BIOASSAY GUIDELINE 2

GUIDELINES FOR TRITIUM BIOASSAY

Report of the Working Group on
Bioassay and *In Vivo* Monitoring Criteria
to the
Federal-Provincial Advisory Committee on
Environmental and Occupational Health

Environmental Health Directorate
Health Protection Branch

Published by authority of the
Minister of National Health & Welfare

81-EHD-

FOREWORD

This Guideline is one of a series under preparation by the Federal-Provincial Working Group on Bioassay and *In Vivo* Monitoring Criteria. This Working Group was formed under the auspices of the Federal-Provincial Conference of Deputy Ministers of Health, through the Advisory Committee on Environmental and Occupational Health and the Subcommittee on Radiation Surveillance. The terms of reference include a mandate to prepare a series of documents which elaborate criteria for bioassay programs, to be presented as recommendations to the Atomic Energy Control Board. In order to obtain a broad representation, the membership includes experts from federal and provincial governments, universities and industry (Appendix A). Membership may change slightly depending on the radionuclides under discussion.

Guidelines and criteria for specific radionuclides are based on the best available metabolic and dosimetric models. If new information that will significantly affect the guidelines becomes available, the documents will be updated. Comments and views from interested persons and agencies should be addressed to the co-chairmen.

TERMINOLOGY

The following definitions are applied to the terminology used in this guideline. Where possible, definitions are based on International Commission on Radiological Protection (ICRP) terminology as applied in ICRP Publication 26(1). For a complete understanding of the terminology, "General Criteria for Bioassay Programs" (2) should be read in conjunction with all guidelines for specific radionuclides. Abbreviations for some of the terminology differ slightly from those in the general guideline in keeping with the latest ICRP recommendations.

Internal Exposure:

-the exposure resulting from a source of radiation inside the body.

External Exposure:

-the exposure resulting from a source of radiation outside the body.

Committed Dose Equivalent ($H_{50,T}$):

-the dose equivalent that will be accumulated by an organ or tissue, T, over 50 years, following a single intake of radioactive material.

Effective Dose Equivalent (H_E):

-sum of the weighted dose equivalents to various organs or tissues:

$$H_E = \sum_T W_T H_T$$ where the weighting where the weighting factors W_T are as given in ICRP 26(3)

Committed Effective Dose Equivalent:

-the sum of the weighted dose equivalents to various organs or tissues that will be accumulated over 50 years following a single intake of radioactive material:

$$H_{50,E} = \sum_T W_T H_{50,T}$$

Annual Limit on Intake (ALI) for Occupational Exposure:

-the intake in any year of a radionuclide which will result in neither either a committed effective dose equivalent to reference man more than of 50mSv* nor or a committed dose equivalent in any organ or tissue more than of 500 mSv.

Derived Air Concentration (DAC):

-the concentration of any radionuclide in air that if breathed by reference man for a working year of 2000 hours under conditions of light activity, would result in an ALI by inhalation (4):

$$DAC = ALI / 2.4 \times 10^3 \text{ Bq m}^{-3}$$

*1Sv = 100 rem

Note: For tritium gas the DAC is limited by the dose-equivalent rate in the lung and is not derived from the ALI. In this document HT will be used to denote all forms of tritium gas i.e., HT, DT and T_2.

Bioassay:

-the estimation of internal contamination by the measurement of radioactivity in excreta, other biological samples, or by direct in vivo measurement.

Intake:

-the amount of radioactive material entering the nose, mouth, wound or absorbed through the skin.

Retention Function:

-a mathematical expression of the variation with time of the amount of radioactive material remaining in the body or a specified tissue or organ following an intake. The retention of a radionuclide in an individual must be measured during a period when no further intake occurs in order to determine the retention function.

Investigation Level:

-the value of intake that warrants investigation as described by ICRP 26 (5). For a

routine bioassay program, the investigation level must be set in relation to a single measurement and not the intake in a year. Thus the investigation level is set at $\frac{0.3\ ALI}{f}$, where f is the number of times per year that the individual measurement is made.

How can the intake per year always be calculated from a single measurement? Should these investigation levels in quantity be expected based on ICRP 10A?

Derived Investigation Level (DIL):

-the value of the measurement under consideration, based on reference man and accepted metabolic and dosimetric models, that corresponds to the investigation level.

good.

It is noted that words, "may, might, shall and should" as used in the text have been selected with purpose and are intended to convey the following meanings;

May:

-permissible without compromising the objectives of the criteria

Might:

-statement of possibility of occurrence--no normative connotation

Shall:

-essential to the objectives of the criteria

Should:

-desirable and recommended but not necessarily or always essential to the objectives of the criteria

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1. INTRODUCTION

Tritium (^3H) is the only radioactive isotope of hydrogen. It has a radioactive half-life of 12.3 years and decays to ^3He by the emission of a low energy beta particle. These particles have a maximum energy of 18.6 keV, an average energy of 5.7 keV and a maximum range in tissue of less than 6 μm. Because of this short range, tritium does not constitute a radiation hazard unless it enters the body. The low energy of the beta particles and the lack of photon emission precludes the use of in vivo monitoring, and requires the measurement of tritium in body fluids or excreta. Urine is most commonly used.

