

G. W. Morgan, Chief, Advisory Field Service
Branch, Isotopes Division

January 10, 1949

Albert H. Holland, Jr., M.D., Director of Research and Medicine

WASTE DISPOSAL OF RADIOACTIVE MATERIALS BY OFF-COMMISSION USERS

MEMO TO
SPECIAL AGENT

In reviewing the Tentative Minutes of the Meeting on Waste Disposal of Radioactive Materials by Off-Commission Users, there are a few points which, in my opinion, are the basic premises which should be adopted and incorporated into the Commission's basic policy on this subject.

1. Paragraph 2 on page 3 embodies one of the fundamental ideas mentioned above, i.e., "...simplicity in methods of disposal is of prime importance..."
2. In Paragraph 4, "...it is (probably) a safe procedure to bury radioisotopes of any half-life, provided they are uniformly diluted to 4.15 curies per gram per day with stable isotopes of the same element and in the same chemical form."
3. The legal responsibility connected with the use of radioisotopes resides in the institution and the individual who signs the acceptance forms and to whom the material is formally allocated.

Motion II and Motion III probably represent the best consensus of opinion at the present time. It is suggested, however, that if these recommendations be published, they be specifically labelled as "interim procedures", subject to modification when and if more authoritative information is obtained.

With respect to the contents of Motion IV, it should be noted that, as stated earlier under the discussion of Carbon 14, it is extremely difficult to measure the activity of stack effluence. Secondly, I seriously question whether most users of Carbon 14 are equipped to monitor incineration equipment. The question of stack filtration of particulate matter is likewise somewhat nebulous since it is unlikely that many incinerators will be equipped with the proper type filters.

In view of the above, it is suggested that Motion IV be reviewed by the Committee in order to determine a more realistic set of criteria. In principle, I agree with those proposed in Motion IV but seriously question whether many isotope users can or will follow them.

Motion V is realistic and quite satisfactory. In any contemplated release

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C. W. Morgan

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REFER TO
SYMBOL: RM:AMH

on the information in Motion V, it is suggested that the words "suitably selected" in paragraph one of Motion V be further defined. This is not difficult, but merely means that at least somewhere in writing and in the official publications of the Isotopes Division the questions of high water table, soil drainage, proximity to drinking water supplies, and like matters are at least mentioned.

Albert H. Holland, Jr., M.D.

Holland/sga

UNITED STATES
ATOMIC ENERGY COMMISSION

Oak Ridge, Tennessee
October 15, 1948

Dr. A. H. Holland, Jr.
Medical Advisor
Oak Ridge Operations
Oak Ridge, Tennessee

Subject: REVIEW OF TENTATIVE MINUTES OF MEETING ON WASTE DISPOSAL
OF RADIOACTIVE MATERIALS BY OFF-COMMISSION USERS OF ISOTOPES

Dear Dr. Holland:

We are enclosing a copy of the tentative minutes on the September 20, 1948, meeting on disposal. These minutes were prepared in summary form by G. V. Morgan and N. H. Woodruff. They have attempted to credit the main points to the individuals who were primarily responsible for their introduction.

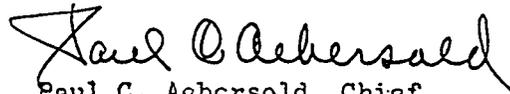
We should appreciate your reviewing these minutes, feeling free to make corrections, additions, or comments on the various points covered.

This office wishes to express its appreciation for your cooperation in participating in the meeting. We feel that these recommendations for the interim period will be very beneficial to the off-Commission users of radioisotopes, and to the various advisory groups.

Since we hope to formalize these recommendations in writing by December 1, please return them to this office by November 15.

With personal regards, I am

Yours very truly,


Paul C. Achbersold, Chief
Isotopes Division
Oak Ridge Operations

Encl.:
Minutes

OCT 15 1948
Rm-739

TENTATIVE MINUTES OF MEETING
ON
WASTE DISPOSAL OF RADIOACTIVE MATERIALS BY OFF-COMMISSION USERS
HELD ON
SEPTEMBER 20, 1948; U. S. A. E. C. BUILDING, WASHINGTON, D.C.

Those participating and voting were:

Dr. K. Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory
Dr. H. M. Parker, Director, Health Physics Division, General Electric Company, Hanford, Washington
Dr. L. F. Nims, Director, Division of Biology, Brookhaven National Laboratory
Dr. S. P. Cowan, Health-Physics Department, Brookhaven National Laboratory
Dr. J. E. Rose, Director, Division of Health Physics, Argonne National Laboratory
Dr. William F. Bale, Professor of Radiation Biology, University of Rochester
Dr. Hymer L. Friedell, Director, A.E.C. Medical Research Project, Western Reserve University
Dr. Edith Quimby, Presbyterian Hospital
Dr. Robley D. Evans, Massachusetts Institute of Technology
Dr. A. H. Holland, Jr., Medical Advisor, Oak Ridge Operations
Dr. Bernard Wolfe, Medical Advisor, New York Operations
Dr. Carl Braestrup, Consultant, New York Operations
Dr. Paul C. Acbersold, Isotopes Division, Oak Ridge Operations

Those also participating were:

From the Washington office, A.E.C.:

Dr. Spofford English, Division of Research
Dr. John Z. Bowers, Division of Biology and Medicine
Mr. Oliver H. Townsend, Office of Public Information
Mr. A. E. Gorman, Division of Engineering
Commander E. W. Hirbar, U.S.N., Office of Military Application
Major Maxwell Dauer, Office of Military Applications
Dr. J. H. Jensen, Division of Biology and Medicine

From Oak Ridge Operations, A.E.C.:

Dr. Harry G. E. Stoeckle, Jr., Division of Medicine and Research
Dr. N. H. Woodruff, Isotopes Division
Dr. G. W. Morgan, Isotopes Division

From Oak Ridge National Laboratory:

Mr. Ross Thackeray, Health Physics Department

A. Introduction

Dr. Nims, who agreed to serve as the chairman, initiated the discussion by explaining the purpose of the meeting. He pointed out the urgent need for practicable recommendations on the disposal of radioactive waste or unused materials by off-Commission users. He emphasized that: (1) The discussion should be limited to the immediate problems of off-Commission users, without consideration of the long-range disposal program; (2) Any recommendations developed during the meeting should be directed toward the problems contemplated for the next two years.

Dr. Kobersold pointed out that the Isotopes Division can give good advice on all phases of handling radioactive materials, except that of disposal. On the latter there appears to be wide variation of opinion, which has not yet been crystallized by a committee or a group such as the one now in session. He stated further that although this problem is not acute at present, some definite recommendations on disposal should be formulated to serve during the interim period, until a formal committee is established for this purpose. He emphasized that this meeting will not interfere with the work to be performed by the National Committee on Radiation Protection of the National Research Council. Any recommendations made by the present group could not in any case be expected to be "permanent," but would essentially be superseded by those made by the National Committee.

Dr. Taylor, Chairman of the National Committee on Radiation Protection, indicated the desirability of having the present group make recommendations on methods of disposal, in order to avoid conflicting advice now arising from the various sources. He stated that Dr. Warren, Director of Biology and Medicine, A.E.C., requested him to form a subcommittee to take over the responsibility of disposal; but since probably a year or year-and-a-half would elapse before recommendations would be forthcoming from the National Committee, it was decided to hold the present meeting to formulate recommendations to serve during the interim period. The reasons for this were: (1) immediate need for working recommendations; (2) desire to avoid conflicting advice, which would unduly confuse the off-Commission user; (3) the opinions expressed here would be valuable for the deliberations of the new subcommittee when formed.

B. General Problems of Disposal

Summary of discussion

Dr. Nims directed the attention of the group to Item 4 of the attached agenda. The following points were brought out in discussion:

1. The committee should try to set up limits on the maximum quantities of radioactive materials that may be disposed of in certain ways, as well as limits below which radioactive materials would not be classified as being "radioactive." These limits may not be ideal or permanent limits, but operating limits. (Nims)

2. It was emphasized that simplicity in methods of disposal is of prime importance, and that recommendations should not be set unnecessarily severe so that they will not be adhered to by the user. (Friedell and Evans)
3. There are certainly some safe limits for the disposal of any radioisotope. Assuming this, such limits should be established, particularly for P 32, I 131, and C 14, which constitute over 90 per cent of the activity distributed by the Isotopes Division. (Aebersold)
4. Attention was directed to the appendices and each was reviewed. Special emphasis was placed on Appendix 10, in which values are listed for representative radioisotopes indicating the required degree of dilution with stable element, water, and soil, to achieve a dissipation of 4.15 ergs per gram of dilutant per day. It was generally agreed that it is a safe procedure to bury radioisotopes of any half-life, provided they are uniformly diluted to 4.15 ergs per gram per day with stable isotopes of the same element and in the same chemical form.
5. On the question of whether 0.1 microcurie per liter of water is safe, it was indicated that although it would be difficult to set up strict rules for dilution of all radioactive isotopes, we should agree on levels for short half-life isotopes. (Aebersold and K. Z. Morgan)
6. It was pointed out that the British and Canadian projects do not agree entirely with our levels and tend to be in general more conservative.
7. On the question of discussing disposal recommendations with people who operate the sewer system, it was pointed out that discussion should come after some generally agreed upon recommendations are formulated by the present committee. (Gorman and Aebersold)
8. On the question of relative legal responsibility of the isotope user, it was generally assumed that the institution accepts the responsibility for safe handling and disposal of radioactive materials by signing the acceptance form, which contains clauses covering these points (Appendix 2 of Agenda). However, no member of the legal staff was present to render opinions.
9. For other discussions on disposal, see Agenda, Appendices 16 (Quimby), 17 (Holland), 18 (Friedell), and 19 (Evans).

To direct the discussion to something concrete, it was agreed to focus the attention on the disposal of radioiodine as an example of a short half-life material that is shipped in large quantities.

