ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

Carbon-14

Radiological Safety Guidance

Revision Date: 09/27/18

Physical Data

BETA ENERGIES
• 156.4 keV (maximum)
• 49.5 keV (average) (100%)

Physical Half-Life	5730 years
Biological Half-Life	10 days (Whole Body)
Effective Half-Life	10 days (Bound/Whole Body)
Effective Half-Life	40 days (Unbound/Bone)
Specific Activity	4460 millicuries/gram
Maximum Beta Range in Air	25.400 cm = 10.0 inches
Maximum Beta Range in Water/Tissue*	0.030 cm = 0.012 inches
Maximum Range in Plexiglas/Lucite/Plastic	0.025 cm = 0.010 inches

*Fraction of C-14 beta particles transmitted through dead layer of skin (0.007 cm) = 17%

Shielding

None required (≤ 3 mm plexiglass)

Half-Value Layer (Water)	0.005 cm = 0.05 mm

Tenth-Value Layer (Water)	0.017 cm = 0.17 mm

Volatility

- Inherent Volatility (STP) is **Not Significant**

Exposure: Radiological Safety Information

There are three main classes of carbon compounds which may be inhaled: organic compounds, gases (CO or CO2), and aerosols of carbon containing compounds such as carbonates and carbides.

Exposure Rates

Dose Rate from a 1.0 millicurie isotropic point source of C-14:

DISTANCE	RAD/HOUR
1.0 cm	1241.4
2.0 cm	250.4
15.2 cm	0.126
20.0 cm	0.0046

Exposure Prevention

- **Always** wear a lab coat and disposable gloves when working with C-14.
- Possibility of organic C-14 compounds being absorbed through gloves.

Administrative Controls

- Care should be taken **not** to generate CO_2 gas that could be inhaled.

Regulatory Compliance Limits (10 CFR 20/Appendix B)

REGULATION	UNIT OF MEASURE	NOTE
Derived Air Concentration (DAC): Occupational	1.0E-6 uCi/mL (labeled compound) 9.0E-5 uCi/mL (carbon dioxide) 7.0E-4 uCi/mL (carbon monoxide)	
Airborne Effluent Release Limit	3.0E-9 uCi/mL (labeled comp'd) 3.0E-7 uCi/mL (carbon dioxide) 2.0E-6 uCi/mL (carbon monoxide)	Applicable to the assessment and control of public doses (10 CFR 20.1302). If this concentration was inhaled or ingested continuously over 1-year would produce a TEDE of 50 millirem.
Urinalysis	Not required	However, may be requested by RSS personnel after a C-14 radioactive spill or suspected intake.
Unrestricted Area Removable Contamination Limit	1,000 dpm/100 cm^2	
Container Labeling Quantity (10 CFR 20.1905)	> 1,000 uCi	

Annual Limit on Intake (ALI)

- Ingestion: 2 mCi (ingestion: labeled organic comp'd)
  - 1.0 ALI = 2 mCi (ingested C-14 organic comp'd) = 5,000 mrem CEDE
- Inhalation:
  - 2000 mCi (inhalation: carbon monoxide)
  - 200 mCi (inhalation: carbon dioxide)

Contamination

Radiological Data

Critical Organ	Fat Tissue
Routes of Intake	• Ingestion • Inhalation • Puncture • Wound • Skin Contamination (Absorption)
External exposure (deep dose) from weak C-14 beta particles is not a radiological concern.	
Internal exposure and contamination are primary radiological concerns.	Committed Dose Equivalent (CDE): (Fat Tissue) • 2.08 mrem/uCi Committed Effective Dose Equivalent (CEDE) • 2.50 mrem/uCi (ingestion)

Skin Contamination (C-14)

- Skin contamination, ingestion, inhalation, and puncture are primary concerns (potential internal doses).
- Skin Contamination Dose Rate: 1055 mrem/hour per 1.0 uCi/cm^2 (without air reflection)
  * (Localized Basal Cell Dose at 7 mg/cm^2 or 0.007 cm depth in tissue)
- Immersion in C-14 Contaminated Air = 2.183E7 millirem/year per uCi/cm^3 at 70 um depth of tissue and 4.07E6 millirem/year per uCi/cm^3 value averaged over dermis.

Internal Contamination

- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3-times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- Organic Compounds - most organic compounds are NOT very volatile under normal circumstances and the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

- Gases - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO2 in the blood exists mainly as a bicarbonate.
- Carbonates and Carbides - It is assumed that inhaled or ingested C-14 labeled compounds are instantaneously and uniformly distributed throughout all organs and tissues of the body where they are retained with a biological half-life of 40 days.

Detect Contamination

Survey Instrumentation

- Monitor for removable surface contamination by smearing, swabbing, swiping, or wipe testing where used and counting in a liquid scintillation counter.
- Slowly monitor your hands, shoes, clothing and work area using a G-M survey meter for gross C-14 contamination (3% counting efficiency).
- Can detect C-14 using a survey meter equipped with a G-M pancake/frisker (15.5 cm^2 surface area); however, the survey meter probe **must** be at a very close range (≤ 1 inch).
- G-M survey meters have very low counting efficiency for C-14 (3%).
- Liquid scintillation counter (indirect counting) should be used to detect removable C-14 contamination on smears, swipes, swabs, etc.
- Typical liquid scintillation counter counting efficiency for C-14 (full window/maximum) ~ 95%.

Required Personal Radiation Monitoring

Dosimeters (Whole Body Badge or Finger Tabs): Not Needed (beta energy too weak).