swiping area of 100 cm^2 and assuming wipe efficiency 10% use formula:

$$\underset{\text{(Bq/cm2)}}{\text{Surface contamination}} = \text{Net count (cps)} \times \frac{100}{\text{Detector efficiency specific for radioisotope (\%)}} \times 10$$

> *At The University of Manitoba, save yourself the calculation and use a decontamination level of twice background!*

What is Cerenkov Counting?

Some beta emitting radioisotopes can be analyzed on an LSC without using any cocktail. The literature of several manufacturer's discusses counting high energy (E_{max} > 800 keV) beta emitters without cocktail or with only a little water, using a technique called Cerenkov counting.

When high energy beta particles travel faster than the speed of light relative to the medium they are traversing (e.g., water, etc.) Cerenkov radiation (i.e., light) is produced. Cerenkov radiation is the blue light that you see when you look into a reactor pool. Cerenkov radiation allows some beta emitting radio-nuclides to be analyzed with a liquid scintillation counter without using any cocktail. For more information see the references below.

References

Beckman Instruments, LS 1801, 3801, 5801 Series Liquid Scintillation Systems Operating Manual, 1985.
Packard Instrument Company, Liquid Scintillation Analysis; Science and Technology, Rev. C, 1986.
Packard Instrument Company, Tri-Carb Liquid Scintillation Analyzers: Models 2100TR/2300TR, Operations Manual, 1995.
University of Wisconsin - Madison, Radiation Safety for Radiation Workers Handbook, 1998.

Part C: Contamination Meter/Surveying for Radioactive Contamination

Review before attending Radiation Safety Workshop

During the radiation safety workshop, you will complete the "Contamination Meter/Surveying for Radioactive Contamination Practical Activity" based on the information below.

What is a 'contamination meter'?

For the purposes of the University of Manitoba Radiation Safety Program, Contamination Meter is the common term for a hand-held meter used to measure the presence of radioactive material. To measure the radiation exposure (in Sv or rem) only an appropriately calibrated meter may be used.

EHS has a calibrated Survey (Dose) Meter to measure radiation exposure that is available 24/7 to the University community by contacting Radiation Safety personnel. After business hours Radiation Safety personnel can be contacted via Security Services.

> *At The University of Manitoba, contamination meters are typically one of two types -Geiger Counters or hand held Sodium Iodide Scintillation Counters.*

When is contamination monitoring with a contamination meter required?

- When more than 18.5MBq (500uCi) of any radioisotope with a half-life greater than two hours other than H-3 or C-14, has been used. Monitor all areas where radioactive materials are used with an appropriate contamination meter after each procedure.
- Accepted in lieu of Wipe Test for Weekly Monitoring when the meter has an EHS or HSC sticker validating the action/decontamination level for the meter and probe combination for the radioisotope, and the sticker is valid for a maximum of 36 months.(radioisotopes other than P-32 will have an AAMD and this will be specified on the Internal Radioisotope Permit and will be in the Permit Specific section of the Radiation Safety manual)

How do you use a contamination meter to monitor for radioactive contamination?

> *At the University of Manitoba, refer to the Quick Step Guide for Contamination Monitoring in your Radiation Safety Records binder for new requirement to document Quality Control (QC).*

1. Before monitoring, follow manufacturer's operational checks (battery check, measure a check source i.e. source of known activity, if available). Document the checks made. Know the decontamination level for the radioisotope that was in use.
2. Measure and record the background with the meter set on 'slow'.
3. Monitor areas with the meter, switched on 'fast', by passing the detector slowly (less than one inch per second) with the detector face towards the surface. Keep the distance between the detector and the surface as small as possible without touching.
4. Record results in the contamination monitoring records. Record the instrument used, the background reading and the maximum highest reading measured for these areas. Remember to include the units. Dates must include the year, month and date.
5. If contamination is detected (reading greater than 2x background), stop and obtain a measurement with the meter set on 'slow'. Note maximum reading for locations monitored. Decontaminate areas where

contamination above the decontamination level was found and re-monitor. Include details of action taken and the results of re-monitoring in the records. Remember to record highest and final readings – including units.

6. Contamination in excess of 6 x background must be reported promptly to the Radiation Safety Officer.

How is ‘Becquerel per centimeter^2’ calculated from CPM when using a contamination meter?

Calculating Decontamination Level for Contamination Meters

$$\underset{(\text{Bq/cm}^2)}{\text{Surface Contamination}} = \underset{(\text{cps})}{\text{Net Count*}} \times \frac{100}{\underset{(\%)}{\text{detector efficiency}}} \times \frac{1}{\underset{(\text{cm}^2)}{\text{operational area of detector}}}$$

$$\underset{(\text{counts/second})}{\text{*Net Count}} = \underset{(\text{cps})}{\text{Measured Count}} - \underset{(\text{cps})}{\text{Background Count}}$$

Use detector efficiency from Radiation Safety Manual, 2017 RSP-3, section 10 “University Decontamination Levels” or Quick Step Guide for Contamination Monitoring in the Radiation Records Binder.