C. Radioiodine Disposal

Summary of discussion

1. The value of 0.1 microcurie per liter (Item IV-A, Agenda) is not necessarily safe for disposal if there is the possibility of selective absorption and reconcentration. (Parker)
2. The value of 0.1 microcurie per liter was set for drinking water and not for sewage. (Wolfe)
3. Iodine is to some extent removed from water by absorption in organic matter of sewage. (Friedell)
4. It is impractical to dilute excreta from therapeutic patients to give a dilution of 0.1 microcurie per liter in any particular branch of the sewer system, since every 0.1 millicurie of iodine would require one thousand liters of water. (Evans)
5. Normal uptake of iodine by the thyroid of humans is in the order of 30 micrograms per day; the active material is excreted in two liters of urine per day. For discussion on disposal of iodine in hospitals, see Appendix 16 of Agenda. (Quimby)
6. As to the practicability of storing contaminated excreta, it was pointed out that it is impractical to store excreta contaminated with radioiodine, because of excessive volume requiring too much storage space, malodor, and unnecessary exposure of laboratory personnel. (Taylor and Quimby)
7. Radioiodine could be rendered safe by dilution with stable iodine in proper chemical form. (Friedell)
8. An upper limit of disposal of 100 mc per week, Item IV-A-3 of Agenda, would limit treatment with radioiodine to a few patients in any particular hospital. To cover the scale of treatment now used, an upper limit of 200 mc per week would be satisfactory. (Holland and Quimby)
9. On basis of 0.3 r per week, the maximum permissible concentration value for radioiodine is 24 microcuries per liter based on ingestion (Appendix VIII of Agenda). A concentration of 0.5 microcuries per liter will give a safety factor of 50 to allow for possibility of reasonable values of reconcentration. (Lebersold)

MOTION I (Made by Lebersold, seconded by Quimby)

Radioiodine may be discharged from an institution into the main sewer, provided that:

1. The daily volume of water flowing from the sewage outlet of the institution to the main sewer is sufficient to dilute the radioiodine to 0.5 microcurie per liter;

2. Maximum activity disposed of from any one institution will not exceed 200 millicuries per week;
3. Regular radiation surveys are made of plumbing fixtures;
4. Appropriate surveys are made before repairing the plumbing between the disposal outlet and the main sewer.

Item 1 above originally read: "Radioiodine is diluted to the level of 0.5 microcurie per liter in the sewage outlet of the institution into the main sewer." (Amended at the suggestion of Drs. Holland and Bale to allow for average dilution over day's time)

MOTION I WAS PASSED

Further discussion on radioiodine

1. Item 1, Motion I, will limit the use of radioiodine to hospitals having more than 50 beds, since on this basis 2,000 liters of water per day would be required for each patient, in order to discharge one millicurie from each five patients. An alternate method using dilution with iodine should be recommended. (Evans)
2. In response to a question regarding the basis for selecting the value of 0.5 microcurie per liter (Evans), the following reasons were given:
 - a. To prevent endangering the health of the individuals who might come in contact with the effluent; (Friedell)
 - b. For the safety of the plumber (however, this is not the limiting factor). (K. Z. Morgan)
3. Concerning the possibility of diluting with potassium iodide, the latter should be added at the time of disposal. (Quimby)
4. Iodine is excreted mostly as iodide; consequently, dilution with an iodide such as potassium iodide insures proper chemical form for mixing. (Friedell)
5. The concentration of radioiodine in water can be safely raised to 100 microcuries per liter if one gram of potassium iodide is added for each millicurie of active material. With this elemental dilution, a maximum of one-thirtieth microcurie could be absorbed by the thyroid gland in one day, since this would be the quantity contained in 30 micrograms of iodine, the normal thyroid uptake. (Evans and Quimby)
6. A concentration of 100 microcuries per liter is too high for exposure of the body surface when it is immersed. (Parker)

MOTION II (Made by Evans, seconded by Friedell)

Radioiodine may be discharged from an institution into the main sewer, provided that:

1. To each millicurie of radioiodine discharged, one gram of potassium iodide is added at the time of disposal;
2. Radioiodine will be diluted to 10 microcuries per liter in the sewage outlet from the institution into the main sewer;
3. Regular radiation surveys are made of plumbing fixtures;
4. Appropriate surveys are made before repairing the plumbing between the disposal outlet and the main sewer.

Item 2 above originally read: "Radioiodine will be diluted to 100 microcuries per liter in the sewage outlet from the institution into the main sewer." (Amended at the suggestion of K. Z. Morgan and Parker to allow a safety factor for possible body immersion)

MOTION II WAS PASSED.

D. Phosphorus 32 Disposal

Summary of discussion

1. In the first three days of treatment, a patient will excrete about 30 per cent of the dose of phosphorus, which has a biological half-life of from 8 to 9 days. (Friedell)
2. Since 0.8 per cent of the dry solid matter in sewage is phosphorus, P 32 should receive high dilution with the element in the ordinary sanitary sewer system. (Lebersold)
3. Ten per cent of the phosphorus absorbed by the body will go to the bone unless the phosphorus is in such chemical content that it is selectively absorbed by some other organ. (K. Z. Morgan)
4. The maximum permissible concentration of P 32 in drinking water as listed in appendix 8 of the agenda should be corrected to read 5 microcuries per liter. (K. Z. Morgan)
5. It has been demonstrated that under special conditions favoring selective uptake, P 32 can be concentrated 100,000-fold above the water content. Therefore, potential users should be warned of this possibility. A concentration of 5 microcuries per liter is too high if one considers the body surface dose for swimming in the water. Because of the factor of body surface dose and the possibility of reconcentration of the active material, the permissible concentration should not be greater than 0.1 $\mu\text{c}/\text{l}$. (Parker)

6. It should definitely be safe to dispose of phosphorus in concentrations of one microcurie per 67 grams of phosphorus, since this is the value according to appendix 10 of the agenda. (Aebersold)
7. High elemental dilution should take place in the sewage, since much phosphorus is contained in sewer systems, rivers, and lakes. (Quimby)

MOTION III (Made by Aebersold, seconded by Friedell)

Radiophosphorus may be discharged into the sewer, provided that:

1. It is diluted to 0.1 microcurie per liter in the sewage system;
2. Each millicurie is diluted with 10 grams of phosphorus as phosphate at the time of discharge. (Note: The stable phosphate considered in the dilution may be both material occurring naturally or artificially supplied);
3. The maximum activity disposed of in any one institution does not exceed 200 millicuries per week;
4. Appropriate radiation surveys are made before repairs are made to the plumbing and disposal outlets to the main sewer;
5. The sewage does not enter directly into fresh water systems.

In the original motion Item 1 read: "The daily volume of water is sufficient to reduce the level to 5 microcuries per liter." (Amended at the suggestion of Parker and K. Z. Morgan to allow a factor for possible reconcentration)

MOTION III WAS PASSED

E. Carbon 14 Disposal

Summary of discussion

1. It is particularly important that this committee make recommendations on the disposal of C 14, since some universities have refused to sanction work with this isotope. (Nims)
2. The biggest problem is disposal of radioactive CO₂ during the initial stages of use in an animal. (Friedell)
3. It should be supersafe to assume that 110 microcuries per man (appendix 7 of agenda) is a permissible value, or 117 grams of carbon per microcurie, since this is based on a concentration of a factor of 10 over uniform distribution in the body. (Quimby)

4. If one considers data from recent experiments with young animals, which showed concentration of carbon in the bones and teeth, 110 microcuries per man would give above permissible dosage rate to the teeth and possibly certain parts of the bone. (Rose)
5. The value of 34 microcuries per man, as set forth by Dr. Brues, is in line with my most recent calculations of 32 microcuries. (K. Z. Morgan)
6. As a basis for the dilution of Carbon 14, it was assumed that in general the Carbon 14 may be reduced to carbonate and then uniformly diluted with elemental carbon in the same chemical form. (Aebersold)
7. Obviously a person cannot eat as much as one pound of carbon, so the figure of 117 grams per microcurie (appendix 7) could be reduced considerably when considering disposal of Carbon 14 in liquid or solid materials. (Friedell)
8. Dilutions of 117 grams per microcurie might not be safe for continued assimilation by people under 20 years of age if one takes into account the data on uptake by young animals. (Rose)
9. When incinerating materials containing radioisotopes such as C 14, it is extremely difficult to determine the concentration in the effluent from an incinerator (Item VI-E of Agenda). (K. Z. Morgan)
10. Very few actual values on safe permissible concentration in air or of the rate of release of active materials during incineration are available; consequently, calculations would have to be based on the value stated in Item VI-E-1. (Parker)
11. It is essential to scrub the effluent if the concentration is very high. (Bale)
12. At Western Reserve University animals being used in C 14 experimentation are disposed of in an incinerator, the effluent escaping through an unusually high stack. Difficulty has been experienced in finding any activity in the incinerator, except immediately after incineration. The level of activity in the ashes has been below usual methods of C 14 detection. If activity were detected, it would be difficult to separate the radioactive isotope from the ashes. (Friedell)
13. The value of 10^{-5} microcuries of Carbon 14 of CO₂ per cc of air would be considered safe under certain circumstances, but all particulate matter should be filtered from the effluent. (Rose)

MOTION IV (Made by Aebersold, seconded by Friedell)

Radiocarbon may be exhausted in the air, provided that:

1. No person shall be exposed to the inhalation of air containing greater than 10^{-5} microcuries per cc;
2. Particulate matter is filtered from the exhaust air.

MOTION IV WAS PASSED.

MOTION V (Made by Aebersold, seconded by Friedell)

Radioisotopes of any half-life may be buried in the earth if they are uniformly diluted with stable isotopes of the same chemical element and in the same chemical form, to the extent that 4.15 ergs are dissipated per gram of element per day, provided that:

1. The burial is made only in suitably selected areas which are in possession of, and will be maintained by, the user;
2. The material is buried at a minimum depth of 5 feet.

MOTION V WAS PASSED.

MOTION VI (Made by Nims, seconded by Aebersold).

It is recommended that Item IV-C of Agenda be tabled for discussion at a later meeting.

MOTION VI WAS PASSED.

The meeting was adjourned.

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AGENDA OF MEETING ON WASTE DISPOSAL
OF RADIOACTIVE MATERIALS BY OFF-COMMISSION USERS

U. S. Atomic Energy Commission
A. E. C. Building, Washington, D. C.
September 20, 1948.

I. Announcement of Meeting and Personnel Invited:

- A. Announcement of need for the meeting and names of persons invited, together with names of institutions with which they are affiliated, are found in Appendix 1.

II. Scope of Discussion:

- A. The discussion should pertain specifically to the disposal of radioactive waste materials of the types and quantities involved in off-Project utilizations.
- B. The discussion should not now emphasize the long-range problem, involving a total amount of distributed radioactive material which might be orders of magnitude larger than that delivered during the past 12 months. It is more desired now to concentrate on procedures which will serve safely for the next year or two during which the types of isotopes distributed will not change significantly and the total distributed quantities will most likely be much less than an order of magnitude larger. The immediate goal should be interim recommendations to guide off-Commission users now. These can be supplemented or modified in a year or two as dictated by program expansion and disposal experience.

