INDIANA UNIVERSITY

DEPARTMENT OF ENVIRONMENTAL HEALTH AND SAFETY
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FEE EXEMPT

March 4, 1987

Bruce Mallett, Ph.D.
Material Licensing Section
Region III
United States Nuclear Regulatory Commission
799 Roosevelt Rd.
Glen Ellyn, IL 60137

Dear Dr. Mallett

Re: Proposed Amendment to License 13-00108-05
Indiana University, Bloomington
Field Use of Byproduct Material

An experiment is proposed to study the physiological integration of Mayapple rhizomes utilizing Carbon-14. A total of 250 plants will be studied over a 3 year period using a maximum of 500 microcuries per plant. Therefore, a limit of 100 millicuries is requested for the entire field experiment.

The following information is pertinent:

1. Type and amount of material to be used:

   $^{14}CO_2$ will be released into polyethylene bag chambers surrounding shoots of the Mayapple plant. The ^{14}C will be transported in the form of Carbonate solutions in capped microcentrifuge tubes containing individual quantities of about 100 to 500 microcuries. The reaction will be initiated using an excess of lactic or phosphoric acid for about 30 minutes and will be stopped by adding an excess of NaOH to absorb the remaining $^{14}CO_2$.

2. Location of use

   A plan (attachment A) indicates the area for the experiment including the property lines.

3. Training and Experience of Individual using the Material

   The Responsible Investigator will be approved by the Radiation Safety Committee in accordance with the broad license issued to Indiana University. The Radiation Safety Officer will audit the procedures being used.

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4. Experimental Protocal

Experiments involving the release of $^{14}CO_2$ in sealed chambers will be conducted in the field. A separate chamber, designed as illustrated in Figure 1 (or an equivalent structure), will be constructed for each plant to be labeled on a given day. Before transporting the chambers to the field, appropriate aliquots of either Ba $^{14}CO_3$ or Na$^{14}CO_3$ will be pipetted, in the lab, into sealable centrifuge tubes within each chamber (one tube per chamber). The centrifuge tubes will be sealed and the chambers then will be placed in an insulated box, such as an insulated picnic hamper, that has been lined with absorbant paper. Dry ice will also be placed in the box to ensure that the label stays in solution during transport. The box will have some form of fasteners to further ensure that the radioactive material is contained. Once in the field, individual chambers will be removed from the container, as needed, and placed on plants as illustrated. At this time, the cap will be removed from the centrifuge tube in which the label is contained. The chambers will be secured and sealed. $^{14}CO_2$ will be released by adding an excess of l[illegible]tic acid to the centrifuge tube in the chamber, by pass[illegible] hypodermic needle through a small port in the chamber [illegible] the top of the tube. This port will be taped shut im[illegible]tely, to ensure that label is confined to the chamb[illegible] the end of the exposure period of about 30 minut[illegible] tape will be removed from the port and NaOH will be [illegible]ed into the tube in order to absorb any $^{14}CO_2$ sti[illegible]aining in the chamber. After approximately 10 more minutes, the chamber will be removed from the plant. The centrifuge tube will again be sealed and the whole chamber returned to the lab in the insulated box. In the lab, the material will be handled according to the guidelines for liquid radioactive waste.

5. Estimate of Releases in the Field

As indicated above, it is the intent to recover as much of the initial radioactivity as possible by removing the entire plants during the follow-up portion of the experiment. Further, the labeling phase will be conducted in a closed system and excess $^{14}CO_2$ will be absorbed as a carbonate and returned to the laboratory.

It is anticipated that no more than 20% of the introduced activity will actually be released either as $^{14}CO_2$ or as residual organic matter that will be converted to $^{14}CO_2$ by bacterial action.

6. The following calculations, using conservative assumptions, illustrate the maximum doses that could occur:

A. Assumptions

1. 1mCi release as $^{14}CO_2$ in 8 hrs
2. One hour of time the down wind plants in the sun are taking up CO_2 while the Mayapples are still expiring CO_2
3. Atmospheric conditions stable - little mixing
4. Edible plant uptake, 60 meters downwind
   - 45 day growing season
   - 16 hr uptake of CO_2 per day for 1 hr uptake of $^{14}CO_2$. The fraction of growing time exposed to CO_2 = 1/(45 x 16) = 1/720
5. A person inhales the $^{14}CO_2$ for 8 hrs -- also intake of 1/3 of annual carbon from the above crop

B. Atmospheric Diffusion

1. Ref: Hanna, Steven R., Briggs, Gary A., Hosker, Jr, Rayford P., "Handbook on Atmospheric Diffusion" DOE-TIC-11223 (1982)