The dose rate to an organ or tissue T containing tritium is expressed by the following equation:

$$\dot{H}_T = 1.4 \times 10^{-8} \varepsilon C_T(t) \qquad [1]$$

where $\dot{H}_T$ = the dose rate (Sv d^{-1}) to organ or tissue T

ε = the effective energy per disintegration = 0.0057 MeV

$C_T(t)$ = the tritium concentration (Bq kg^{-1}) in organ or tissue T

The committed dose to organ or tissue T is expressed by the equation:

$$H_{50,T} = 7.9 \times 10^{-11} \int_0^{50\ years} C_T(t)\,dt \qquad [2]$$

and the committed effective dose is

$$H_{50,E} = \sum_T W_T H_{50,T} \qquad [3]$$

where W_T are the weighting factors recommended by the ICRP(3).

In this report tritium compounds have been grouped into four categories for the purpose of calculating Annual Limits on Intake (ALI) and Investigation Levels (IL): tritium gas, tritiated water, tritium-labelled compounds and nucleic acid precursors.

Persons using this guideline are warned that except for tritiated water, there is considerable uncertainty associated with these values and with the retention functions used in the calculations. Therefore in the event of a significant intake, extra effort should be made to determine the individual's retention function as a basis for dose assessment.

1.1 Tritium Gas (HT)

The ICRP has recently recommended that only the dose to the lung from HT in the air in the lungs need be considered[6], and has calculated a Derived Air Concentration (DAC) of 2×10^{10} Bq m^{-3}(6). This concentration would result in a lung dose of 0.42 Sv a^{-1} to reference man, (0.05 Sv effective dose) assuming a working year of 2000 hrs. This DAC is a factor of about 10^4 that for tritiated water (HTO, DTO, T_2O) and consequently, when HT is converted to HTO either inside or outside the body, the dose from HTO may become limiting.

When tritium is observed in the urine of individuals working

with HT, and if the HT/HTO ratio in air is unkown, it must be assumed that a significant exposure has occurred and an immediate investigation shall be initiated. The concentration of tritium in urine shall be used to calculate the dose to tissues and organs other than the lung by assuming the exposure was to HTO.

1.2 Tritiated Water (HTO)

Tritiated water, whether inhaled, ingested or absorbed through skin, is assumed to be immediately and completely mixed with the total body water, although this may take as long as 4 hours (7). This tritium is then assumed to be excreted with an effective half-life of 10 days (8). Since the concentration of tritium in urine has been shown to be equal to that in body water, the dose rates to these two fluids are equal.

With the above assumptions, the committed effective dose is expressed by the following equations:

$$H_{50,E} = 7.9 \times 10^{-11} C_o \int_0^{50\ \text{years}} e^{-\lambda t}\, dt \qquad [4]$$

$$= 1.1 \times 10^{-9} C_o \text{ Sv}$$

where C_o = the initial concentration of ^3H in soft tissue (Bq kg^{-1})

and $\lambda = \frac{0.693}{10}\ d^{-1}$

The initial concentration of ^3H in soft tissue may be obtained by dividing the intake by 63 kg (63 kg is the mass of

soft tissue for Reference man (9)).

Hence the committed effective dose per Bq intake is

$$1.8 \times 10^{-11} \text{ Sv}$$

and the ALI is

$$2.8 \times 10^{9} \text{ Bq}$$

which may be rounded to

$$3 \times 10^{9} \text{ Bq}.$$

If the urinary concentration is used to estimate C_o, the measured urinary concentration should be multiplied by 42/63 (42 kg is the mass of body water for Reference Man (9)).

1.3 Tritium-labelled Compounds (TLC)

Tritium-labelled compounds, excluding nucleic acid precursors, may have a shorter retention than HTO (8). However, since much of the tritium may be in exchangeable sites, and since the compounds may be catabolized, it is assumed here that they have the same distribution, retention, and excretion as HTO.

1.4 Nucleic Acid Precursors (NAP)

Nucleic acid precursors generally have a longer retention than HTO although much of the tritium may be in exchangeable sites, or be catabolized (8). However, since work with NAP often involves specific labelling at non-exchangeable sites, and since

these compounds may have a less uniform distribution than HTO, it is recommended that an ALI equal to 1/10 that for HTO be used. This factor arises from an assumed effective half-life 5 times greater and a target tissue with a mass one-half that used for HTO. These values were chosen after review of ICRP 23 (9) and NCRP 63 (10).

2. REQUIREMENT

2.1 Conditions Where Bioassay is Required

Bioassay measurements shall be required for any individual who is occupationally exposed to tritium under conditions where:

a) the total annual dose might exceed 0.3 of the annual limit and the individual may receive an intake in excess of 0.1 ALI listed in Table 1; or

b) respiratory or other protective equipment is required to limit intake; or

c) the quantities handled are in excess of those listed in Table 2 unless it can be demonstrated that significant intake has not occurred; or

d) significant intake of tritium might result because of loss of control even though the quantities involved are less than those listed in Table 2.

Tritium gas is a special case. Since the dose from HT cannot be estimated by bioassay procedures it must be calculated from air sampling data. Therefore air monitoring shall be performed at any workplace where the average air concentration

Table 1: Annual Limits of Intake (ALI) and Derived Air Concentrations Used in this Guideline

Form	ALI (Bq)		DAC (Bq m^{-3})
	Oral	Inhalation	
HT	--	--	2×10^{10}
HTO	3×10^{9}	3×10^{9}	8×10^{5}
TLC	3×10^{9}	3×10^{9}	8×10^{5}
NAP	3×10^{8}	3×10^{8}	8×10^{4}