III. Purpose of Meeting:

- A. To attempt to derive agreement among authorities on radioactive waste disposal within the Commission regarding means of disposal appropriate and practicable for off-Commission users of Commission supplied radioisotopes.
- B. To discuss the relative responsibilities of the Commission and the off-Commission users in the latter's disposal problems.
- C. To formulate quantitative criteria for disposal of certain classes of distributed radioisotopes which will guide off-Commission users in selecting specific disposal methods.

- D. To recommend the nature and extent of laboratory and field research which may be necessary to establish the aforementioned quantitative criteria.
- E. To formulate conditions for return of certain kinds of radioactive wastes to Commission facilities.

IV. Statement of the Problem:

- A. With the increased demand for the distribution of radioactive materials through Commission facilities, it is becoming increasingly apparent that an interim policy for the handling of radioactive waste materials should be adopted pending development of a long-range policy. Since recipients of radioisotopes agree to dispose of radioactive wastes in a safe manner (see App. 2), the Commission is obligated to define more specifically disposal procedures which under present knowledge and conditions may be considered safe.
- B. During the period from July 1, 1947, to July 1, 1948, 2191 shipments of radioisotopes were made from Commission facilities to off-Project users. (See App. 3.) This number is more than double the number of shipments made in the preceding year. Note however that only 0.539 percent of all the activity falls into Group III, classified as very hazardous by Subcommittee No. 6 of the National Committee on Radiation Protection. (See App. 4.) Of these, C 14 accounts for 0.0029 percent of the total activity shipped.
- C. In determining the nature and scope of a waste disposal program, account must be taken of the geographic location of the institution receiving isotopes and the quantities used. (See App. 5-A and 5-B.)
- D. It is pertinent to note that an appreciable expansion in the radioisotope distribution program is expected to take place during the next year primarily because of an increase in trained personnel. It is probable that this will include a considerable expansion in the field of industrial research and development. Many of the coming uses may require higher levels of activity and therefore accentuate the disposal problem. Also to be noted is the possibility, both on the part of industrial and medical investigators, of substituting Cobalt 60 for Radium and X-Rays, as an external source of radiation. However, the total yearly distributed quantity is not expected to reach an order of magnitude larger for several years or more.

V. General Considerations in Evaluating Disposal Problem:

- A. The nuclear and biological properties of the radioisotopes must be given primary consideration. (See App. 6, 7, and 8.)
- B. Consideration must also be given to specific chemical and physical properties of the compound containing the isotope:
- C. The aim should be to recommend procedures which are practical both from the point of view of the Commission and the user,
 - 1. Disposal procedures recommended by the Commission should be sufficiently feasible, both in the time and money involved, to induce faithful practice by off-Commission users, while maintaining adequately safe practices.
 - 2. Disposal procedures should not result in serious suppression of valuable researches and application of radioisotopes, unless absolutely necessary in the interests of general public health.
 - 3. Commission facilities should become involved in radioactive "garbage" collection only wherein absolutely necessary. Arrangements should not substantially increase the burden on scientific and technical personnel of Commission laboratories.

VI. Suggested Procedures for Consideration:

- A. Radioisotopes having half-lives of less than 30 days may be disposed of in the sewer, provided the daily volume of water flowing through the particular outlet used is sufficient to dilute the radioisotope to 0.1 microcuries per liter or to safe limits of concentration as set for that particular isotope. This practice should be contingent on certain provisions such as:
 - 1. The maximum activity disposed of in any one institution will not exceed 100 mc. per week. (See App. 9 and 10.)
 - 2. Regular radiation surveys of the plumbing fixtures.
 - 3. Appropriate surveys before repairing the plumbing between the disposal outlet and the main sewer.
- B. Radioisotopes of any half-life may be buried in the earth, provided that they are uniformly diluted with stable isotopes of the same element to the extent that 4.15 crgs (equivalent to 50 mr/day in tissue) is dissipated per gram of element per day. (See App. 10), provided:

1. The burial is made only in suitably selected areas which are in possession of and will be maintained by the user. These areas should be properly marked and enclosed with suitable fencing. In case of possible release into the soil, a thorough geological investigation should be made of the area selected for burial purposes, and analyses should be provided of the soil, so that the fate of the material can be determined to be a safe dilution.
 2. The material must be buried at a minimum depth of 5 feet.
- C. Radioactive materials may be buried when properly enclosed in a container sufficiently well constructed to retain the isotope for a period of five years, provided
1. For materials having half-lives of < 2 years, the radioisotope is adulterated, prior to enclosure, with sufficient quantities of concrete or stable isotopes of the same element to reduce the dissipation of energy from the remaining activity at the end of 5 years to 4.15 ergs per gram of adulterant. The dosage rate at the surface of the container shall not exceed 6.25 mr/hr.
 2. For materials having half-lives of > 2 years, the radioisotope shall be adulterated, prior to enclosure, with sufficient quantities of concrete or stable isotope to reduce the dissipation of energy to the extent of 4.15 ergs per gram of adulterant per day.
 3. The burial is made in compliance with "B"-1, above.
- D. Materials may be buried at sea when enclosed under conditions stated in "C" above and buried beyond the three-mile limit.
- E. Materials containing radioisotopes may be incinerated if the calculations of safe permissible concentration in exhaust air and in disposed ashes are based on known values. In the absence of specific information, the following assumptions should be made:
1. For the air calculation, that all the active material escapes in the air.
 2. For the handling of the ashes, that all the activity is retained in the ashes. The ashes and/or effluent residue are then disposed of in accordance with Sections "B" and "C".

VII. Recommendations and advice on disposal of radioactive materials now given off-Commission users:

- A. Excerpts from circulated information on disposal of radioactive materials, as recommended by Commission groups, are appended.
1. Argonne National Laboratory. (See App. 12.)
 2. National Committee on Radiation Protection. (See App. 13.)
 3. Isotopes Division Circular B-1. (See App. 14.)
 4. K. Z. Morgan paper, "Tolerance Concentrations of Radioactive Substances," published in The Journal of Physical and Colloid Chemistry, Vol. 51, No. 4, July 1947. (For Comparative Summary of tolerance values, see Appendix 8.)

B. Advisory Field Service Branch of Isotopes Division;

The policy has been to discuss the general problems associated with disposal of radioactive materials and to recommend methods pertinent to the disposal of the particular isotope in question. The final decision as to the method has, however, been left to the isotope user.

C. Excerpts from information on disposal, circulated by other groups.

1. Atomic Energy Project, University of California, Los Angeles. (See App. 15.)
2. Correspondence from Dr. J. J. Nickson, Argonne National Laboratory, to Dr. Philip S. Owen, National Research Council. (See App. 11.)

VIII. Remarks prepared for Meeting by Persons Attending:

- A. Dr. Albert H. Holland, Jr., Medical Advisor, ORDO. (See App. 16.)
- B. Dr. Edith H. Quimby, Presbyterian Hospital, Columbia University. (See App. 17.)
- C. Dr. Hymor L. Friedell, Director, Division of Health Physics, Argonne National Laboratory. (See App. 18.)

APPENDIX 1

Oak Ridge, Tennessee
August 13, 1948

Subject: MEETING TO DISCUSS DISPOSAL OF RADIOACTIVE WASTES BY
OFF-COMMISSION USERS OF ISOTOPES

Dear

As you are well aware, the increased use of radioisotopes distributed by the Commission, presents a growing problem with respect to the proper disposal of radioactive wastes by those outside Commission facilities.

The Isotopes Division has brought the problem to the attention of the General Manager, and arrangements have been made for the Washington Division of Biology and Medicine and the Oak Ridge Isotopes Division to work together in arranging a meeting to discuss off-Commission disposal methods. If possible the meeting should arrive at recommendations for suitable means of disposal to be used by off-Commission users of radioisotopes.

Accordingly, a meeting has now been arranged on this subject for 10:30 a.m., Monday, September 20, in the conference room, AEC Headquarters, Washington, D.C. Knowing that you are one of those directly concerned with this subject, you are cordially invited to attend.

This first meeting will largely be confined to persons connected with the AEC or its contractors, for one of the aspects to be discussed is a system under which certain types of waste might be returned to Commission facilities for disposal. A few persons who are concerned with the use of large quantities of radioisotopes outside Commission facilities are being invited to present the viewpoint of off-Commission users.

It is realized that the National Committee on Radiation Protection is organizing a subcommittee to be concerned with decontamination and disposal of radioactive wastes. It is not our intention to duplicate the functions of this subcommittee, but rather to prepare the way by attempting to derive a certain degree of agreement within the Commission on means of disposal appropriate for off-Commission users, also on conditions for the return of certain

Appendix 1 (Cont.)

radioactive wastes to Commission facilities. The National Committee on Radiation Protection will have the more general problem to derive recommendations for disposal of all radioactive materials, including natural radioactive materials, and radioactive materials produced by nuclear bombardment devices.

A list of the persons being invited is appended.

The Isotopes Division is preparing an agenda which it hopes to send out in advance of the meeting. We would appreciate very much your sending us any pertinent papers or correspondence which you may have written on this subject. We would also like to receive in advance a brief outline of your thoughts and recommendations on means of disposal by off-Commission users. The meeting will accomplish much more if each of those attending has prepared comments and recommendations in advance, especially if these are sent to us in sufficient time for reproduction and circulation.

First, please inform me as soon as possible of your intention to attend the meeting. Second, please send me, by September 7, any comments or material which will be pertinent to facilitate action at the meeting.

With best personal regards,

Very truly yours,

Paul C. Aebersold, Chief
Isotopes Division
Oak Ridge Operations

Encl.:
Appendix-list

Appendix 1 (Cont.)

LIST OF PERSONS INVITED TO ATTEND COMMISSION MEETING ON
DISPOSAL OF RADIOACTIVE WASTES BY OFF-COMMISSION USERS
OF ISOTOPEs

FROM THE AEC STAFF:

1. Dr. A.H. Holland, Jr., Medical Advisor, ORDO
2. Dr. Bernard Wolfe, Medical Advisor, NYDO
3. Mr. Carl Braestrup, Consultant, NYDO

FROM AEC CONTRACTORS:

1. Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Carbide and Carbon Chemicals Corporation, Oak Ridge
2. Dr. H.M. Parker, Director, Health Physics Division, General Electric Company, Hanford, Washington
3. Dr. Leslie Nims, Director, Division of Biology, Brookhaven National Laboratory, Upton, New York
4. Dr. S. P. Cowan, Health-Physics Department, Brookhaven National Laboratory
5. Mr. Nelson Garden, Department of Chemistry, Radiation Laboratory, University of California, Berkeley, California
6. Dr. Austin M. Brues, Director, Division of Biology, Argonne National Laboratory, Chicago, Ill.
7. Dr. J. E. Rose, Director, Division of Health Physics, Argonne National Laboratory, Chicago, Ill.
8. Dr. Wm. F. Bale, Radiologist, University of Rochester, Rochester, New York
9. Dr. Hymor L. Friedell, Director, AEC Medical Research Project, Western Reserve University, Lakeside Hospital, Cleveland, Ohio

OFF-COMMISSION USERS:

1. Dr. Edith Quimby, Presbyterian Hospital, Columbia University, 630 West 168th Street, New York 32, N.Y.
2. Dr. Robley D. Evans, Professor of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts

In addition the following persons will also attend: appropriate personnel from the Division of Biology and Medicine and other members of the Washington office staff; Dr. N.H. Woodruff, Mr. G.W. Morgan and myself from the Isotopes Division, Oak Ridge.

