



MARQUETTE
UNIVERSITY

MARQUETTE UNIVERSITY
RADIOACTIVE ISOTOPE USERS MANUAL

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(Available online at: www.mu.edu/researchcompliance)

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Table of Contents

| | | |
|-------|---|----|
| I. | LICENSE AND AUTHORIZATION..... | 3 |
| A. | Authorizations from DHS | 3 |
| B. | Administration of Licenses and Authorizations | 3 |
| II. | SOURCES OF INFORMATION | 5 |
| A. | Marquette University License Conditions and Commitments | 5 |
| B. | Chapter HFS 157 | 5 |
| C. | NRC Publications | 6 |
| D. | Other Sources | 6 |
| III. | LABORATORY CLASSIFICATION | 6 |
| IV. | SAFETY | 7 |
| A. | Surveys and Monitoring | 7 |
| B. | General Safety Rules | 9 |
| C. | Signs and Other Posted Material | 10 |
| D. | Waste Management | 12 |
| E. | Incidents and Emergencies | 14 |
| F. | Security | 14 |
| V. | ACQUISITION OF RADIOACTIVE MATERIAL | 15 |
| A. | Authorization | 15 |
| B. | Ordering Procedures | 15 |
| C. | Delivery | 15 |
| VI. | RECORD KEEPING | 16 |
| A. | Inventory | 17 |
| B. | Wipe tests | 17 |
| C. | Package inspections | 17 |
| D. | Other pertinent information | 17 |
| VII. | DECOMMISSIONING | 17 |
| A. | When and why? | 17 |
| B. | How? | 17 |
| VIII. | ENFORCEMENT | 18 |
| A. | University | 18 |
| B. | Licensing Agencies | 18 |
| | APPENDIX I | 18 |

I. LICENSE AND AUTHORIZATION

The use of radioactive materials at Marquette University (M.U.) is authorized by the Department of Health Services of the State of Wisconsin (DHS).

A. Authorizations from DHS

The use of accelerator produced, naturally occurring, and reactor produced (byproducts) radioactive isotopes is authorized by the DHS under License No. 079-1161-01, which is available for viewing on the ORC website (www.mu.edu/researchcompliance). This agency also regulates the use of X-ray producing equipment.

B. Administration of Licenses and Authorizations

1. Radiation Safety Committee (RSC)

The use and possession of radioactive sources at M.U. is controlled and administered by the RSC. This committee is made up of five members. Three of the five members are authorized users with technical expertise. The other two members consist of the Director of Environmental Health and Safety and a non-voting management representative.

2. Radiation Safety Officer (RSO)

The responsibility of the RSO is to ensure the safe use of radioactive materials and the compliance with all state and federal regulations and the conditions of the license. The RSO is a member of the RSC and reports directly to the Vice President for Research and Innovation or a management representative. The RSO has the authority to terminate anytime an operation involving radioactive material if he/she determines that a significant safety violation has occurred, which represents a threat to the health and safety of employees or the general public.

3. Radiation Safety Technician (RST)

The responsibility of the Radiation Technician is to assist the RSO in monitoring and supervising the licensed activities in the laboratories of Authorized Users.

4. Authorized Users (AU)

Definition. AU are members of the faculty and staff who, by their training and experience in the use of radioactive materials, are qualified

to work with such isotopes independently and to supervise the use of radioactive isotopes by radiation workers.

Qualification and training. AU must have a college degree at the bachelor level or higher in the physical or biological sciences, or in a field of engineering. He/she must have completed, at least, 40 hours of training and experience in the safe handling of radioactive materials including, but not limited to, characteristics of ionizing radiation, units of dose and quantities (and appropriate calculations), radiation detection instrumentation, and biological hazards of exposure to radiation. The extent of training should be appropriate for the type, physical and chemical form, and quantity of radioactive material used.

Authorization procedure. Individuals wishing to be certified as authorized users must apply to the RSC. Application must be made on the Wis. DPH 45016 Form. These are available from Office of Research Compliance or the RSO or at <http://www.dhs.wisconsin.gov/forms/F4/F45016.pdf> Applications are acted on at the next quarterly meeting of the RSC unless the applicant can show good cause for earlier action.