Table 2: Activity of Tritium (Bq) Handled Which Require Bioassay**

Type of Containment	Chemical Form			
	HT**	HTO	TLC	NAP
None				
per experiment	3.0×10^{10}	3.0×10^{10}	3.0×10^{11}	3.0×10^{10}
per 2 weeks	3.5×10^{9}	3.5×10^{9}	3.5×10^{10}	3.5×10^{9}
per month	7.5×10^{9}	7.5×10^{9}	7.5×10^{10}	7.5×10^{9}
per quarter	2.3×10^{10}	2.3×10^{10}	2.3×10^{11}	2.3×10^{10}
Fumehood				
per experiment	6.0×10^{10}	6.0×10^{10}	1.5×10^{12}	1.5×10^{11}
per 2 weeks	7.0×10^{9}	7.0×10^{9}	1.7×10^{11}	1.7×10^{10}
per month	1.5×10^{10}	1.5×10^{10}	3.7×10^{11}	3.7×10^{10}
per quarter	4.5×10^{10}	4.5×10^{10}	1.1×10^{12}	1.1×10^{11}
Glove Box or Sealed System				
per experiment	3.0×10^{12}	3.0×10^{12}	3.0×10^{13}	3.0×10^{12}
per 2 weeks	3.5×10^{11}	3.5×10^{11}	3.5×10^{12}	3.5×10^{11}
per month	7.5×10^{11}	7.5×10^{11}	7.5×10^{12}	7.5×10^{11}
per quarter	2.3×10^{12}	2.3×10^{12}	2.3×10^{13}	2.3×10^{12}

← Suppose the experiment takes 2 weeks ?

*See Appendix D for explanation and derivation.

**This assumes that no air monitoring for HT or HTO is performed and that all HT may be converted to HTO. If air monitoring is performed, refer to Section 2.1 of the text to see under what conditions bioassay will not be required. If the responsible radiation protection personel judge that complete conversion to HTO cannot occur the activity requiring bioassay may be increased by an appropriate amount.

Appendix D gives a model for predicting air concentrations of HT.

of HT during periods of occupancy in a year might exceed 0.1 DAC. However, if air monitoring cannot distinguish between HT and HTO, then the following actions shall be taken even if HTO is thought not to be present.

a) If the average air concentration (HT and/or HTO) during occupancy is between 0.1 and 1.0 DAC for HTO diagnostic bioassay measurements for HTO will be performed to ensure that doses from HTO will not exceed 0.1 of the annual dose limit.

b) If the average air concentration (HT and/or HTO) during occupancy is above the DAC for HTO a bioassay program for HTO shall be established.

Don't think a bit redundant?

If air monitoring can distinguish between HT and HTO, a bioassay program for HTO shall be established if the average air concentration of HT during occupancy exceeds 10 DAC for HTO, regardless of how low the measured air concentration of HTO may be.

2.2 Conditions Where Bioassay is Not Required

Bioassay measurements are not normally required if any of the following conditions exist:

a) the tritium is in a sealed container;

b) the tritium is in a chemical or physical form that is non-dispersible and cannot be absorbed through the skin. Tritiated foils and targets are excepted

because experience has shown that use of these materials can result in significant intakes from absorption through the skin or release of particulate and gaseous tritium (11,12).

c) workplace monitoring identifies conditions where intakes exceeding 0.1 ALI are most unlikely.

2.3 Pre-operational Measurements

Pre-operational or baseline measurements are not normally required for tritium but may be desirable when the individual's exposure history is unknown.

2.4 Post-operational Measurements

Post-operational measurements where required, as outlined in Section 2.1, shall be made as soon as practicable but within two weeks of possible exposure to tritium and not before equilibrium in the blood and urine has been established (at least 4 hours) (7).

2.5 Women of Reproductive Capacity

There is a possibility that a woman of reproductive capacity may be unknowingly pregnant. However, providing that the radiation dose to the abdomen, i.e. the fetus, is received at a regular rate and the investigation level, $\frac{0.3\ ALI}{f}$ is not exceeded, the dose in any given month will not exceed 1.25 mSV, $(\frac{0.3 \times 50}{12})$. The increased risk to the fetus from this amount of radiation is small when compared with the normal incidence of

malformations and cancers in the general population. It is therefore considered unnecessary to set separate dose limits for women of reproductive capacity.

2.6 Pregnant Women

Once a pregnancy is diagnosed, the woman should only be permitted to work in areas meeting the criteria for Working Class B as defined by the ICRP (13) i.e. in areas where it is most unlikely that the annual exposures will exceed 0.3 of the dose equivalent limits.

3. ACCURACY, FREQUENCY AND SENSITIVITY

The accuracy, frequency and sensitivity requirements for a bioassay program depend on whether or not bioassay is the only method available for detecting intakes. The accuracy required in calculating the committed dose is set out in Bioassay Guideline 1(2). This requirement can be met easily for HTO exposure where the distribution and retention are well-known but cannot be assured for other tritiated compounds.

3.1 Sensitivity

The sensitivity required for measuring tritium in urine shall be better than 4×10^3 Bq L^{-1}. This level can easily be achieved with a standard liquid scintillation counter.

3.2 Frequency for HTO

Appendix C to these Guidelines shows that the accuracy requirements for HTO dose calculations can be met if urine samples are obtained twice a month (f=26) and if a single sample does not exceed a concentration of 2.0×10^5 Bq L^{-1}. If a urinary concentration is above this level, weekly (f=52) samples shall be obtained until the concentration falls below it to ensure that the dose can be estimated with sufficient accuracy.