P.C.A.
August 12, 1948

APPENDIX 2

EXCERPTS FROM ACCEPTANCE OF TERMS AND CONDITIONS
FOR ORDER AND RECEIPT OF BYPRODUCT MATERIALS (RADIOISOTOPES)

The pertinent items are:

5. The applicant will use byproduct materials only for the purposes authorized by the Commission and will not deliver to another person (as defined in the Atomic Energy Act of 1946), or dispose of, all or any part of any byproduct materials purchased or acquired from the Oak Ridge National Laboratory, or from any source on the authorization or approval of the Commission, unless written permission for such delivery or disposal is obtained from the Isotopes Division of the U. S. Atomic Energy Commission, Oak Ridge, Tennessee; provided, however, that this restriction shall not prohibit the disposal of waste or discarded byproduct materials when such disposal is made in a manner which will insure below tolerance irradiation of humans or non-experimental animals and will result in a minimum possible contamination of facilities, equipment, and frequented or accessible regions, areas, or places.
8. Title to and possession of all byproduct materials purchased or acquired from the Oak Ridge National Laboratory, or from any source on the authorization or approval of the Commission, remain subject to the Commission's statutory right to recall. The Commission may recall such materials if the applicant (1) fails to observe such safety standards as are or may be established by the Commission, (2) uses the materials in violation of law or regulations of the Commission, or (3) uses the materials in a manner other than as disclosed in his application therefor. Title to any byproduct materials recalled by the Commission shall vest in the Commission

APPENDIX 2 (Continued)

with the exercise of this right, and the Commission may enter and take possession of said materials any time after notice is given that the materials are being recalled; provided, that if requested, the applicant, at his expense, will make shipment of the recalled materials to a destination designated by the Commission.

9. The applicant shall permit the Commission to make such inspections of his facilities wherein byproduct materials are stored or used as the Commission may deem necessary, and shall make available to the Commission the records required to be kept by the provisions hereof.
10. The applicant will keep accurate and complete records showing the receipt, use, storage, delivery and disposal of byproduct materials, the disposal of waste or discard byproduct materials, and the safety measures used to protect health. The applicant will report to the Commission every delivery or transfer made to any person (as defined in the Atomic Energy Act of 1946), giving the name of the transferee, type and amount of byproduct material, and date of delivery or transfer.

NUMBER OF RADIOISOTOPE SHIPMENTS AND AMOUNT
OF RADIOACTIVITY SHIPPED BY HALF-YEAR PERIODS

APPENDIX 3

ISOTOPE	July 1, 1946 to Dec. 31, 1946		Jan. 1, 1947 to June 30, 1947		July 1, 1947 to Dec. 31, 1947		Jan. 1, 1948 to June 30, 1948		Total to June 30, 1948	
	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount
Separated C ¹⁴	48	45 mc	41	84 mc	67	210 mc	67	260 mc	223	599 mc
Separated I ¹³¹	67	2053 mc	206	8243 mc	281	10945 mc	450	19765 mc	1004	41006 mc
Separated P ³²	35	1757 mc	180	5647 mc	293	11464 mc	361	13978 mc	869	35846 mc
Separated S ³⁵	--	--	10	63 mc	12	291 mc	13	212 mc	35	566 mc
Separated Ca ⁴⁵	--	--	--	--	4	0.017 mc	--	--	4	0.017 mc
Fission Products	10	1112 mc	15	467 mc	15	284 mc	28	461 mc	68	2324 mc
Irradiated Units	85	85 units	243	256 units	263	266 units	286	311 units	877	918 units
Service Irradiations	1	1 irra- diation	4	4 irra- diations	18	18 irra- diations	33	33 irra- diations	56	56 irra- diations
Total	246		699		953		1238		3136	

mc = millicurie

APPENDIX 4

DISTRIBUTION OF ISOTOPES CLASSIFIED ACCORDING TO DEGREE OF HAZARD,
AS SPECIFIED BY SUBCOMMITTEE OF THE NATIONAL COMMITTEE
ON RADIATION PROTECTION

(Period covered: June 1, 1947, to July 1, 1948.)

<u>Isotope</u>	<u>Total Amount of Isotope Shipped in Millicuries</u>
<u>SLIGHT HAZARD</u>	
Na ²⁴	4,521
K ⁴²	8,710
Cu ⁶⁴	2,800
Mn ⁵²	0
As ⁷⁶	25
As ⁷⁷	2.1
Kr ⁸⁵	0
Hg ¹⁹⁷	0
Total	<u>16,058.1</u>
Per cent of total millicuries shipped	9.65

MODERATELY DANGEROUS

Te ¹²⁷	0
Te ¹²⁹	0
I ¹³¹	61,774
Cs ¹³⁷	7
Bo ¹⁴⁰	65
La ¹⁴⁰	80
Ce ¹⁴¹	200
Pr ¹⁴³	2
Nd ¹⁴⁷	1
Ar ¹⁹⁸	8,560
Ar ¹⁹⁹	10
Hg ^{203, 205}	250
H ²	0
P ³²	76,612
S ³⁵	1,227
Cl ³⁶	.05
Mn ⁵⁴	0
Fe ⁵⁹	21
Co ⁶⁰	690
Sr ⁸⁹	31.5
Cb ⁹⁵	1
Ru ¹⁰³	5
Ru ¹⁰⁶	1
Total	<u>149,537.55</u>
Per cent of total millicuries shipped	89.81

APPENDIX 4

(continued)

Isotope

Total Amount of Isotope Shipped
in Millicuries

VERY DANGEROUS

C¹⁴

Ca⁴⁵

Fe⁵⁵

Sr⁹⁰

Y⁹¹

Zr⁹⁵

Ce¹⁴⁴

Cl¹⁴⁷

Bi²¹⁰

488

177

2.8

0

56

174

0

0

0

897.8

Total

Per cent of total
millicuries shipped

0.54

APPENDIX 5-A

QUANTITY OF FOLLOWING ISOTOPES RECEIVED BY LISTED CITIES
 WITHIN A PERIOD FROM JUNE 1, 1947 TO JUNE 1, 1948

(MC)

Isotope	Dallas	New York	Boston	Chicago	Philadelphia	Cleveland
I 131	1,220	14,263	7,129	4,330	17,166	1,235
P 32	1,230	18,116	20,294	1,356	1,300	1,210
S 35	0	63	20	43	0	0
Ne 24	0	330	720	0	0	400
K 42	0	2,080	4,680	0	0	0
Co 60	0	0	60	0	0	0
C 14	0	37	106	31.5	3	2
Sr 89	0	150	55	3	0	0
Au 198	1,920	80	0	0	0	0
Ag 110	0	0	0	0	0	0
Cl 36	0	0	0	0	0	0
Ca 45	0	.8	11.6	10	0	0
Fe 55, 59	0	0	6.6	11.4	0	0

APPENDIX 5-B

EXAMPLES BASED ON ACTUAL DISTRIBUTION

Equilibrium quantities of I^{131} and P^{32} in sewage system at the following institutions or cities, assuming that all material received was disposed of in sewer at the rate of $1/52$ of total millicuries each week (period July 1947 to July 1948):

<u>Institution or City</u>	<u>Isotope</u>	<u>Amount Received in Millicuries</u>	<u>Complete Disposal by Sewer Equilibrium Value in Millicuries</u>
Memorial Hospital	I^{131}	4,000	129.8
	P^{32}	1,400	79.6
Mayo Foundation	I^{131}	2,800	89.0
	P^{32}	1,200	67.8
New York City	I^{131}	14,263	517.0
	P^{32}	18,116	147.0
Cleveland	I^{131}	1,235	39.2
	P^{32}	1,210	68.6

APPENDIX 5-C

EQUILIBRIUM VALUE OF DISPOSED MATERIAL

Assume a disposal rate of 1 mc/week, then:

Isotope	$T_{\frac{1}{2}}$	Equilibrium Time (1)	Millicuries at Equilibrium (2)
C ¹⁴	5,100 y	30,600 y	383,735.3
P ³²	14.3 d	85.8 d	2.94
I ¹³¹	8 d	48 d	1.65
H ³	12 y	72 y	902.9
S ³⁵	87.1 d	522.6 d	17.96
Ce ⁴⁵	180 d	1,080 d	37.1
Au ¹⁹⁸	2.7 d	16.2 d	.556
Ne ²⁴	14.8 h	88.8 h	.127

(1) Note: Transient radioactive equilibrium will be reached closely in about 6 half-lives of the daughter. For the purpose of these calculations, the activity is considered as growing in at the rate of 1 mc/week. Reference MDDC-763, page 45.

(2) Equilibrium value (Q) = $\frac{R}{\lambda}$

R = rate material is added/day

$\lambda = 0.693/T_{\frac{1}{2}}$ in days

APPENDIX 6

CLASSIFICATION OF ATOMIC ENERGY COMMISSION
DISTRIBUTED RADIOISOTOPES BY HALF-LIVES*

HALF-LIFE < 5 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Antimony 122	1.36, 1.94	0.57	50
Arsenic 76	1.1, 1.7, 2.7	0.57, 1.25	25
Arsenic 77	0.8	None	0.70
Bromine 82	0.465	0.547, 0.787 1.35	70
Cadmium 115	1.33, 0.6	0.65	20
Copper 64	0.58 B ⁻ 0.66 B ⁺ K	1.2 (weak)	100
Gallium 72	3.1, 0.8	0.84, 2.25	25
Gold 198	0.97	0.44	80
Gold 199	1.01	0.45	10
Iridium 194	2.07	0.38, 1.65	40
Lanthanum 140	0.9 (20%) 1.40 (70%) 2.12 (10%)	1.63 complex	40
Mercury 197	K, e ⁻ K, e ⁻	0.075 0.13, 0.16	95
Molybdenum 99	1.3	0.77, 0.815 0.84	40
Potassium 42	3.58 (75%) 2.07 (25%)	1.51 (25%)	130
Praseodymium 142	2.14	1.9	40
Rhenium 186	1.0	None	75
Ruthenium 97	K, e ⁻	0.22, 0.18	10
Samarium 153	0.73	0.1, 0.57 (weak)	16

*All fission products are not included due to their complexity.