Limitations. The use of radioactive material by an AU is limited to the specific isotopes, possession limits, locations and experimental procedures, which have been approved by the RSC in response to the AU's application.

Exceptions. Under special circumstances, individuals with a working knowledge of radioactive materials may be recruited to serve on the RSC, and as such, may be designated by the RSO as an AU who a) chooses not to use radioactive materials at this time, and b) gets designated in SIAM database as "cannot use" to avoid possible confusion regarding their ability to purchase or possess radioactive materials. The RSO has authority to appoint these AUs immediately upon obtaining proof of training.

5. Radiation Workers (RW)

Definition. RW are individuals who have completed the necessary training to qualify for work with radioactive isotopes under the supervision of an AU at Marquette University.

Training. *All RWs are required by our license to go through the*

Marquette University training program. This consists of two DVDs) and a one-hour lecture by the RSO. The DVDs are available from the Office of Research Compliance located at 560 North 16th Street, Room 102. Following the completion of the training sessions, RWs must pass a test administered by the RSO and sign a form acknowledging that they have received the required training. **No RW may start working with radioactive materials until the above requirements have been met.**

Limitations. RWs may not use radioactive isotopes independently until receiving hands on training by an AU. After such training, the AU is responsible for RW supervision.

6. Office of Research Compliance (ORC)

The ORC handles all administrative aspects of Marquette University's license including, but not limited to, record keeping, control of acquisition and inventory of radioactive sources. This office is located at 560 North 16th Street, Room 102.

II. SOURCES OF INFORMATION

A. Marquette University License Conditions and Commitments

The DHFS requires that M.U. adhere to all conditions and commitments, which were presented in the license application. A copy of the application is available for viewing at the ORC or from the RSO.

B. Chapter HFS 157

Copies of this document are available from the RSO, or online at https://docs.legis.wisconsin.gov/code/admin_code/dhs/110/157

1. *Subchapter X. Notices, Instructions and Reports to Workers.*

This part contains licensee's obligation to workers.

2. *Subchapter III. Standards for Protection from Radiation.*

This part contains all essential aspects of radiation protection standards and procedures. Most license conditions are based on information in Subchapter III.

3. *Subchapter II. Licensing of Radioactive Material.*

This part contains general information about licensing and license-related activities including definition of types of licenses, exempt quantities, and the activities which necessitate a license.

4. *Subchapter II, part 157.13. Specific Licenses.*

This part contains information regarding the requirements of a specific license, such as Marquette University's license.

C. NRC Publications

The United States Nuclear Regulatory Commission periodically publishes pertinent information in the form of various documents. These include Regulatory Guides, Generic Letters, proposed changes in regulations, etc. Most of these are also published in the Federal Register. They are also available at www.nrc.gov. States generally follow changes in NRC policies and regulatory guides within three years following the effective date of the NRC change.

D. Other Sources

Other sources of information for radiological protection may come from publications of the *National Council on Radiation Protection and Measurements (NCRPM)* and the *International Commission on Radiological Protection (ICRP)*.

III. LABORATORY CLASSIFICATION

Laboratories for use of radioactive isotopes are classified as Type A, B, or C. Currently, all laboratories at M.U. are classified as Type C. Type C is the lowest level and consists of a standard chemical laboratory equipped with sinks, fume hoods and adequate ventilation. Some laboratories may temporarily be classified as Type B, whenever procedures, quantities or volatility of radioactive material require higher level of safety and containment. No Type A laboratories are currently allowed at M.U.

IV. SAFETY

A. Surveys and Monitoring

1. Personnel

External Exposures.