When the frequency of bioassay is not set by the accuracy requirements given above at least one person in each working area shall be monitored once per week and all persons shall be monitored each month (f=12). If any one person has a urine concentration greater than 4×10^3 Bq L^{-1}, all persons who have been working in the area shall be requested to submit samples for analysis within one week of the high sample. If it has been demonstrated that air monitoring can detect significant intakes (>0.1 ALI in a year), bioassay shall be required only after the occurrence of air concentrations corresponding to intakes in excess of the above amount.

3.3 Frequency for TLC and NAP

Exposure conditions that result in the routine excretion of TLC or NAP would be unacceptable as these compounds are not very volatile. Any sample containing tritium above the sensitivity requirement shall require further investigational samples to

estimate the committed dose.

4. Investigations and Actions

4.1 Investigation Level

As specified in the General Guidelines (2), the investigation level is set at $\frac{0.3\ ALI}{f}$ where f is the number of measurements per year as defined in section 3.1. This expression implies that as the time interval between measurements decreases, the fraction of the annual limit on intake that can be ingested or inhaled in the period between the measurements also decreases.

Since it must be conservatively assumed that any tritium observed in urine originates from an intake occuring immediately following the previous measurement, the effective half-life of the tritium must be taken into account when calculating the derived investigation level. Table 3 shows the calculated DIL for measurements made at 7 day, 14 day and 1 month intervals, where the urine concentration corresponding to an intake of 0.3 ALI within 24 hours is 13.20 MBq L^{-1} after equilibrium with the soft tissue is reached, but before any excretion occurs (Appendix C).

Table 3

Interval	$\frac{1}{f}$	Half-life Correction Factor	Total Correction Factor	Derived Investigational Level kBq/L	Derived Action Level MBq/L	Derived Emergency Level MBq/L
7 days	.019	0.62	.012	240	41	200
14 days	.038	0.38	.014	280	25	130
1 month	.083	0.12	.010	200	7.9	40

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Thus for practical purposes, for frequencies of 12 measurements a year or more, a DIL of 200 kBq L^{-1} would be appropriate.

At this level the steps listed in the General Guidelines, section 8, shall be followed i.e.:

1. Confirm the results;

2. Determine when the intake occurred;

3. Check the working conditions for faults and ascertain whether others could have been exposed.

Investigations should also be made when any unexpected result is observed, e.g., when results show a significant deviation from the past average, or when results are inconsistent with air or surface monitoring results.

4.2 Administrative Control Level

It may be useful to define a control level different from the DIL but below the Action Level (defined below) for administrative or dose control purposes.

4.3 Action Level

Based on a committed dose of 50 mSv from a single intake, urine levels corresponding to action levels for f = 12, 26 and 52 are given in Table 3. When the action level is exceeded, one may wish to consider therapeutic action to increase water turnover (14). A physician should be consulted before any therapeutic action is undertaken.

Other actions shall be as listed in the General Guidelines (2), section 8. i.e.:

1. Protect the individual from any further intakes;

2. Protect the individual from any further external exposure;

3. Determine retention function, using a suitable sampling schedule;

4. Determine total accumulated dose from both internal and external sources, and add the committed dose based on present measurements. If this total exceeds the annual dose limit then the Atomic Energy Control Board shall be informed (15). If not, then the individual may resume normal duties.

4.4 Emergency Level

Based on a committed dose of 250 mSv from a single intake, urine levels corresponding to emergency levels are given in Table 3. Above these levels, therapeutic measures should be considered in consultation with a physician. Other actions shall be as listed in the General Guidelines, Section 9, i.e.:

1. Remove the individual from work immediately;

2. Notify A.E.C.B. or designated officer (15);

3. Determine the retention function using daily samples;

4. Calculate total dose as in section 4.3.4;

5. DOCUMENTATION

The following information shall be documented in sufficient detail that the adequacy of the bioassay program, and the committed dose estimates based on bioassay measurements, can be re-evaluated at a later date:

a) Methods and Equipment:
Details of sampling and analytical procedures including equipment used shall be recorded and updated as changes are made.

b) Dose Calculations:
Whenever bioassay measurements are used to estimate dose, details of the calculation shall be recorded. A recommended method is given in Appendix B.

c) Quality Assurance:
Details and results of both internal and external quality assurance programs shall be recorded.

d) Chemical Form:
In view of the paucity of data concerning the metabolic and biological half-life of many compounds of tritium, the chemical form of the material should be recorded.

e) Other:

All other relevant information shall be documented.

6. RECORDS

Records of individual bioassay measurements (date and concentration), estimated committed doses and program audits shall be kept until disposal is authorized by the appropriate government agency. The bioassay results should be made available to the Radiation Protection Bureau as requested for inclusion in the National Dose Registry.

REFERENCES

1. ICRP Publication 26, 1977. Annals of the ICRP, Vol. 1, No. 3. Recommendations of the International Commission on Radiological Protection (as amended in ICRP publication 28, (1978)). Pergamon Press, Oxford.

2. Bioassay Guideline 1, 1980. General Guidelines for Bioassay Programs. 80-EHD-56.

3. ICRP Publication 26, para. 105.

4. ICRP Publication 30, Part 1, 1979. Annals of the ICRP, Vol. 2, No. 3/4. Limits for Intakes of Radionuclides by Workers, p. 9.

5. ICRP Publication 26, para. 178.

6. ICRP Publication 30, Part 1, 1979. Section 8.2.1.

7. Osborne, R.V., 1966. Absorption of Tritiated Water Vapour by People. Health Phys. 12: 1527-1537.

8. ICRP Publication 30, Part 1, 1979. pp. 65-68.

9. ICRP Publication 23, 1975. Report of the Task Group on Reference Man. Pergamon Press, Oxford.

10. NCRP Report #63. Tritium and other Radionuclide Labeled Organic Compounds Incorporated in Genetic Material. NCRP Washington 1979.