APPENDIX 6 (CONT'D)

HALF-LIFE < 5 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Rhodium 105	0.5	0.3	10
Sodium 24	1.4	1.4, 2.8	20
Tungsten 187	0.6, 1.3	0.086 - 0.94 complex	40
Yttrium 90	2.16	None	100

HALF-LIFE = 5 - 10 DAYS

Bismuth 210	1.17	None	10
Iodine 131	0.6	0.367, 0.08	130
Silver 111	1.0	None	10

HALF-LIFE = 10 - 15 DAYS

Barium 131	K, e ⁻	1.2 (weak)	6.0
Phosphorus 32	1.69	None	1500
Phosphorus 32	1.69	None	350

HALF-LIFE = 15 - 30 DAYS

Cerium 141	0.55	0.21	50
Chromium 51	K	0.32	50
Osmium 193	0.35	Present	40
Palladium 103	K	None	Undetermined
Rubidium 86	1.60	None	100

APPENDIX 6 (CONT'D)

HALF-LIFE = 30 - 60 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Cadmium 115	1.85	0.5	1
Hafnium 181	0.8	0.5	50
Indium 114	I.T.e ⁻ 1.95	0.19	10
Iron 59	0.26, 0.46	1.1, 1.3	1.0
Mercury 203,205	0.3	0.28	40
Strontium 89	1.5	None	1.5

HALF-LIFE = 60 - 90 DAYS

Antimony 124	0.53, 2.25	1.72	4
Iridium 192	0.59	0.2 - 0.6 complex	40
Scandium 46	0.36	1.12, 0.90	15
Sulfur 35	0.17	None	1.0
Titanium 51	0.36	1.0	1
Tungsten 185	0.7	None	10
Zirconium 95	1.0 (2%) 0.394 (98%)	0.73 0.92	12

HALF-LIFE = 90 - 180 DAYS (6 MONTHS)

Selenium 75	K, e ⁻	<0.3 complex 0.5	65
Tantalum 182	0.53	1.13, 1.22 <1.0 complex	40

APPENDIX 6 (CONT'D)

HALF-LIFE = 6 MONTHS (180 DAYS) -- 2 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Calcium 45	0.250	None	0.8
Silver 110	0.59	0.66 (44%) 0.90 (47%) 1.40 (9%)	35
Zinc 65	0.4 B ⁺ (1%) K, e ⁻ (99%)	1.14	15

HALF-LIFE = 2 TO 3 YEARS

Antimony 125	0.8, 0.3	Present	1
Cesium 134	0.645	0.584, 0.776 (95%) 1.35 (5%)	20
Thallium 204	0.58	None	7

HALF-LIFE = 3 TO 5 YEARS

(61) 147 (illinium)	0.223	None	.001
------------------------	-------	------	------

HALF-LIFE = 5 TO 10 YEARS

Cobalt 60	0.3	1.1, 1.3	20
Europium 154	0.34 (50%) 0.82 (50%)	1.4 et al	40

HALF-LIFE = > 10 YEARS

Chlorine 36	0.66	None	0.005
Nickel 59	K, e ⁻		1
Technetium 99	0.3	None	0.00001
Carbon 14	0.154	None	
Tritium	.015, .011	None	

APPENDIX 7

EQUILIBRIUM RETENTION OF ACTIVITY IN MAN
ON THE BASIS OF 4.15 ERGS/GM/DAY
OR 50 MREP/DAY

Element	Total Content Gms/Man	Isotope	D. A. R. (1)	Permissible $\mu\text{c}/\text{man}$	Permissible $\mu\text{c}/\text{gm}$ of Element	Minimum Permissible Dilution by Stable Element $\text{gm}/\mu\text{c}$
C	12,950	C ¹⁴	1	1100 ⁽²⁾	0.0849	11.78
		C ¹⁴	10	110	0.00849	117.8
		C ¹⁴	--	34 ⁽³⁾	0.0026	384.6
P	670	P ³²	1	100 ⁽²⁾	0.149	6.71
		P ³²	10	10	0.0149	67.1
S	112	S ³⁵	1	1010 ⁽²⁾	9.017	.11
		S ³⁵	10	101	0.9017	1.10
Ca	1,160	Ca ⁴⁵	1	678 ⁽²⁾	0.584	1.71
		Ca ⁴⁵	16.6 ⁽⁴⁾	40.8	0.035	28.57
I	0.020	I ¹³¹	1	86 ⁽²⁾	4309	.00023
		I ¹³¹	1168 ⁽⁵⁾	0.0736	3.75	.26
Fe	4.375	Fe ⁵⁹	1	21.3 ⁽²⁾	4.868	.21
		Fe ⁵⁹	10	2.13	0.4868	2.05
Na	63	Na ²⁴	1 ⁽⁴⁾	12.1 ⁽²⁾	0.192	5.21
K	150	K ⁴²	1 ⁽⁴⁾	39.5 ⁽²⁾	0.263	3.80

- (1) D. A. R. for any tissue, this is the ratio of concentration of an isotope in that tissue to the average concentration in the body (neglecting excretion). Marinelli - "Dosage Determination with Radioactive Isotopes." The American Journal of Roentgenology and Radium Therapy, Vol. LIX, No. 2, Feb. 1948.
- (2) Assuming equal distribution.
- (3) Dr. Austin Brues' value.
- (4) Known D. A. R. value.
- (5) Calculated D. A. R. value from Skohl, Mineral Metabolism.

APPENDIX 8

A COMPARATIVE SUMMARY OF SOME TOLERANCE VALUES*

Organ Affected and Fraction of Count in Body	Fraction Taken into Body that Reaches Organ	%c in Organ to Produce Tolerance Rate When t = 0	%c in Organ to Produce an Average Tolerance During Year	One-Year Tolerance Concentration rate in Air	One-Year Tolerance Concentration in Water
	0.25	0.013	0.23	7.5x10 ⁻⁹ μ c/cc.	2.0x10 ⁻¹⁰ μ c/cc.
	0.05	0.155	0.16	5.1x10 ⁻⁹ μ c/cc.	2.0x10 ⁻¹⁰ μ c/cc.
	0.25	0.035	0.15	4.7x10 ⁻⁹ μ c/sec.	4.4x10 ⁻⁶ μ g/cc.
	0.003	0.42	0.43	1.4x10 ⁻⁸ μ c/cc.	1.3x10 ⁻¹⁰ μ g/cc.
	0.375	0.42	0.43	1.4x10 ⁻⁸ μ c/cc.	2.0x10 ⁻¹⁰ μ g/cc.
	0.25	0.041	0.17	5.5x10 ⁻⁹ μ c/cc.	1.5x10 ⁻¹⁰ μ g/cc.
	0.25	0.039	0.16	5.1x10 ⁻⁹ μ c/cc.	1.4x10 ⁻¹⁰ μ g/cc.
	0.25	0.037	0.156	5.0x10 ⁻⁹ μ c/cc.	1.3x10 ⁻¹⁰ μ g/cc.
	0.11	0.010	0.033	1.0x10 ⁻⁹ μ c/cc.	6.4x10 ⁻¹⁰ μ g/cc.
	0.001	0.010	0.033	1.0x10 ⁻⁹ μ c/cc.	1.4x10 ⁻¹³ μ g/cc.
	0.075	32	190	6.0x10 ⁻⁶ μ c/cc.	4.5x10 ⁻⁵ μ g/cc.
	0.075	88 (20)*	34	11x 10 ⁻⁶ μ c/cc.	3.4x10 ⁻³ μ g/cc.
	0.25	32	130	4.3x10 ⁻⁶ μ c/cc.	1.2x10 ⁻⁷ μ g/cc.
	0.25	2260	5.7x10 ⁴	1.8x10 ⁻³ μ c/cc.	4.8x10 ⁻⁵ μ g/cc.

APPENDIX 8
(continued)

Table: A Comparative Summary of Some Tolerance Values. (Continued)
Explanation of contents of table.

The tolerance values in columns 9, 10, 11, 12 and 13 are for continuous exposure. If the exposure is for a 40-hr. week, multiply these values by 4.2.

Column 9 is the tolerance concentration rate, in $\mu\text{c}/\text{sec.}$, to the body organ that will produce a tolerance rate of exposure after 365 days of consumption.

It should be noted that the values given in column 6 depend on the chemical form and in the case of inhalation they depend upon the size of the particles. Until the most likely forms of these elements in a given laboratory are known, it is difficult to assign typical values of tolerance concentration in columns 10, 11, 12 and 13.

Values in column 9 can be obtained by dividing values in column 8 by the seconds in a year.

Column 8 is the $\mu\text{c.}$ in the lung, bone, kidney, or blood required to irradiate the organ with 3.65 roentgens of α or 36.5 roentgens of $\beta\gamma$ in a year. It is the $\mu\text{c.}$ in the thyroid required to irradiate it with 365 roentgens of β in a year

*The Sr-Y activity reaches a maximum after 15 days. The 88 $\mu\text{c.}$ is required to produce tolerance exposure rate soon after Sr reaches the bone. Only 20 $\mu\text{c.}$ is required to produce tolerance exposure rate on the 15th day. The 34 $\mu\text{c.}$ produces an average yearly tolerance dose.

**It is assumed that the fraction reaching the skin by way of the gut is 0.05 and by way of the lungs in 0.1 in the case of S^{35} . For Ca^{45} it is assumed that 0.15 reaches the bone by way of the gut and 0.4 by way of the lung.

APPENDIX 9

EXAMPLE OF DATA ON CITY SEWAGE.

Report on the Pollution of Tennessee River in and
Near Knoxville and Sewage Treatment for Knoxville

Chemical analysis of city water based on 6 months average for 1945:

pH	7.6	p.p.m.	Carbonate Alkalinity	0	p.p.m.
SiO ₂	5.0	"	Total Alkalinity	70.0	"
Fe	0.02	"	SO ₄	31.0	"
Al ₂ O ₃	0.85	"	Cl	24.0	"
Ca	40.0	"	Dissolved Solids	180.0	"
Mg	5.0	"	Soap Hardness	120.0	"

Waste from Tennessee Packing Company:

Annual average waste of 240,000 would contain 3,200 pounds of suspended solids and 2,560 pounds of B.O.D.* per day.

