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OPERATING GUIDE FOR RADIOCHEMICAL LABORATORIES AT VARIOUS ACTIVITY LEVELS

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ABSTRACT

This memorandum is presented as a guide for determining the quantities of radioactive materials which may be handled safely in the various laboratory facilities.

Operating Guide for Radiochemical Laboratories at Various Activity Levels

All radiochemical operations have the fundamental problem of prevention and/or control of contamination. Although the health and safety of personnel are of primary concern, the cost of decontamination and possible permanent shutdown of a badly contaminated facility must also be considered. For this reason every precaution must be taken to prevent release of activity, and in the event of an accidental release contain its spread to a minimum area. Adequate facilities and trained personnel are therefore a prime necessity.

Radiation Safety Policy

Conditions leading to unforeseen accidents, resulting in spread of contamination, are a result of the breakdown of one or all of the following basic requirements of a good radiation safety policy.

1. Properly trained personnel and adequate procedures.

2. Good laboratory facilities, particularly from a containment and isolation viewpoint.

3. Competent supervision and strict enforcement of all radiation safety regulatory policies.

In the development of these requirements for operations which are varied and extensive it is frequently difficult for supervision to determine the type of laboratory and auxiliaries and the degree of containment necessary for the various radioactive isotopes that must be processed. To aid in making these decisions, a guide relating types of laboratories for varying amounts of activities versus relative radiotoxicities of the isotopes to be handled, is presented.[1,2]

Radiotoxicity refers to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioatom introduced into the body.

Radiochemical Laboratory Requirements

Both radiation and contamination hazards must be considered in the radiochemical laboratory. Of the two, the radiation problem is less complex and may be handled by proper shielding. The governing problems are those dealing with the spread of contamination and the attendant problems resulting from penetration, ingestion and inhalation. Relative radiotoxicities of the various isotopes, physical form of the isotope and complexity of

operation therefore provide a basis for determining the type of laboratory and degree of containment required.

Taking these factors into account, approximately 150 radioisotopes were classified into four broad categories of relative radiotoxicity - very high, high, moderate, and slight - as shown in Table 1. The types of laboratories and the amounts of radioactivity which can be safely handled are given in Table 2.

Laboratory Requirements - Successful work with radioisotopes requires the use of facilities and equipment specially designed for the purpose.

Generally speaking, this consists of a basic laboratory in which the floors, walls, ceiling, benches, etc., present a smooth, continuous surface of non-porous and noncorroding material for ease in decontamination. Hoods, glove boxes, or hot cells with forced ventilation and filtered discharge (99.95% efficiency for particles > 0.3 micron) are required for operations with more than low levels of activity. Hot areas must be at a negative pressure with respect to surrounding cold areas. Specialized equipment suitable for the type and level of activity being used must be provided.

Table 2 provides a means for determining the type of laboratory for stated curie amounts of activity versus relative radiotoxicity.

Table 1

Classification of Isotopes According to Relative Radiotoxicity Based on Inhalation Hazard* Amounts (Curies) Equivalent to One Gram of Pu-239 (HEP)

Class 1 (Very high radiotoxocity) HEP $\leq$ 0.07	Sr-90 + Y-90, Po-210, Po-210 + Bi-210, Ra-226, Th-228, U-232, Pu-238, Pu-239, Pu-240, Pu-241, Am-241, Cm-242
Class 2 (High radiotoxicity) HEP = 0.86–17	Na-22, P-32, Ca-45, Sc-46, V-48, Fe-59, Co-58, Co-60, Ni-63, Zn-65, Rb-86, Sr-89, Y-91, Zr-95 + Nb-95, Ru-103, Ru-106 + Rh-106, Ag-105, Ag-110, Cd-109 + Ag-109, Cd-115, In-114, Sn-113, Sb-122, Sb-124, Sb-125, I-131, Cs-134, Cs-137 + Ba-137, Ba-140 + La-140, Ce-144 + Pr-144, Pm-147, Sm-151, Eu-152, Eu-154, Tm-170, Hf-181, Ta-182, Ir-192, Hg-203, Tl-204, Bi-210, At-211, U-233[1], Th-234 + Pa-234, Np-237, Pu-242
Class 3 (Moderate radiotoxicity) HEP = 22-220	Be-7, Na-24, S-35, K-42, Ca-47, Sc-47, Sc-48, Mn-52, Mn-54, Fe-55, Mn-56, Cu-64, Ga-72, As-74, As-76, As-77, Se-75, Br-82, Sr-85, Y-90, Nb-95, Mo-99, Pd-103 + Rd-103, Rh-105, Pd-109, Ag-111, Cd-115, Sb-122, Te-127, Ba-131, La-140, Ce-141, Pr-142, Pr-143, Nd-147, Ho-166, Sm-153, Ho-170, Lu-177, W-181, W-185, W-187, Re-183, Re-186, Os-191, Ir-190, Ir-192, Ir-194, Pt-191, Pt-193, Au-196, Au-198, Au-199, Hg-197, Tl-200, Tl-201, Tl-202, Ac-227, pure U-233, U-234
Class 4 (Slight radiotoxicity) HEP > 430	H-3, C-14, F-18, Cl-36, A-37, Cr-51, Ni-59, Ge-71, Kr-85, Tc-98, Tc-99, Ru-97, Rh-103, Te-129, I-129, I-132, Xe-133, Pb-203, U-235, U-236, Th-natural, U-238, U-natural