11. Kocol, H., McNelis, D.N. and A.A. Moghissi, 1976. A Study of the Particulate and Gaseous Emissions of Tritium from Neutron Generator Targets. Health Phys. 31: 76-78.

12. Carlton W.H., Braselton W.E., Bransome E.D. 1975. Release of Radioactivity from a Scandium Tritide Electron Capture Detector Used in Gas Chromatography. Health Phys. 29: 411-413.

13. ICRP Publication 26 paragraph 161.

14. Norwood, W.Ø. 1975. Health Protection of Radiation Workers. p. 201. Charles C. Thomas, 153N 0-398-03291-2.

15. Atomic Energy Control Regulations 1974. SOR/DORS/74-334 Canada Gazette pt. II vol. 108 No. 12.

APPENDIX A

Members of Federal-Provincial Working Group on Bioassay and *In Vivo* Monitoring Criteria for Bioassay Guideline 2

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APPENDIX B

CALCULATION OF DOSES FROM ROUTINE BIOASSAY SAMPLES

This recommended method of dose calculation essentially follows that given in AECL-5507 (C1). It assumes that the monitoring frequency has been set as described in Appendix C.

The accumulated dose to time t_k represented by the last of a series of urine samples taken at times t_i that had concentrations C_i is, using the linear approximation

$$H_E = 7.9 \times 10^{-11} \sum_{i=0}^{k-1} \frac{(C_i + C_{i+1})\,(t_{i+1} - t_i)}{2}$$

where the C_i are in Bq kg^{-1} and the t_i are in days

The committed dose from time t_k is

$$H_{50,E} = 7.9 \times 10^{-11}\, C_k \int_0^{\infty} e^{-\lambda t}\, dt$$

$$= 1.1 \times 10^{-9}\, C_k$$

where a half life of 10 days has been chosen.

The sum of H_E for the year and $H_{50,E}$, and any other accumulated or committed doses, should be compared to the annual limit on dose for dose control purposes.

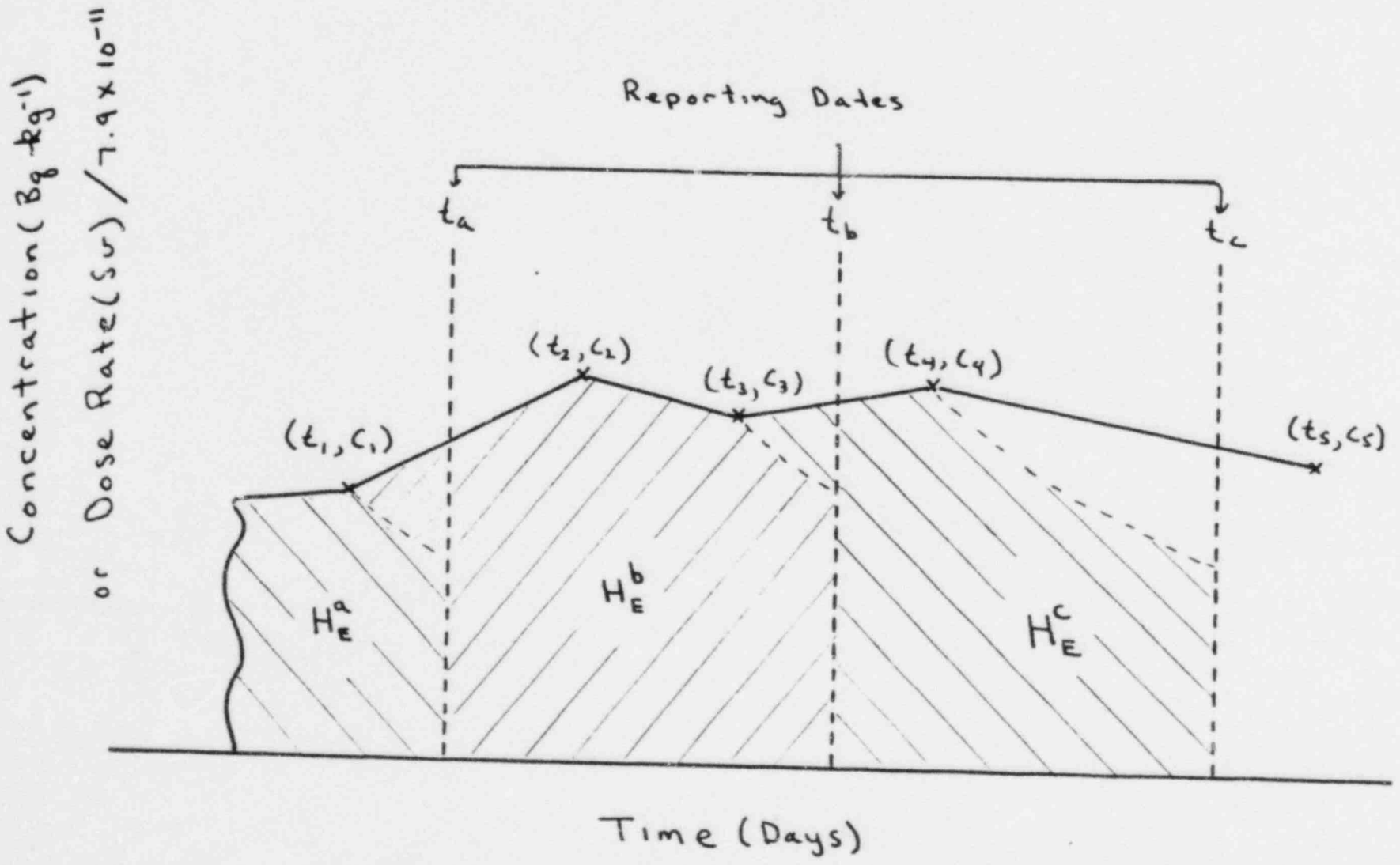
When accumulated doses are reported routinely for dose accounting purposes it is recommended that only the committed dose up to the reporting time be reported. With reference to Fig B-1, if t_a is a reporting time, then the dose reported at t_a will be the accumulated dose to t_1 and the dose between t_1 and t_a calculated by assuming a 10 day half life. Similarly, the dose accumulated between t_a and t_b is