In 1944: Per Capita
 Industrial Use Domestic Use Population 160,000
 38 gallons 49 gallons

Water pumped per capita for Knoxville = 88 gallons per 24 hours

The total load of suspended solids and 5-day B.O.D.* in the raw sewage for 1945 is estimated to be as follows:

<u>Year</u>	<u>Pounds per 24 hours suspended solids 5-day B.O.D.</u>	
1945	42,000	49,500

Average sanitary sewage flow is 24.7 million gallons per day.

There are 32 sanitary sewer outlets into the river at Knoxville.

*Biological Oxygen Demand

APPENDIX 10 .

RADIOISOTOPE ADULTERATION

ELEMENT DILUTION WHICH WILL ACHIEVE ADULTERATION
TO 4.15 ERGS/GM/DAY IN THE ADULTERANT

Isotope	Total Absorbable Energy per Disintegration	Kilograms of Adulterant per mc of Isotope	Liters of Element Time = 0	Liters of Element Time = 30 days	Liters of Water Time = 0	Liters of Water Time = 30 days	Liters of Earth Time = 0	Liters of Earth Time = 30 days
C ¹⁴	5.08x10 ⁻²	62	17.6	17.6	62	61.9	11.2	11
P ³²	.558	680	309	72.5	680	159.5	123	28.9
I ¹³¹	.645	787	159.3	11.8	787	58.5	142.5	10.6
H ³	4.95x10 ⁻³	6	66.8	66.5	6	5.97	1.1	1.09
S ³⁵	5.61x10 ⁻²	68	34	26.8	68	53.49	12.4	9.75
Ca ⁴⁵	.083	101	65.7	58	101	89.6	18	16.2

Note:- 4.15 ergs/gm of tissue, is considered a safe permissible daily dose.

APPENDIX 11

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIALS

from

Dr. J. J. Nickson, Director, Medical Division,
Argonne National Laboratory,

to

Philip S. Owen, M.D., National Research Council,

concerning

"Protection Against Radiation Hazards"

Disposal of Waste Radioactive Materials

Wastes which contain less than 0.1 mc/liter in a clear alkaline solution are classified as radioactive wastes which may be discarded into the usual city sewer system. Acid solutions should not be discarded in this fashion because of the danger of precipitation of the radioactive material when the activity comes in contact with the organic material in the sewer. Animal carcasses and excreta are here discarded by collection and storage in a suitable monitored guarded area. Should incineration be considered as a means of disposal of organic wastes containing radioactive materials it is obvious that monitoring of the content of activity in the air should be done at all times.

Perhaps a brief description of our waste disposal system here might be in order. We have set up a system whereby all material contaminated with radioactive material is placed in special containers which are to be used only for such materials. At least one container is present in every room in which radioactive material is handled in the laboratory. In addition suitable containers (usually stainless steel) for solutions containing radioactive materials in excess of the 0.1 mc/liter figure given above are placed in several of the laboratories in each building so that the solutions which are not to be dumped down the sink can find a suitable resting place. Both the dry active waste containers and the liquid active waste containers are collected at intervals dictated by their use; the material transferred to large containers are taken to a guarded monitored area and there held.

It is recognized that such a system is expensive. However, we do not feel justified in allowing dry active wastes or liquid active wastes to enter the normal channel of waste disposal if we can humanly avoid it. Even with this system it has been necessary to routinely monitor all ordinary dry active wastes leaving the project because, on occasion, through error or through indifference, dry wastes contaminated with radioactive materials are placed in the non-active waste containers.

It cannot be too strongly recommended that all these wastes should be placed in a holding area under the control of the institution in

APPENDIX 11 (Continued)

question. It is desirable that the holding containers be of such a nature that they can be readily transported without over-exposure to the personnel involved. It is hoped that the national policy will be decided within an interval which will not necessitate too large local holding areas.

It is my feeling that any local decisions by any given institution to make definitive disposal of radioactive wastes should be discouraged. Although we do not ordinarily consider it so, the sea is a finite body. Should all countries decide to use the ocean as a dumping ground for radioactive materials, it is possible to foresee a condition in not too many generations in which plant and animal life within the ocean (which are capable of concentrating many fold the activity present in the water) would contain a radiation level which on a long term basis would be harmful to humans.

APPENDIX 12

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIALS

from the
Argonne National Laboratory manual,
"Radiation Hazard Control"

1. Contaminated Dry Objects

1.1 Dry Active Waste Cans. Contaminated dry objects such as glassware, used kleenex, and contaminated apparatus should be placed in the Dry Active Waste Cans for disposal by the Safety Section. The Health Physics group should be contacted before attempting to dispose of any appreciable activity in this manner.

When alpha active material in an amount greater than microgram levels is placed in a Dry Active Waste Can, the scientist is responsible for notification of the Health Physics Division. This is important because it is very difficult or even impossible for the surveyor to tell how much alpha activity may be present in the Dry Active Waste Can.

Under no circumstances should active solutions be placed in these cans.

1.2 Material which cannot be placed in the Dry Active Waste Cans. Articles which are too large to be placed in these cans, such as: ring stands, tripods, pieces of masonry, transite, plaster boards, pipes, etc., should be checked by Health Physics, labelled, and arrangement for their disposal by the Safety Section made through the Health Physics Division.

2. Active Solutions.

Active solutions should be retained for disposal by the Safety Section. Such solutions should be placed in bottles small enough to be easily handled (if possible, the size should be kept below 2 1/2 liters), and in the case of beta-gamma active materials to prevent excessive exposure to those removing the material. The Health Physics group will make the necessary arrangements for their disposal. All bottles should be carefully and completely labelled before being removed from the laboratory.

APPENDIX 13

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIAL

from

"Safe Handling of Radioisotopes"

(Provisional Draft of a Report Prepared for the
National Committee on Radiation Protection)

Disposal of Contaminated Wastes

(1) Absorbent papers, wipes, etc.

Waterproof disposable containers to hold the discarded absorbent bench paper and wiping papers should be provided at each laboratory station. Regular collections of these disposal vessels from the laboratory should be made. The eventual disposal of such items is conditioned by the half-life and toxicity level of the isotopes involved. With short half-lives, retention of the materials in a controlled area, until their residual activity is insignificant, is a preferred method. With long-lived isotopes, the laboratory management is committed to a prevention of contamination of the public domain. The association of groups of laboratories to provide a single controlled and economical disposal area may be feasible.

(2) Active solutions

The disposal of active solutions to the public sewers can only be considered safe when the possible subsequent chemical, physical, and biological concentrations will still leave the material at safe concentrations. Disposal to a water system should include consideration of the accumulation of activity in soil or mud, and in algae and similar organisms. Concentration of the order of 100,000 fold may occur. Whenever possible, the principal activity in the waste solution should be precipitated, and discarded as active solid material.

Urine from isotope-injected animals or patients, and liquors from equipment or clothing decontamination, may require attention as active solutions.

(3) Tools

Tools and other miscellaneous equipment used in handling long-lived isotopes should be regarded as contaminated and should not be released for other work until proven otherwise.

APPENDIX 14

EXCERPTS ON DISPOSAL OF RADIOACTIVE MATERIALS*

from

Isotopes Branch Circular B-1,
"General Rules and Procedures Concerning Radioactive Hazards"

1. Storage and handling of plutonium or similar hazardous substances
 - a. Quantities of plutonium greater than 1 microgram shall be securely covered during storage and kept in a hood equipped with doors, or in other spaces specifically accepted by the Health Division Director, or his representative, as suitable under the given circumstances. (Such as shelves constructed in an out-pocketing from existing hoods or separate boxes equipped with doors and vented to a proper exhaust.)
 - b. All transfer of materials between hoods and storage devices must be done in such a manner as to avoid the possibility of spillage or breakage. Double containers to eliminate contamination and breakage danger should be used.
 - c. Any work with materials susceptible to atmospheric distribution of plutonium** (that is, dusting, spillage, vaporizing, effervescence of solution, etc.) shall be done in an "adequate hood."
2. Disposal of materials contaminated with plutonium or similar hazardous substances. All discarded material which has been liable to plutonium contamination is to be buried. Distinctive cans are to be provided, and these handled with proper discretion. If a dust hazard is involved, a Health-Physics representative shall accompany the can when it is taken to be buried to see that respirators and protective clothing are used when needed. In rooms where large (1 to 2 microgram) amounts of plutonium are handled, a small red-closed can should be provided with a paper lining to receive waste of known contamination, so that the closed paper lining may afford some measure of protection against spread at the time of disposal.
3. Disposal of active trash, unwanted active materials or equipment
 - a. Two trash cans painted entirely red (both top and can) are to be provided at each desired location for trash which is contaminated.

*From AEC Regulation Safety No. 3, "Standard Safety Requirements"

**This rule applies to other radioisotopes which present a similar health hazard. (1 microgram approximately 1/16 microcurie)

APPENDIX 14 (Continued)

- b. Only one of these two cans should be used at a time and the one in use should be tagged by Supervision of the Area - "Use This Can."
 - c. It shall be the responsibility of supervision to see that these cans are monitored at sufficiently frequent intervals to prevent active materials from accumulating to such an extent that radiation levels of greater than 12.5 mr/hr occur.
 - d. Once a can has been labeled "Driver, O.K. to Pick Up," no more contaminated trash shall be put in that can. When the can has been emptied and returned, Maintenance should remove the tag so that it may be held in reserve while the second can is in use.
4. Burying ground - All contaminated material and equipment that is to be discarded shall be thrown only in the trenches provided for that purpose.
- a. Sufficient earth must cover active materials in a trench to keep the level of radiation at the top of the trench below 12.5 mr/hr.
 - (1) Keep sufficient earth over trash to prevent trash from being blown or floated outside the trench.
 - (2) Keep an adequate record of all equipment taken to the burial ground for burial or for storage.
 - b. The burial ground will be periodically surveyed.

APPENDIX 15

EXCERPTS ON DISPOSAL OF RADIOACTIVE MATERIALS

from

Atomic Energy Project,
University of California at Los Angeles,
"Health Physics Regulations"

by Stafford L. Warren, M.D., Project Director

DISPOSAL OF RADIOACTIVE WASTES AND CONTAMINATED MATERIALS:

The disposal of radioactive wastes must be carefully regulated so that the permanent or long-time high contamination of areas or disposal systems outside the control of this project or at the project does not occur.