Please review these last two sections to help you understand how to use a contamination meter – you are not expected to memorize it!

How does a Geiger Counter/Contamination Meter work?

At The University of Manitoba, the most common Geiger counter is a Ludlum with a Ludlum 44-9 probe attached.

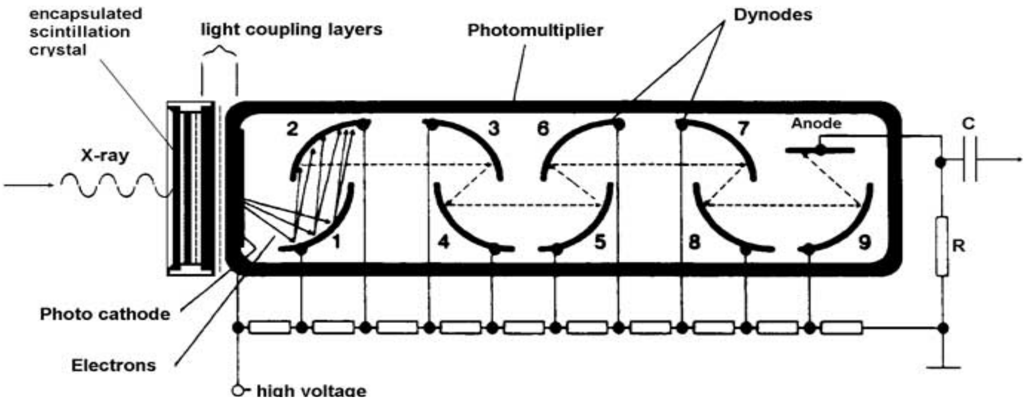
Geiger counters are used to detect ionizing radiation (usually beta particles and gamma rays, but certain models can detect alpha particles). An inert gas-filled tube (usually helium, neon or argon is doped by adding halogens) briefly conducts electricity when a particle or photon of radiation makes the gas conductive (gas is ionized). The tube amplifies this conduction by a cascade effect and outputs a current pulse, which is then often displayed by a needle or lamp and/or audible clicks. Some Geiger counters can be used to detect gamma radiation, though sensitivity can be lower for high energy gamma radiation than with certain other types of detector, because the density of the gas in the device is usually low, allowing most high energy gamma photons to pass through undetected (lower energy photons are easier to detect, and are better absorbed by the detector). Other good alpha and beta scintillation counters also exist, but Geiger detectors are still favored as general purpose alpha/beta/gamma portable contamination and dose rate instruments, due to their low cost and robustness.

How does a Scintillation Counter/ Contamination Meter work?

At The University of Manitoba, The most common scintillation counter/meter is a Ludlum with a Ludlum 44-3 probe.

Sodium iodide scintillation counters are better devices for detecting gamma rays. When a charged particle (ion) strikes the scintillator, a flash of light is produced; each charged particle produces a flash of light. The intensity of the light flash depends on the energy of the charged particles. Sodium iodide (NaI) containing a small amount of thallium (doped) is used as a scintillator for the detection of gamma waves.

The association of a scintillator and photomultipier with the counter circuits forms the basis of the scintillation counter apparatus. The scintillation counter (probe) has a layer of phosphor cemented in one of the ends of the photomultiplier. Its inner surface is coated with a photo-emitter with less work potential. This photoelectric emitter is called a photocathode and is connected to the negative terminal of a high tension battery. A number of anodes called dynodes are arranged in the tube at increasing positive potential. When a charged particle strikes the phosphor, a photon is emitted. This photon strikes the photocathode in the photomultipier, releasing an electron. This electron accelerates towards the first dynode and hits it. Multiple secondary electrons are emitted, which accelerate towards the second dynode. More electrons are emitted and the chain continues, multiplying the effect of the first charged particle. By the time the electrons reach the last dynode, enough have been released to send a voltage pulse across the external resistors. This voltage pulse is amplified and recorded by the electronic counter.



At the University, you can use the following methods to monitor for the most commonly used radioisotopes.

Radioisotope	Type of Emission	Energy (MeV)	Half-life	Acceptable for weekly monitoring	Acceptable for surveying after using > 500uCi
H-3	Beta-	Lowest 0.018	12 years	LSC	Not possible
C-14	Beta-	Low 0.156	5730 years	LSC	Ludlum 44-9
S-35	Beta-	Low 0.167	88 days	LSC	Ludlum 44-9
P-32	Beta-	Mid 1.71	14 days	LSC or Ludlum-44-9	Ludlum 44-9
I-125	X-ray/ Gamma	Low 0.035	60 days	LSC	Ludlum 44-3
Tc-99m	Gamma	Low 0.14 (85%)	6 hours	LSC or Ludlum-44-3	Ludlum 44-3
Cr-51	X-ray/ Gamma	Low 0.32 (10%)	28 days	LSC	Ludlum 44-9
F-18	Beta+/ Gamma	0.633/0.511	109.8 minutes	Well Counter/Ludlum	Ludlum 44-9
I-124	Beta+/ Gamma	1.532/0.511	4.18 days	LSC	Ludlum 44-9