$$H_E^b = 7.9 \times 10^{-11} \left[\frac{(C_1 + C_2)\cdot(t_2 - t_1)}{2} + \frac{(C_2 + C_3)(t_3 - t_2)}{2} + C_3 \int_0^{t_b - t_3} e^{-\lambda t}\, dt - C_1 \int_0^{t_a - t_1} e^{-\lambda t}\, dt \right]$$

The reporting of committed doses only up to the time of reporting is no different in principle from reporting committed doses to 50 years. However, if committed doses to 50 years were used it would be necessary to report a negative dose in all periods during which no intake of HTO had occurred if the individual measured half life was less than 10 days.

Figure B-1

Recommended Dose Calculating and Reporting Procedure



APPENDIX C

This appendix is based on, but not identical to, information given in a report by J.R. Johnson(C1), and a presentation by R.V. Osborne and J.R. Johnson(C2). The purpose of this appendix is to show that the dose from HTO exposures calculated by a linear interpolation between the concentration measurements of tritium in urine will result in doses that meet the accuracy requirements specified in Bioassay Guideline 1. This accuracy requirement states that the estimated dose must be within 50% of the 95% upper limit on dose, and if the annual dose is less than 0.02 Sv, an accuracy of 0.01 Sv at the 95% limits is sufficient.

Given two urine samples at t_1 and t_2 with concentrations C_1 and C_2 the linear interpolation dose is (see Introduction and Appendix B)

$$D_{lin} = \frac{KT\,(C_1 + C_2)}{2} \qquad C\text{-}1$$

$$K = 5.26 \times 10^{-11}\ \text{Sv kg Bq}^{-1}\ \text{d}^{-1}$$

$$T = t_2 - t_1$$

The maximum dose in this period would result if an acute exposure occurred immediately after t_1. This maximum dose would be

$$D_{max} = K\,C_2\,e^{\lambda T}\int_0^T e^{-\lambda t}\,dt \qquad C\text{-}2$$

Butler et al ( ) gives a range of values for retention from which the 90% confidence interval for halflives can be estimated to be 5.4 to 13.6 days. The 95% upper limit on D_{max} is therefore obtained by setting

$$\lambda = \lambda_{max} = \ell n(2)/5.4\ \text{d}^{-1}$$

The accuracy requirements stated above refer to doses received in a year, whereas D_{1in} and D_{max} refer to doses received in the period T. As it is highly unlikely that the maximum dose will occur in each of the 365/T periods in a year in a routine monitoring program, the accuracy requirements on the dose in any given period are relaxed. This relaxation is achieved by considering that, if only one urine sample was analysed in a year, the maximum dose, D_{max}, may have resulted, whereas if many samples were analysed in a year the likelihood of the D_{max} occurring in each of the periods between samples is small. In order to calculate a minimum frequency for bioassay samples, it is assumed that a single intake occurs at a random time between samples. Then the accuracy requirement is that the calculated dose should be within 50% at the 95% confidence level of the average dose between samples, D_A (see equation C-6 below) using $\lambda = \lambda_{max}$.

If the annual dose is projected to be below 0.02 Sv, then the calculated dose only needs to be within 0.01 Sv of the average dose D_A. The annual dose will be below 0.02 Sv if the urinary concentrations are all below 9×10^5 Bq kg^{-1}.

The inequalities that satisfy the accuracy requirements are then

$$\frac{D_A - D_{1in}}{D_A} \leq 0.5 \qquad \text{C-3}$$

if the annual dose is above 0.02 Sv, and

$$D_A - D_{1in} \leq 0.01\ T/365\ \text{Sv} \qquad \text{C-4}$$

if the annual dose is below 0.02 Sv.

Values of D_A are calculated as follows.

The dose in the period t_1 to t_2 from a single intake at time t ($t_1 \leq t \leq t_2$) is

$$D = KC_1 \int_0^t e^{-\lambda t}\, dt + KC_2\, e^{\lambda(T-t)} \int_t^T e^{-\lambda(t-t')}\, dt'$$

$$D = \frac{KC_1}{\lambda}\,(1 - e^{-\lambda t}) + \frac{KC_2}{\lambda}\,(e^{-\lambda(t-T)} - 1) \qquad \text{C-5}$$

If t is equally probable on the interval $t_1 \to t_2$, the average dose to a person over many intervals is

$$D_A = \frac{1}{T} \int_0^T D\, dt$$

$$= KC_1\,[1/\lambda - (1-e^{-\lambda T})/\lambda^2 T] \qquad \text{C-6}$$

$$- KC_2\,[1/\lambda - (e^{\lambda T}-1)/\lambda^2 T]$$

$(D_A - D_{1in})/D_A$ is plotted on Figure C-1 as a function of T, the time between samples for $C_1 = 0$; $C_1 = 0$ giving the largest difference between D_A and D_{1in}. While it is unlikely that $C_1 = 0$ for all periods unless C_2 is also zero, it will insure that the accuracy requirements are met for all values of C_2 if $(D_A - D_{1in})/D_A$ is below 0.5, or from the graph, if T is less than or equal to 14 days.