TLD Dosimeters. All individuals working with the following isotopes will need to wear TLD whole body dosimeters. TLD whole body dosimeters are required for anyone working with ^{32}P , ^{22}Na , (^{125}I if 1.0 mCi or more), which bear detection by **TLD Dosimeters**, are required to wear **TLD**

Dosimeters when handling such isotopes. **TLD Dosimeters** are to be developed quarterly and all records of exposure must be reviewed by the RSO. More frequent monitoring may be required at the discretion of the RSO in the case of pregnant individuals or if there is reasonable evidence that a significant exposure may have occurred. **Ring badges.** In addition to the **TLD Dosimeters**, individuals working with more than 100 μCi of ^{32}P in a single experiment/dose, are also required to wear a ring type badge (TLD ring).

Records inspection. Employees may inspect their exposure records anytime upon request. Copies are maintained by Landauer, digitally by the RSO, or historical records are available at the ORC. Annual reports of exposure should be provided to all individuals who have been monitored by film and/or ring badges. Individuals with previous monitoring records at other institutions must sign a release form, which will authorize the RSO to request copies of previous exposures.

Internal Exposures. Internal exposure can result from uptake of radioactive isotopes through ingestion, inhalation, or contact with such material. Actual internal exposure can be measured only through bioassays. The need for such bioassays will be determined by the RSO based on the isotope, quantity, physical and chemical form, the experimental procedure involved and the results of air monitoring in the work area by the RSO. However, concerned individuals may request a bioassay anytime. Instructions for bioassays may be obtained from the RSO. They may involve collection of urine samples, thyroid scans, or other procedures.

Exposure limits.

Adults (Occupational exposure). The combined external and internal exposure dose may not exceed 5,000 mrem/year deep-dose for the whole body, 50,000 mrem/year shallow-dose to the skin or the extremities, or 15,000 mrem to the lens of the eye.

However, see comment below !!!

Minors (Occupational exposure). Annual limits for minors are 10% of those specified for adults.

Declared pregnant women (Occupational exposure). The cumulative combined external and internal exposures may not exceed 500 mrem for the entire pregnancy. This assumes a uniform exposure rate over the duration of the pregnancy. Significant variations should be avoided. Women must declare their pregnancy in writing to their supervisors or to the RSO.

Members of the public. The combined internal and external exposure limit for members of the public is 100 mrem/year. External exposure may not exceed 2 mrem/hour or 50 mrem/year.

!!! Comment: The above limits for all four groups of individuals represent maximum limits. State guidelines require that licensees follow the **ALARA** principle. This stands for “As Low As Reasonably Achievable”. It is up to the user to demonstrate that everything reasonable was performed to reduce exposure. Repeated significant exposures, without attempts to reduce such exposures, may result in penalties even if none of the readings exceeded the maximum limits.

2. Work Area Surveillance

Instrument Surveys. For isotopes that are detectable with a survey meter, the work area should be monitored following each use. It is also a good idea to monitor hands (even if gloves were worn) and the bottom of shoes before leaving the facility.

Wipe tests. For all isotopes, working surfaces and storage areas should be wipe tested at monthly intervals. Results must be recorded and available for inspection at all times. The record should also include the following information:

- Date when the wipe test was conducted
- Identity of the individual who performed the wipe tests
- The instrument that was used to count the wipe samples
- The last calibration date of the instrument
- The efficiency of the instrument for the isotope(s) tested
- Background counts

If the results of any individual wipe test exceeds 150 counts per minute, the RSO or the Radiation Safety Technician (RST) should be consulted.

Exceptions to the monthly interval are the following:

- If zero radioactive isotopes have been used during a calendar month, then in lieu of a wipe test, zero use status must be recorded with date and initials at the end of each calendar month.
- If working with ^{32}P in quantities exceeding 1 mCi per single use, wipe test must be performed immediately following the completion of the experiment.
- If working with ^3H only and in quantities of less than 200 μCi per single use, quarterly intervals are permissible.

- Sealed sources in use must be leak tested every three months by the authorized user. **Physical inventory must confirm their** presence every three months. Sealed sources in storage must be inventoried every 6 months, be leak tested every 5 years, or be leak tested before they are returned to regular use. The results of all leak tests are to be given to the RSO or RST when completed.

3. Instrument Calibration

Survey meters. All survey meters must be calibrated annually. Calibration must be performed by an approved company or individual.