I. Radioactive Wastes:

- a. In all laboratories where radioactive materials are handled no solutions are ever discarded into a sink or sewer unless the lack of activity or the approximate activity of the solution is known to be within the safe limit for disposal. (See I b 2 below for safe limit.)
- b. Usually the activity of a solution which has been used or involved in an experiment is known, thus when the disposal of one of these solutions is desired it will depend upon the nature of the active solution as to which method of disposal to follow:
 1. If the solution is highly active, then transfer to the "Solution Containers for Sea Burial."
 2. If the solution is of low or medium activity then, if practical, precipitate the activity out of the solution and the clear, alkaline solution of less than 1 microcurie per liter and not in excess of 10 liters per day may be discarded down the sewer with proper flushing.
 3. Active solids precipitated out of the active solutions or other active solid wastes shall be placed in the "Solid Waste Container for Sea Burial."

II. Contaminated Materials:

- a. Contaminated items of clothing or protective devices will be placed in large clean paper bags and turned into the Health Physics Section for disposal. The paper bag should

APPENDIX 15 (Continued)

be labeled with the nature of contents, degree of contamination (low, medium or high), date and name of person turning the item in.

- b. Contaminated glass or other discarded equipment, contaminated with long-lived activity, which are impracticable to decontaminate shall be placed in special container marked "Contaminated Glass and Other Waste for Sea Burial."
- c. Animal carcasses and organic materials containing short half-lived (one month or less) active materials may be disposed of by incineration, provided the total activity does not exceed 0.1 mc. per incineration.
- d. The disposal of animal carcasses and organic materials containing active materials of half-lives of longer than one month will be accomplished by placing these materials in the special containers that are labeled ("Contaminated Animal Wastes for Sea Burial").
- e. All laboratories where active materials are handled will have a special waste can containing paper bag lining and painted completely red for contaminated paper coverings, wipes and tissues. Although these red cans will be marked "Radioactive Waste Only," laboratory personnel should be reminded by their supervisor of the above regulations on the disposal of the various contaminated items and these cans reserved for contaminated papers, etc., only.

APPENDIX 16

REMARKS FORWARDED BY DR. EDITH H. QUIMBY

In patients receiving radioiodine therapy, unless it is desired to keep a record of excretions, it seems desirable not to preserve the urine at all, but to have it flushed away as voided. However, if it is desired to determine the total volume and measure a small part, it is usually possible to obtain the patient's own assistance in handling the material during the measurement, and afterward disposing of it. Here, of course, we come directly into collision with the various formulated rules concerning flushable waste, and I want to consider the situation in some detail, as it has been studied by the group of New York hospital physicists concerned with this problem.

General recommendations have been of the order of not more than 100 μc per flush, and not more than 5 mc per week down any particular drain. On the other hand, the Provisional Draft of the Report for the National Committee on Radiation Protection on Safe Handling of Radioisotopes sets a permissible level for water contamination as 0.1 μc per liter. According to information received from Mt. Sinai and Presbyterian Hospitals, a large hospital flushes into the sewage system about 1800 liters per day per person; thus for a 300 bed hospital, assuming two people per bed, - one patient and one employee, - this would be about a million liters. One hundred millicuries dispersed in this amount of water is 0.5 μc /liter. On this basis each hospital of this size could flush away 100 mc of I^{131} weekly without bringing the sum total of sewage contamination from its own drains above the permitted level. And evidently such hospitals represent a very small part of the total sewage water.

Of course questions immediately arise as to the rate of removal of the material from the individual drain to the general sewage system; how rapidly it gets diluted to this level, and whether it may be caught in traps or interact with material of the pipes to form an insoluble compound. The ordinary toilet uses about 10 liters per flush, and in a bathroom used by a number of patients would be flushed several times per hour. Thus the material would be quite rapidly pushed along into main sewers and into the general system. It is very unlikely that any stoppage or accumulation in traps would occur. In institutions where this type of disposal has been practiced, monitoring of the sewage lines has not shown appreciable activity. In one reported instance, following a large disposal, the background near a trap was appreciably raised for a time, but not to anything like tolerance level. In selecting drains for the disposal of such active material, precautions should be taken to assure that they do not run in the vicinity of any room where any Geiger-counting apparatus may be used. Where possible, a direct outlet to the main sewer is highly desirable. In a large hospital, where bathrooms are usually located in a tier, it is not likely that a bathroom drain will pass through or near a room in which measurements are being made.

APPENDIX 16

(continued)

If this type of disposal is practiced, it should always be borne in mind, however, that if any plumbing repairs are necessary in a sewage line containing possible contamination, traps or joints should be monitored upon opening, and so should waste removed from them, or water discharged at the time of the opening. This necessitates an understanding on the part of hospital personnel that the laboratory should be notified in the case of such repairs.

In the matter of disposal of radioactive wastes, it is the community at large that must be considered. No user of isotopes can consider his disposal problems as though he were the only one in the community working with them. Disposal measures adopted by any group at the present time in the light of its own uses and the known situation in the community, must be reviewed at frequent intervals.

APPENDIX 17

REMARKS FORWARDED BY DR. ALBERT H. HOLLAND, JR.

Submitted herewith are a few tentative proposals for the off-project disposal of isotopes.

It is not unreasonable to expect isotope users to retain short-lived isotopes, say, those with a half-life of thirty days or less, until the activity decreases to a safe level for disposal in city sewage systems. Therefore, in effect, we are concerned with the disposal of long-lived isotopes. This can be accomplished in the following ways:

- a. Calculated dilution and controlled disposal into city sewage systems.
- b. Burial in controlled university or institutional burial grounds. This, in my opinion, is not a safe procedure, at least for the present. We are currently studying some of the agricultural and geological problems associated with this procedure. Perhaps in a matter of six months to a year we will be able to draw valid conclusions concerning the advisability of this procedure.
- c. Disposal at sea. This probably is a satisfactory interim procedure for those institutions located near the oceans, but in the final analysis does not constitute a fool-proof approach.
- d. Concentration and return of long-lived materials to the regional laboratories of the Atomic Energy Commission. I do not believe we are particularly interested in operating a garbage disposal system. However, procedures could be worked out requiring the packaging of such material in disposable containers which would require a minimum of handling on our part. Pending the development of satisfactory information concerning local burial, this method of disposal appears to me to be the only one which we could publicly support and recommend.

APPENDIX 18

REMARKS FORWARDED BY DR. HYMER L. FRIEDEL

1. Disposal of material by off-Commission users should be the responsibility of these users with guidance only from the Atomic Energy Commission.
2. The individuals who are responsible for the disposal must have a clear understanding of the problem. This provides a greater safeguard than specific rules and regulations formulated by an outside agency.
3. If unusual means of disposal are required by off-Commission users, the whole project should be carefully studied at its inception - in other words, at the time that the allocation of the isotopes is made.
4. Emphasis should be placed on simple procedures such as dilution or addition of non-radioactive elements in rendering the materials non-toxic.

APPENDIX 19

REMARKS FORWARDED BY DR. ROBLEY D. EVANS

The exemption clause in the I.C.C. regulations for the transportation of radioactive materials was formulated out of the joint and unanimous suggestions of representatives of the AEC, hospitals, universities, film industries, etc. The U.S. Post Office has already indicated its intention of using the I.C.C. exemption clause as its definition of the maximum amount of radioactive material which may be put in a single package and will be regarded as having such a small activity as to be entirely nonhazardous, and therefore not subject to postal regulations of any type.

It occurs to me that in considering the disposal problem we will be obliged to specify what quantities of radioactive materials are exempt from the regulations. The numerical specification of such an exemption clause is always an arbitrary matter, but our problem may be considerably simplified if the committees involved would use the I.C.C. exemption clause. In this way an ideal measure of uniformity would be achieved.

(RESTRICTED)
(DISTRIBUTION)

AGENDA OF MEETING ON WASTE DISPOSAL
OF RADIOACTIVE MATERIALS BY OFF-COMMISSION USERS

U. S. Atomic Energy Commission
A. E. C. Building, Washington, D. C.
September 20, 1948.

I. Announcement of Meeting and Personnel Invited:

- A. Announcement of need for the meeting and names of persons invited, together with names of institutions with which they are affiliated, are found in Appendix 1.

II. Scope of Discussion:

- A. The discussion should pertain specifically to the disposal of radioactive waste materials of the types and quantities involved in off-Project utilizations.
- B. The discussion should not now emphasize the long-range problem, involving a total amount of distributed radioactive material which might be orders of magnitude larger than that delivered during the past 12 months. It is more desired now to concentrate on procedures which will serve safely for the next year or two during which the types of isotopes distributed will not change significantly and the total distributed quantities will most likely be much less than an order of magnitude larger. The immediate goal should be interim recommendations to guide off-Commission users now. These can be supplemented or modified in a year or two as dictated by program expansion and disposal experience.

III. Purpose of Meeting:

- A. To attempt to derive agreement among authorities on radioactive waste disposal within the Commission regarding means of disposal appropriate and practicable for off-Commission users of Commission supplied radioisotopes.
- B. To discuss the relative responsibilities of the Commission and the off-Commission users in the latter's disposal problems.
- C. To formulate quantitative criteria for disposal of certain classes of distributed radioisotopes which will guide off-Commission users in selecting specific disposal methods.

- D. To recommend the nature and extent of laboratory and field research which may be necessary to establish the aforementioned quantitative criteria.
- E. To formulate conditions for return of certain kinds of radioactive wastes to Commission facilities.

IV. Statement of the Problem:

- A. With the increased demand for the distribution of radioactive materials through Commission facilities, it is becoming increasingly apparent that an interim policy for the handling of radioactive waste materials should be adopted pending development of a long-range policy. Since recipients of radioisotopes agree to dispose of radioactive wastes in a safe manner (see App. 2), the Commission is obligated to define more specifically disposal procedures which under present knowledge and conditions may be considered safe.
- B. During the period from July 1, 1947, to July 1, 1948, 2191 shipments of radioisotopes were made from Commission facilities to off-Project users. (See App. 3.) This number is more than double the number of shipments made in the preceding year. Note however that only 0.539 percent of all the activity falls into Group III, classified as very hazardous by Subcommittee No. 6 of the National Committee on Radiation Protection. (See App. 4.) Of these, C 14 accounts for 0.0029 percent of the total activity shipped.
- C. In determining the nature and scope of a waste disposal program, account must be taken of the geographic location of the institution receiving isotopes and the quantities used. (See App. 5-A and 5-B.)
- D. It is pertinent to note that an appreciable expansion in the radioisotope distribution program is expected to take place during the next year primarily because of an increase in trained personnel. It is probable that this will include a considerable expansion in the field of industrial research and development. Many of the coming uses may require higher levels of activity and therefore accentuate the disposal problem. Also to be noted is the possibility, both on the part of industrial and medical investigators, of substituting Cobalt 60 for Radium and X-Rays, as an external source of radiation. However, the total yearly distributed quantity is not expected to reach an order of magnitude larger for several years or more.