Values of C_2 ($C_1 = 0$) for which

$$D_A - D_{1in} = 0.01\ T/365 \qquad \text{C-7}$$

are plotted on figure C-2 as a function of time. If all measured

urinary concentrations are below this line inequality C-2 will be satisfied. In particular, if urinary concentrations are below 2×10^5 Bq kg^{-1}, a monitoring frequency of once a month (f = 12) will satisfy the accuracy requirements. ~ 5 μCi/l

References:

C1 Johnson, J. R. 1976 "Estimation, Recording, and Reporting of Whole Body Doses from Tritium Oxide Exposure at CRNL." AECL 5507

C2 Osborne, R. V., Johnson, J. R. 1979 "Problems in Estimating Effective Dose Equivalent from the Results of Bioassay for Tritium."

Presented at the Annual General Meeting of the Health Physics Society, Philadelphia, 1979.

APPENDIX D

RATIONALE FOR CONSTRUCTION OF TABLE 2

The following assumptions were used in obtaining the entries in Table 2, (D1):

1. Any intake that might occur under conditions of no containment would be reduced by the following factors when either a fumehood or closed system is utilized:

Compound	Reduction Factor	
	Fumehood	Closed System
HTO	2	100
NAP	5	100
TLC	5	100

2. The amount of material handled with no containment that could unknowingly be taken into the body.

   HTO: 1%

   NAP and TLC: 0.1%

3. For tritium gas, the concentration in a room is given by:

$$C = \frac{Xr}{\lambda V}\left[1-e^{-\lambda t}\right]$$

where C = air concentration (Bq/m^{-3})

X = total amount of tritium handled (Bq)

r = leak rate constant from tritium handling system (h^{-1})

V = volume of room (m^3)

λ = air change rate constant of room (h^{-1})

As an example: V = 100 m^3, λ = 2 changes/hour, and C = 0.1 DAC,

then at equilibrium

$$Xr = \lambda CV$$
$$= 4 \times 10^{11} \text{ Bqh}^{-1}$$

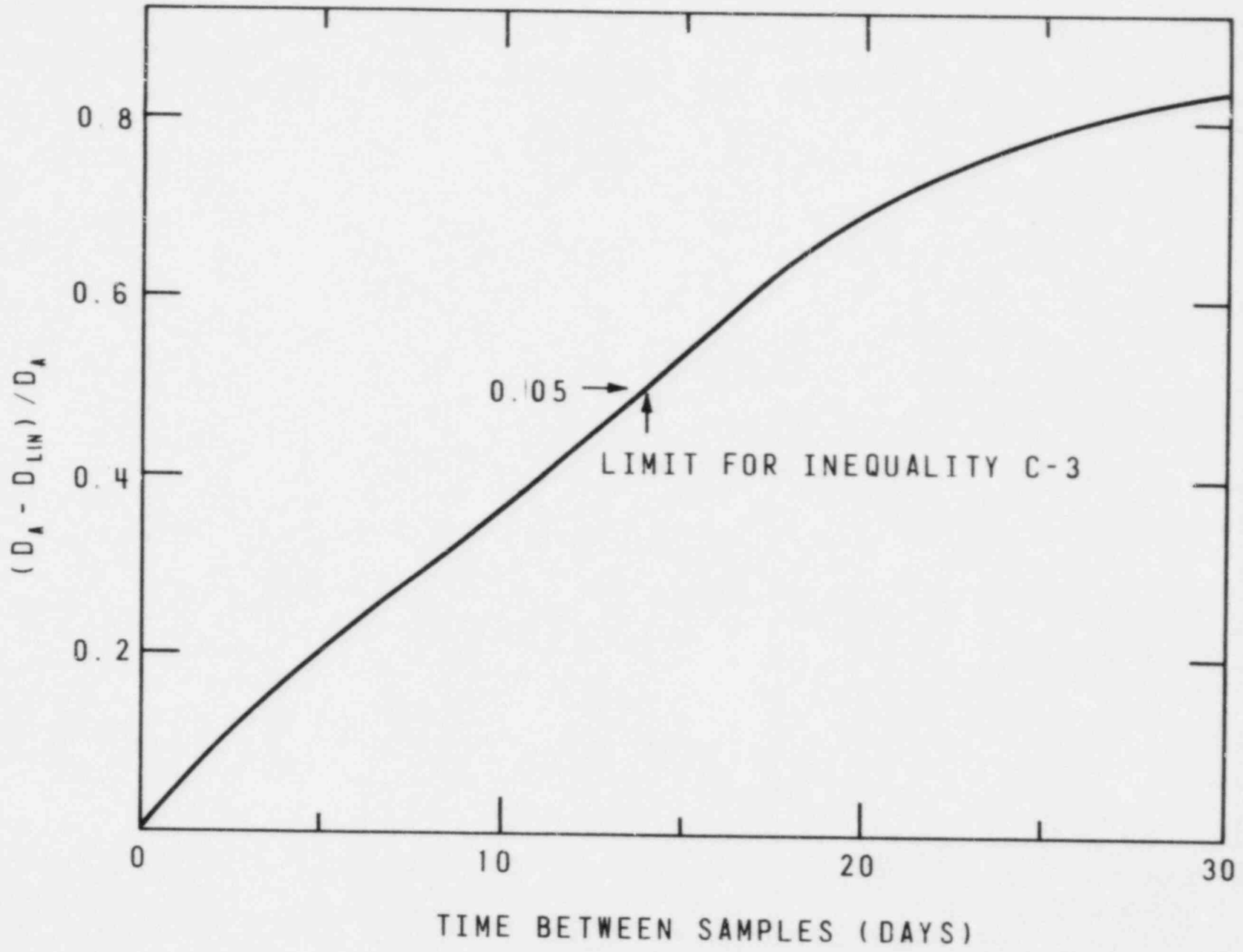
and if r is taken as 10^{-3} h^{-1} for a closed system