Liquid scintillation counters (LS). LS must be calibrated against an unquenched standard at least once per year and every time that repair work has been done on the instrument.

Gamma scintillation counters (GSC). GSC must be calibrated at least once per year and every time the instrument has been repaired. Models that are designed to signal when the instrument is out of calibration must be calibrated whenever that signal appears.

B. General Safety Rules

1. Wear laboratory coats or other protective clothing when working with radioactive materials or in areas where radioactive materials are in use.
2. Wear disposable latex or vinyl gloves at all times when handling radioactive materials.
3. Leave laboratory coats and gloves in the laboratory when leaving the laboratory.
4. Cover bench tops, where radioactive material is used, with plastic backed absorbent paper.
5. When isotope is detectable by survey meter, check hands and shoes following completion of procedures.
6. Do not eat, drink, smoke, or apply cosmetics in any room where radioactive material is used.
7. Do not store food, drink or personal items with radioactive materials.
8. Always wear personal monitoring devices (TLD dosimeters and/or ring badge) when working with radioactive materials that require such monitoring, and in places where such material is in use. When not in use, monitoring devices should be stored in a low background area.

9. Monitoring devices should be worn under protective clothing to prevent contamination and false positive readings. Ring badges should be worn under the glove.
10. Dispose of radioactive waste only in designated container (liquid) or designated waste cans (solids).
11. Never pipette by mouth any radioactive material or non-radioactive material in areas where radioactive material is in use.
12. Label your radioactive materials properly.
13. Use shielding when necessary.
14. Know location of emergency telephone numbers.
15. **Always keep proper records of receipt, use, disposal and other pertinent information on radioactive materials.**
16. **Keep laboratories where radioactive materials are used and/or stored, secure at all times. Doors to these areas must be locked whenever the room is unattended, unless the room is used only for storage, and stored material is in a locked and secured location (e.g. locked refrigerator or freezer)**

C. Signs and Other Posted Material

1. Warning Signs

Caution Radioactive Materials. This sign must be posted on or next to the door of every room where radioactive isotopes are used or stored. If radioactive isotopes are not used but only stored in the room, it may be possible to label only the storage compartment (e.g. freezer) as long as the compartment can be locked and secured.

Radiation Area. This sign must be posted on or next to the door of every room in which radiation levels are sufficiently high that an individual could receive an exposure in excess of 5 mrem/hr at a distance of 30 cm from the source.

2. Maps

A map, showing the location of radioactive isotope use and storage, should be posted adjacent to the CAUTION RADIOACTIVE MATERIALS sign.

3. Notice to Employees

Notice to Employees (PPH 45027, 06/02), available from the ORC

should be prominently displayed in every room where radioactive materials are used.

4. Addendum to Notice to Employees Form

The addendum, describing the location and accessibility of Marquette University's license and application, should be posted along with the Notice to Employees Form.

5. Labeling

Equipment. All equipment (centrifuges, scintillation counters, freezers, refrigerators, incubators, etc), that is used for work with radioactive materials, must be labeled with a Radioactive Materials sign. Moving such equipment into a non-restricted area (e.g. to shop for repair) may only be made after thorough wipe testing to ensure that it is not contaminated.

Containers.

Containers for storing stock solutions. Containers holding stock solutions should be labeled with sufficient detail to allow identification of contents. Information should include the M.U. ID#, the isotope number, the chemical form, the activity and date of acquisition.

Temporary containers. Containers used temporarily during the conduct of experiments (such as test tubes) do not have to be labeled individually as long as they are placed in labeled holding racks or are under continuous observation by the user.

Use area. It is a good idea to outline bench top areas, where radioactive materials are used, with tape displaying the radioactive symbol.