2. Pg 25 assuming z=h=0 (ground level release)

   $C/Q=1/(\pi\ \sigma_y\ \sigma_z\ u)\ \exp[-(y/\sigma_y)^2/2]$

   where C=μCi/m^3 concentration at distance X

   $\sigma_y = 0.11X(1+0.0004X)^{-1/2}$ (Pg 30)

   $\sigma_z = 0.08X(1+0.00015X)^{-1/2}$

   (selected urban terrain, which is complex as is a wooded area, and stability factors E-F, most stable)

   μ= 0.5 m/s (Pg 25, quiescent conditions)

   X= 30 m (downwind position)

   Q= μCi/s release rate

3. Calculating for y=0

   σ_y= 3.28 m

   σ_z= 2.39 m

   $C/Q = 1/(\pi \times 3.28 \times 2.39 \times 0.5) = 0.0812$ s/m^3

   $Q = 1000 / (8 \times 3600) = 0.0347$ μCi/s

   $C = 0.0347 \times 0.0812 = 2.82E-3$ μCi/m^3

C. Weighted Committed Dose ^{14}CO inhalation

1. Ref: Annals of the ICRP Vol 7 No 1-3 (1982) pg 23 Derived Air Concentration (DAC) =3E6 Bq/m^3 based on 2000 hrs/yr exposure to yield committed dose equivalent of 5 rems (0.05 Sv)

2. Calculating

$$\frac{2.82E\text{-}3\,(\mu Ci)\;8(hr)\;3.7E4(Bq)\qquad(m^3)\;5(rems)}{(m^3)\qquad\qquad(\mu Ci)\;3E6(Bq)\;2000(hr)}$$

=7.0E-7 rems (7.0E-4 mrems)

D. Weighted Committed Dose ^{14}C ingestion

1. Ref: Annals of the ICRP Vol 7 No 1-3 (1982) Annual Limit on Intake (ALI) for organic compounds (Pg 18) 9E7 Bq (Oral) based on a committed dose equivalent of 5 rems

2. Ref: NCRP Report No 81, "Carbon-14 in the Environment" (1985) Pg 61 (Graph) Read 344 m^3 CO_2 per m^3 Air (Volume parts per million) in 1987

   Using 2.241E-2 m^3 of gas at STP per mole

$$\frac{344E\text{-}6(m^3\;CO_2)}{(m^3\;air)}\,\frac{12(g\;C)}{2.241E\text{-}2(m^3\;CO_2)} = 0.184\;g\;C/m^3\;Air$$

3. Ref: Annals of the ICRP Vol 6 No 213 (1981) Pg 4 Daily intake of carbon 300 g

4. Calculations

   a. Ratio of ^{14}C to stable C in air For 1 hr release/uptake period

$$\frac{2.82E\text{-}3(\mu Ci)\qquad(m^3)}{(m^3)\quad 0.184(g)} = 0.0153\;\mu Ci/g$$

   b. Concentration in food

$$\frac{0.0153}{720} = 2.12E\text{-}5\;\mu Ci/g$$

   c. Annual intake of ^{14}C from local produce

$$\frac{300(g)\;365(days)\;2.12E\text{-}5(\mu Ci)}{3\qquad(yr)\qquad(g)} = 0.774\;\mu Ci$$

   d. Dose

$$\frac{0.774(\mu Ci)\;3.7E4(Bq)\;5(rems)}{(\mu Ci)\;9E7(Bq)} = 1.6E\text{-}3\;rem$$

5. Adjustment for an Area Source

The above calculations were based on a point source, 30 meters from the property line. The actual areas as seen on the map are more like two ellipses, the larger of which has a major axis of about 320 meters and a minor axis of 160 meters with the closest distance from the perimeter to tillable land being 60 meters.

A computer program was used to assess Q/C values based on point sources distributed every meter throughout the elipse using the same diffusion model . This yielded an average C/Q of 6.62XE-4, a factor of 1/122 of the value in B.3, above.

The dose from ingestion therefore becomes

1.59E-3/122 = 1.3E-5 rem (0.013 mrem).

E. Comments

The above is an extreme calculation. A one mCi release is assumed at quiescent conditions from an area source to a "point" size garden. If 100 mCi is used in the experiment in a 3 year period, the total release will be about 7 mCi per year or about 4 mCi from the eastern site for which the calculations apply (closest to houses and tillable land). If it were all released under the above assumptions, the dose from ingestion is only 0.06 mrems per year.

More reasonable assumptions would assume a garden with dimensions, say 10 meters on a side, meandering winds over a 1 hour period, and uptake of ^{14}C by plants between the release and the garden. Release of CO_2 from decaying organic matter by bacterial action will occur over time. The longer time (months) provides winds in every direction and therefore more dilution for any one site. This latter source of CO_2 would be released, in part, during times of active photosynthesis. The only crops being grown near the site are animal feed crops, at this time, providing further dilution.