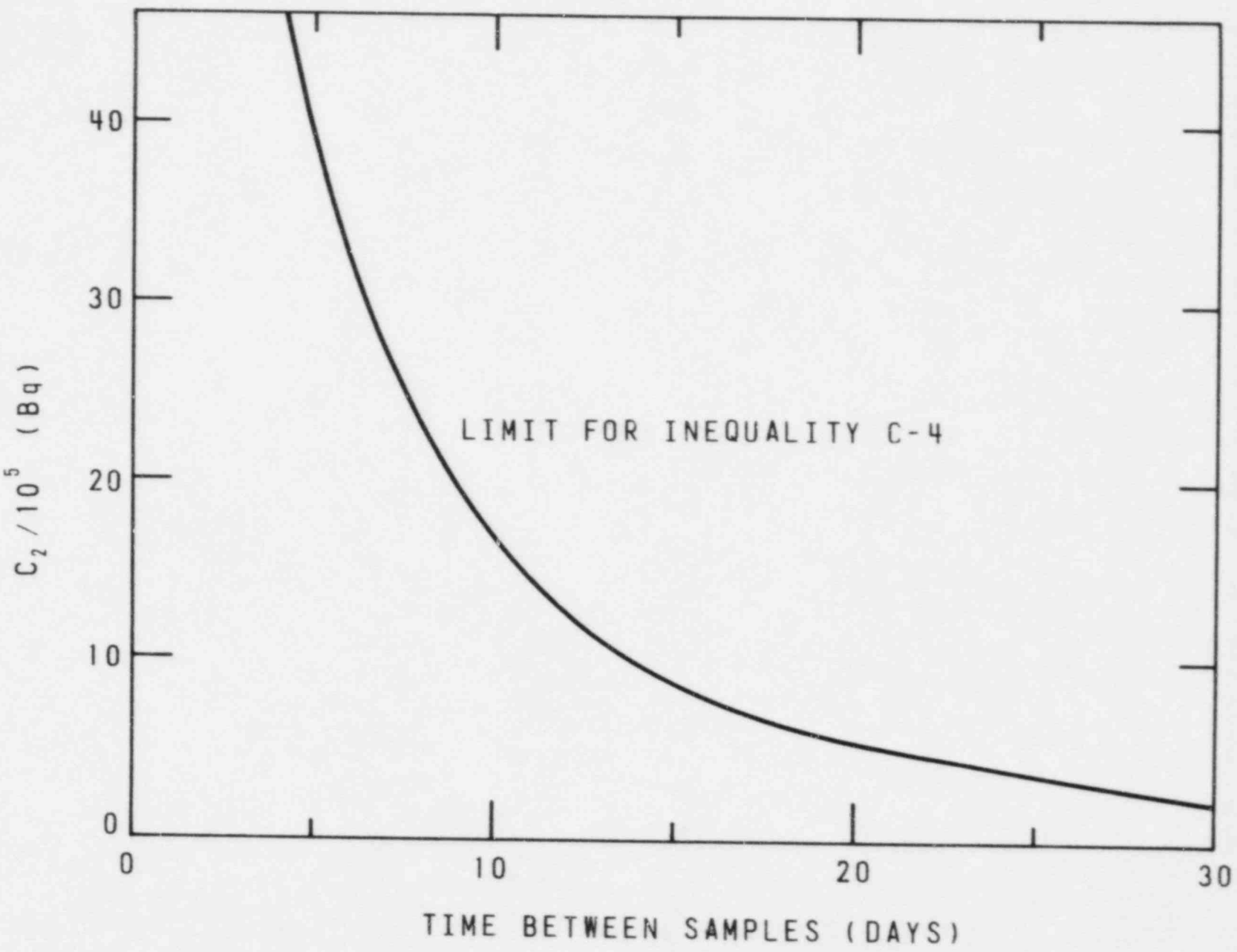
$$X = 4 \times 10^{14} \text{ Bq}$$

For a fumehood, r is taken as 10^{-2} h^{-1},
and for a bench top r is taken as 10^{-1} h^{-1}.

REFERENCES

D-1. Brodsky, A., 1977. Experiences with Intakes of Tritium from Various Processes. Health Phys. 33 : 94-98.


0.8
0.6
0.4
0.2
0
10
20
30
0.05
LIMIT FOR INEQUALITY C-3
$(D_A - D_{LIN}) / D_A$
TIME BETWEEN SAMPLES (DAYS)


40
30
20
10
0
$C_2 / 10^5$ (Bq)
LIMIT FOR INEQUALITY C-4
0
10
20
30
TIME BETWEEN SAMPLES (DAYS)