D. Waste Management

1. Temporary Laboratory Storage.

Solid and liquid waste material must be sorted according to long-lived and short-lived isotopes and placed in 5 gallon metal pails lined with 4 mil plastic bags (solid), or carboys (liquids) provided by the RST. There must be no liquid waste placed in solid waste pails. All pails and carboys must be clearly labeled with the radioactivity caution sign, and indicating isotope(s) and authorized user. Pails and carboys should be

kept in a remote area of the laboratory to avoid exposure of individuals. If the detectable external radiation exceeds 2 mrem/hr, the pail or carboy should be shielded with an appropriate material. Solid and liquid waste pickup will be conducted by the RST on an as needed, or quarterly basis. Please notify the RSO and RST *before* a waste container is full.

2. Disposal of Radioactive Waste

Procedure for handling liquid radioactive waste. Materials for collecting liquid waste are provided by the Office of Research Compliance. If you are using ^{32}P or other high energy emitters, you may also be provided an acrylic storage box with hinged lid to properly shield the liquid waste during storage. **Important:** All liquids containing radionuclides are to be collected in the containers you have been provided by ORC. **Under no circumstance should you dispose of liquid radioactive waste in a sink in your lab.** Collect all waste in carboys designated long-lived or short-lived radioactive waste. Keep shielded to reduce possible exposure to workers of high energy, ie. ^{32}P as liquid waste. Shielding is not required for low-level emitters such as ^{14}C , ^3H . All carboy lids must be securely tightened at all times to avoid accidental spills.

If a carboy reaches the $\frac{3}{4}$ mark you should contact the RSO (Jane Dorweiler) or RST. A new carboy will be delivered, and the $\frac{3}{4}$ full one will be removed. Exchanges will be completed no later than the next business day. In the event of a spill, please follow established procedures in your radiation safety manual.

Decay in storage for dry waste. This route of disposal is restricted to isotopes with half-life of less than 65 days. The only exception to the 65 day limit is Sulfur-35 with an 87.5 day half-life (see appendix I for half lives of commonly used radioisotopes). The waste is stored until it has decayed to an undetectable level and then thrown out as regular (non-radioactive) waste; therefore, **all radioactive labels must be removed** before placing dry waste in 5-gallon radioactive waste collection pails.

Burial at licensed land site. These methods must be used for all non-water soluble solid waste containing isotopes with half-life longer than those listed above in IV.D.2 **decay in storage**. All waste placed in barrels must be solid. Any liquid must be converted to solid form with appropriate absorber. Appropriate barrels for this purpose are located in the WLS-B008 storage room described above in IV.D.2. Do not mix short (stored for decay) and long (stored for burial or incineration) half-

life isotopes. When barrels are full, the University will contract with a licensed transporter to ship the waste to the licensed facility. Keep in mind that there is only one burial site left in the country with limited access. Therefore, careful separation of contaminated material from non-contaminated waste is recommended. Disposal is also very expensive.

Dry Waste removal from AU labs: Similar to liquid waste carboys, full 5-gallon pails are exchanged for fresh pails no later than the next business day after contacting the RSO or RST. The RSO or RST will transfer waste into University storage in Wehr Life Science Building room B008.

The activity contained in the waste, decayed to the day of disposal, and the disposal date must be reported to the RSO using the **Radioisotope Use and Disposal Form**. All entries must be identified with the authorized user's name. See Appendix I for isotope half lives, or use the following link <http://www.radprocalculator.com/Decay.aspx>.

Specific wastes.

The following wastes may be disposed of as if they were not radioactive:

Liquid scintillation fluid that contains less than 0.05 μCi (1.85 kBq) of ^3H , ^{14}C , or ^{125}I per gram. The counting vials that contained such fluid may also be disposed as non-radioactive.

Animal carcasses that contain less than 0.05 μCi (1.85 kBq) of ^3H , ^{14}C , or ^{125}I per gram of animal tissue averaged over the entire body weight of the animal.

NOTE: Records of such disposals must be maintained.

All disposals should be reported to the ORC on an M.U. Disposal Report Form. All activities should be corrected for decay to the date of the report.

Remember that if you do not report your disposals, you may exceed your possession limits and may be denied authorization on your next attempt to order!!

E. Incidents and Emergencies

1. Spills and releases

The extent of the response to accidental release of radioactive material into the surrounding environment can not be generalized. It will depend on the isotope, quantity, the chemical and physical form, volatility, etc.