[1] $\leq$ 500 ppm U-232

*These values are based on inhalation and immersion (for inert gases) hazard only. Other factors that must be considered are criticality, chemical toxicity and reactivity, and pyrophoricity.

$HEP = 2.16 \times 10^9 \ MPC_a \times A$

MPC_a = μc/cc for 40 hr wk

A = g/c or 0.1, whichever is greater.

Table 2

Type of Laboratory with Quantity Handled Versus Radiotoxicity

Radiotoxicity of Isotopes	Type A High Level Laboratory	Type B Radiochemical Laboratory	Type C Good Chemical Laboratory	Type D Good Chemical Laboratory
Very high	> 10 mc	10 μc - 10 mc	0.1 μc - 10 μc	0 - 0.1 μc
High	> 100 mc	100 μc - 100 mc	1.0 μc -100 μc	0 - 1.0 μc
Moderate	> 1 c	1 mc - 1 c	10 μc - 1 mc	0 - 10 μc
Slight	> 10 c	10 mc - 10 c	100 μc - 10 mc	0 -100 μc

Definition of Laboratory Types - Unless otherwise stated, the requirements of a basic laboratory or equal facility are understood.

Type A - Operations to be conducted in glove boxes or hot cells in facilities specifically constructed for handling high levels of radioactive materials. Containment features must prevent spread of activity within or release from the facility. Complete isolation (physical separation) from neighboring facilities, laboratories, offices, etc., is necessary.

Type B - Operation must be conducted in approved glove boxes. Air inlet and discharge ports must be fitted with high efficiency filters and ventilation air from laboratories containing glove box operations must also pass through high efficiency filters. Glove box safety features, air locks and bagging techniques are also a necessity.

A degree of isolation such as hot change facilities or air locks to prevent spread of contamination to surrounding offices or laboratories must be maintained.

Type C - Operations must be conducted in approved chemical hoods which are vented through high efficiency filters. Hood openings must have a minimum face velocity of 100 fpm; however, 200 fpm may be required for various hazardous operations, especially if hot plates, aspirators, or Bunsen burners are used.

Type D - Bench-top operation is normally satisfactory. Hood operations should be considered for upper levels of activity.

Modifying Factors - Because the physical form of the radioactive materials or complexity of procedures to be followed can either increase or decrease the degree of hazard in handling radioisotopes, certain modifying factors must be applied to the values in Table 2 according to the complexity of the operations involved. The following factors, Table 3, are suggested, but due regard must be paid to the circumstances affecting each individual case.

Table 3

Operational Factors to Modify Table 2

Operation	Modifying Factor
Storage	x 100
Very simple wet operation	x 10
Normal chemical operation	x 1
Complex wet operations with risk of spills and simple dry operations	x 0.1
Dry and dusty operations and those where isotopes are evolved as gases	x 0.01

These factors normally apply to operations in B-type and C-type laboratories. Examples of these are: (1) storage items may include stock solution, bulk irradiated materials, sources, etc.; (2) very simple wet operations include manipulations such as mixing, dilutions, pH determinations, etc.; (3) most quantitative and qualitative analyses may be considered as normal chemical operations; (4) complex wet operations and simple dry operations, normally involve those which require elevated temperatures, pressure, vacuum, open dish fuming or evaporation; and (5) mixing, grinding, pulverizing, size separation and source fabrication are classified as dry and dusty operations. Operations listed in item (5) are normally reserved for A-type and B-type laboratories.

References

1. "Safe Handling of Radio-isotopes," published by The International Atomic Energy Agency, Karntner Ring, Wien I, Austria, 1958.

2. ORNL Health Physics Manual, A-5.3.