7. Attachment B is a letter from Professor Polley McClure and John Smith, joint owners of the land, giving permission for the experiment.

8. Attachment C is a letter from Hal S. Stocks, Chief, Radiological Health Section, Indiana State Board of Health indicating he has reviewed the proposal and concurs with our request.

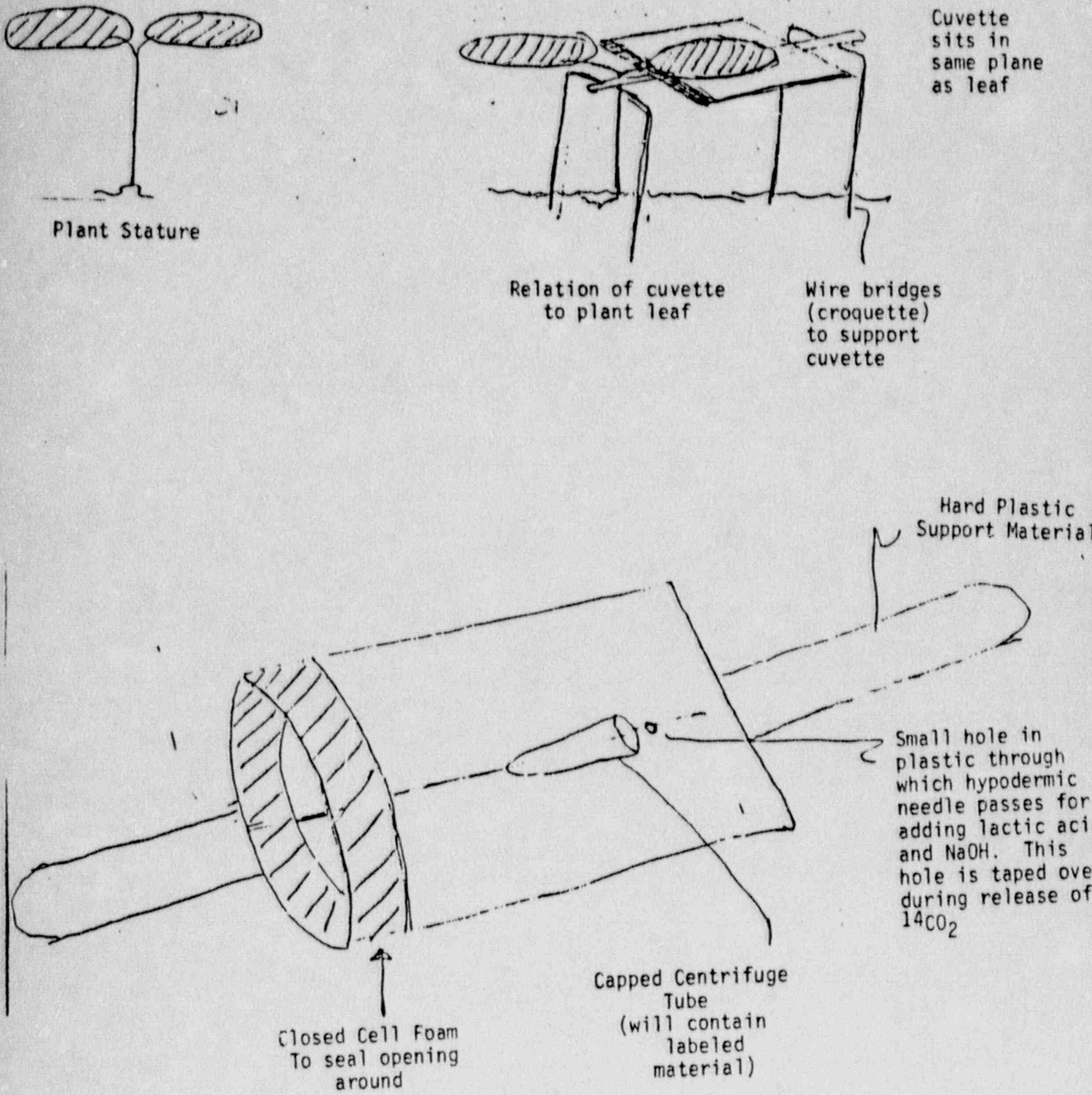
Very truly yours,

Henry C. Briggs

Henry C. Briggs,
Radiation Safety Officer

HCB:jlb

Figure 1



Plant Stature
Cuvette sits in same plane as leaf
Relation of cuvette to plant leaf
Wire bridges (croquette) to support cuvette
Hard Plastic Support Material
Small hole in plastic through which hypodermic needle passes for adding lactic acid and NaOH. This hole is taped over during release of $^{14}CO_2$
Capped Centrifuge Tube (will contain labeled material)
Closed Cell Foam To seal opening around

Attachment A