For example the spilling of 1 μCi of non-volatile form of ^3H will not require the same response as the release of 1mCi of ^{125}I in a volatile form. No amount of training can substitute for good common sense. The most important initial response in such incidents is **CONTAINMENT and ISOLATION**. It is essential that the spread of the contamination be limited as much as possible without a significant increase in the risk of exposure to the responding individual(s). Keep all unauthorized individuals away from the contaminated area. After such initial response, the authorized user must be immediately contacted. If the AU is not available, the RSO should be contacted.

Under no circumstances should a radiation worker attempt decontamination without instructions from the AU or the RSO.

In case of more serious incidents, the AU should contact the RSO for evaluation. A written follow-up report must be sent to the RSO within two weeks following the incident, detailing the circumstances, the quantity of each isotope involved, the chemical nature of the isotope and the details of the response to the incident. An attempt should be made to estimate the possible exposure to individuals involved and the AU should indicate what steps will be taken to prevent such an incident in the future.

2. Lost sources

The loss or theft of a radioactive source must be immediately reported to the RSO following discovery of the loss or theft. The authorized user should inform the RSO of the identity of the isotope, the estimated activity and the chemical and physical form of the source. The RSO will determine the reporting requirements to DHS.

F. Security

1. Work Areas

All rooms, which are posted with the signs “CAUTION RADIOACTIVE MATERIALS” or “RADIATION AREA”, are designated as restricted areas. **The door to these rooms must be closed and locked at all times when the room is unattended.**

2. Stored material

If a room is not designated as a restricted area, but radioactive material is stored (not used) in the room, the storage compartment (e.g. refrigerator, freezer) must be labeled and secured with a lock at all times when the room is unattended.

V. ACQUISITION OF RADIOACTIVE MATERIAL

A. Authorization

Acquisition of radioactive material is restricted to authorized users. For authorization see I.B.4.c.

B. Ordering Procedures

Commercial Vendors

Authorized users must complete a M.U. Registration Form for purchase of radioactive materials. The form and instruction for completion are available on the ORC website or from the ORC. The first 14 digits of the source I.D. number must be assigned on the form. The form must be signed by the authorized user. The completed form must be e-mailed or faxed to the Office of Research Compliance for approval. Only upon ORC approval can the AU complete the purchase order.

Other sources

Radioactive materials obtained from non-commercial sources (e.g. a colleague at another institution) must still be authorized through a completed registration form and ORC approval before they can be shipped to M.U.

C. Delivery

Location

All shipments must be delivered to a central location. Currently, the location is the Biological Sciences Stock Room or the Biological Sciences Office (Wehr Life Sciences Building). Most packages are delivered to the Office because of easier access for the delivery person. The Biological Sciences Office receives a copy of the approved registration form from ORC.

Transfer to User

Following central delivery, the authorized user is informed by telephone that the package has arrived. It must be picked up by the authorized user or his/her radiation worker within 30 minutes following notification. If it is not picked up within 30 minutes, the package will be transferred to the

RSO or RST for safe storage. When the package is picked up, the person accepting the package must complete and sign the registration form. The last six digits of the I.D. number must be completed by entering the date of receipt or, in some cases, the date of calibration. The completed registration form is faxed from the Biological Sciences Office to the ORC and the source is then entered into the AU's possession.

Package Inspection (must be completed within three hours following receipt). All packages must be examined for external damage. If such damage is observed, it should be reported to the RSO.

- Packages containing volatile forms of an isotope should be opened in a fume hood.
- Disposable gloves should be worn for opening the package.
- For isotopes which bear detection with survey meter, all packaging material should be monitored.
- For isotopes, which cannot efficiently be detected by survey meter (e.g. low energy β emitters), containers should be examined for broken or missing seals and leakage. If such damage is observed, all packaging material should be wipe tested before disposal into regular waste.
- Shipments containing more than 10 mCi (0.37 g Bq) of such isotopes require wipe testing of packaging material regardless of the condition of the container.
- Results of the inspection should be recorded in the laboratory logbook, even if they were negative. Radioactive labels on packaging material should be removed or defaced before disposal.

Remember to ascertain the presence in the package of all sources that were ordered before disposing of packaging. If an ordered source is missing from the package, but is listed on the packing slip, immediately notify the vendor and the RSO!!

VI. RECORD KEEPING

A. Inventory

Logbooks should contain an accurate record of the receipt, use and disposal of all sources. Sources should be identified with the same I.D. number as the one listed on the M.U. Registration Form.

B. Wipe tests

Results of all wipe tests and other surveys should be recorded in the AU lab logbook. For required information, see IV.A.2.b. It is preferable to label and save the original printout from the counter. If no monthly wipe tests were performed because no radioactive materials have been used since the last wipe test, the log book must contain dated statement to that effect.

C. Package inspections

Results of all package inspections should be recorded regardless of whether the results were positive or negative. Identify all inspections with the proper I.D. number and indicate who performed the inspection.

D. Other pertinent information

All other information, which may be important in assessing the effectiveness of the AU's isotope usage program, should be recorded. This should include, but not be limited to, incidents which may have occurred.

VII. DECOMMISSIONING

A. When and why?

When an authorized user discontinues all use and possession of radioactive sources, his/her facilities must be properly decommissioned. This may occur at retirement, permanent departure from the university or because the individual no longer needs radioactive materials in his/her research or teaching. Until the proper decommissioning process has been completed, the facilities must remain a restricted area and subject to all regulations for such areas.

B. How?

1. The authorized user must account for, and properly dispose of, all radioactive sources, which are listed in his/her possession by the inventory program at ORC.
2. The facilities must be properly wipe tested by the AU. If areas of contamination are detected, they must be properly decontaminated and retested. Results of all disposals and wipe tests, and the logbook must be turned over to the RSO. The RSO or the RST will then wipe test all areas to confirm lack of contamination. If areas of contamination are found, the AU will be responsible for further decontamination. If all results are negative and inspection of logbook accounts for all sources,

the decommissioning process is complete and the facilities may become a non-restricted area for general public use.

VIII. ENFORCEMENT

A. University

1. All AUs are subject to an annual audit by the RSO and his/her staff. The criteria used for these audits are similar to those used by Regulatory Agencies during their inspections of the University's licensed activities. In addition to the annual audit, the RST may inspect logbooks and evaluate safety items in each laboratory during her/his quarterly wipe tests for surface contamination.
2. AUs are expected to be in compliance at all times with the University's license conditions. Failure to do so will result in disciplinary action by the Radiation Safety Committee (RSC). The level of response by the RSC depends on the severity of the violation(s). They may range from a warning to immediate termination of all licensed activities. The RSO has the authority to terminate all licensed activities of an AU if he/she determines that serious threat to public safety is involved. Such a move by the RSO will be reviewed by the RSC. Minor violations, which merit only a warning, may escalate to a more serious level if subsequent inspections reveal no corrective action and repeated violations of the same item are observed.

B. Licensing Agencies

The Wisconsin DHFS conducts periodic, unannounced inspections. These are thorough and rigorous processes. Any violations of license conditions or DHFS regulations will result in citations. The level of the citations can range from 5 to 1, depending on the seriousness of the violation. Level 1 is the most serious. All can result in civil penalties. Repeated violations of a lower level can escalate to a higher category. Deliberate acts of negligence or attempts to conceal a violation will be traced to the individual user, who can be fined or, in very serious cases, criminally prosecuted.

Appendix I. Properties of commonly used radioactive isotopes.

| Property | ³ H | ¹⁴ C | ³⁵ S | ¹²⁵ I | ³² P | ³³ P |
|------------|----------------|-----------------|-----------------|------------------|-----------------|-----------------|
| Half-life | 12.3 years | 5730 years | 87.4 days | 60 days | 14.3 days | 25 days |
| Decay Mode | β | β | β | γ | β | β |
| Shielding | none | acrylic | acrylic | lead | acrylic | acrylic |