V. General Considerations in Evaluating Disposal Problem:

- A. The nuclear and biological properties of the radioisotopes must be given primary consideration. (See App. 6, 7, and 8.)
- B. Consideration must also be given to specific chemical and physical properties of the compound containing the isotope.
- C. The aim should be to recommend procedures which are practical both from the point of view of the Commission and the user.
 1. Disposal procedures recommended by the Commission should be sufficiently feasible, both in the time and money involved, to induce faithful practice by off-Commission users, while maintaining adequately safe practices.
 2. Disposal procedures should not result in serious suppression of valuable researches and application of radioisotopes, unless absolutely necessary in the interests of general public health.
 3. Commission facilities should become involved in radioactive "garbage" collection only wherein absolutely necessary. Arrangements should not substantially increase the burden on scientific and technical personnel of Commission laboratories.

VI. Suggested Procedures for Consideration:

- A. Radioisotopes having half-lives of less than 30 days may be disposed of in the sewer, provided the daily volume of water ^{from the institution} flowing through the particular outlet ^{to the main sewer} used is sufficient to dilute the radioisotope to 0.1 microcuries per liter, or to safe limits of concentration as set for that particular isotope. This practice should be contingent on certain provisions such as:
 1. The maximum activity disposed of in any one institution will not exceed 100 mc. per week. (See App. 9 and 10.)
 2. Regular radiation surveys of the plumbing fixtures.
 3. Appropriate surveys before repairing the plumbing between the disposal outlet and the main sewer.
- B. Radioisotopes of any half-life may be buried in the earth, provided that they are uniformly diluted with stable isotopes of the same element to the extent that 4.15 ergs (equivalent to 50 mr/day in tissue) is dissipated per gram of element per day. (See App. 10), provided:

1. The burial is made only in suitably selected areas which are in possession of and will be maintained by the user. These areas should be properly marked and enclosed with suitable fencing. In case of possible release into the soil, a thorough geological investigation should be made of the area selected for burial purposes, and analyses should be provided of the soil, so that the fate of the material can be determined to be a safe dilution.
 2. The material must be buried at a minimum depth of 5 feet.
- C. Radioactive materials may be buried when properly enclosed in a container sufficiently well constructed to retain the isotope for a period of five years, provided
1. For materials having half-lives of < 2 years, the radioisotope is adulterated, prior to enclosure, with sufficient quantities of concrete or stable isotopes of the same element to reduce the dissipation of energy from the remaining activity at the end of 5 years to 4.15 ergs per gram of adulterant. The dosage rate at the surface of the container shall not exceed 6.25 mr/hr.
 2. For materials having half-lives of > 2 years, the radioisotope shall be adulterated, prior to enclosure, with sufficient quantities of concrete or stable isotope to reduce the dissipation of energy to the extent of 4.15 ergs per gram of adulterant per day.
 3. The burial is made in compliance with "B"-1, above.
- D. Materials may be buried at sea when enclosed under conditions stated in "C" above and buried beyond the three-mile limit.
- E. Materials containing radioisotopes may be incinerated if the calculations of safe permissible concentration in exhaust air and in disposed ashes are based on known values. In the absence of specific information, the following assumptions should be made:
1. For the air calculation, that all the active material escapes in the air.
 2. For the handling of the ashes, that all the activity is retained in the ashes. The ashes and/or effluent residue are then disposed of in accordance with Sections "B" and "C".

VII. Recommendations and advice on disposal of radioactive materials now given off-Commission users:

- A. Excerpts from circulated information on disposal of radioactive materials, as recommended by Commission groups, are appended.
1. Argonne National Laboratory. (See App. 12.)
 2. National Committee on Radiation Protection. (See App. 13.)
 3. Isotopes Division Circular B-1. (See App. 14.)
 4. K. Z. Morgan paper, "Tolerance Concentrations of Radioactive Substances," published in The Journal of Physical and Colloid Chemistry, Vol. 51, No. 4, July 1947. (For Comparative Summary of tolerance values, see Appendix 8.)

B. Advisory Field Service Branch of Isotopes Division:

The policy has been to discuss the general problems associated with disposal of radioactive materials and to recommend methods pertinent to the disposal of the particular isotope in question. The final decision as to the method has, however, been left to the isotope user.

- C. Excerpts from information on disposal, circulated by other groups.
1. Atomic Energy Project, University of California, Los Angeles. (See App. 15.)
 2. Correspondence from Dr. J. J. Mickson, Argonne National Laboratory, to Dr. Philip S. Owen, National Research Council. (See App. 11.)

VIII. Remarks prepared for Meeting by Persons Attending:

- A. Dr. Albert H. Holland, Jr., Medical Advisor, ORDO. (See App. 16.)
- B. Dr. Edith H. Gimby, Presbyterian Hospital, Columbia University. (See App. 17.)
- C. Dr. Hymor L. Friedell, Director, Division of Health Physics, Argonne National Laboratory. (See App. 18.)

APPENDIX 1

Oak Ridge, Tennessee
August 13, 1948

Subject: MEETING TO DISCUSS DISPOSAL OF RADIOACTIVE WASTES BY
OFF-COMMISSION USERS OF ISOTOPES

Dear .

As you are well aware, the increased use of radioisotopes distributed by the Commission, presents a growing problem with respect to the proper disposal of radioactive wastes by those outside Commission facilities.

The Isotopes Division has brought the problem to the attention of the General Manager, and arrangements have been made for the Washington Division of Biology and Medicine and the Oak Ridge Isotopes Division to work together in arranging a meeting to discuss off-Commission disposal methods. If possible the meeting should arrive at recommendations for suitable means of disposal to be used by off-Commission users of radioisotopes.

Accordingly, a meeting has now been arranged on this subject for 10:30 a.m., Monday, September 20, in the conference room, AEC Headquarters, Washington, D.C. Knowing that you are one of those directly concerned with this subject, you are cordially invited to attend.

This first meeting will largely be confined to persons connected with the AEC or its contractors, for one of the aspects to be discussed is a system under which certain types of waste might be returned to Commission facilities for disposal. A few persons who are concerned with the use of large quantities of radioisotopes outside Commission facilities are being invited to present the viewpoint of off-Commission users.

It is realized that the National Committee on Radiation Protection is organizing a subcommittee to be concerned with decontamination and disposal of radioactive wastes. It is not our intention to duplicate the functions of this subcommittee, but rather to prepare the way by attempting to derive a certain degree of agreement within the Commission on means of disposal appropriate for off-Commission users, also on conditions for the return of certain

Appendix 1 (Cont.)

radioactive wastes to Commission facilities. The National Committee on Radiation Protection will have the more general problem to derive recommendations for disposal of all radioactive materials, including natural radioactive materials, and radioactive materials produced by nuclear bombardment devices.

A list of the persons being invited is appended.

The Isotopes Division is preparing an agenda which it hopes to send out in advance of the meeting. We would appreciate very much your sending us any pertinent papers or correspondence which you may have written on this subject. We would also like to receive in advance a brief outline of your thoughts and recommendations on means of disposal by off-Commission users. The meeting will accomplish much more if each of those attending has prepared comments and recommendations in advance, especially if these are sent to us in sufficient time for reproduction and circulation.

First, please inform me as soon as possible of your intention to attend the meeting. Second, please send me, by September 7, any comments or material which will be pertinent to facilitate action at the meeting.

With best personal regards,

Very truly yours,

Paul C. Aebbersold, Chief
Isotopes Division
Oak Ridge Operations

Encl.:
Appendix-list

Appendix 1 (Cont.)

LIST OF PERSONS INVITED TO ATTEND COMMISSION MEETING ON
DISPOSAL OF RADIOACTIVE WASTES BY OFF-COMMISSION USERS
OF ISOTOPES

FROM THE AEC STAFF:

1. Dr. A.H. Holland, Jr., Medical Advisor, ORDO
2. Dr. Bernard Wolfe, Medical Advisor, NYDO
3. Mr. Carl Braestrup, Consultant, NYDO

FROM AEC CONTRACTORS:

1. Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Carbide and Carbon Chemicals Corporation, Oak Ridge
2. Dr. H.M. Parker, Director, Health Physics Division, General Electric Company, Hanford, Washington
3. Dr. Leslie Nims, Director, Division of Biology, Brookhaven National Laboratory, Upton, New York
4. Dr. S. P. Cowan, Health-Physics Department, Brookhaven National Laboratory
5. Mr. Nelson Garden, Department of Chemistry, Radiation Laboratory, University of California, Berkeley, California
6. Dr. Austin M. Bruce, Director, Division of Biology, Argonne National Laboratory, Chicago, Ill.
7. Dr. J. E. Rose, Director, Division of Health Physics, Argonne National Laboratory, Chicago, Ill.
8. Dr. Wm. F. Bale, Radiologist, University of Rochester, Rochester, New York
9. Dr. Hymor L. Friedell, Director, AEC Medical Research Project, Western Reserve University, Lakeside Hospital, Cleveland, Ohio

OFF-COMMISSION USERS:

1. Dr. Edith Quimby, Presbyterian Hospital, Columbia University, 630 West 168th Street, New York 32, N.Y.
2. Dr. Robley D. Evans, Professor of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts

In addition the following persons will also attend: appropriate personnel from the Division of Biology and Medicine and other members of the Washington office staff; Dr. N.H. Woodruff, Mr. G.W. Morgan and myself from the Isotopes Division, Oak Ridge.

P.C.A.
August 12, 1948

APPENDIX 2

EXCERPTS FROM ACCEPTANCE OF TERMS AND CONDITIONS
FOR ORDER AND RECEIPT OF BYPRODUCT MATERIALS (RADIOISOTOPES)

The pertinent items are:

8. Title to and possession of all byproduct materials purchased or acquired from the Oak Ridge National Laboratory, or from any source on the authorization or approval of the Commission, remain subject to the Commission's statutory right to recall. The Commission may recall such materials if the applicant (1) fails to observe such safety standards as are or may be established by the Commission, (2) uses the materials in violation of law or regulations of the Commission, or (3) uses the materials in a manner other than as disclosed in his application therefor. Title to any byproduct materials recalled by the Commission shall vest in the Commission with the exercise of this right, and the Commission may enter and take possession of said materials any time after notice is given that the materials are being recalled; provided, that if requested, the applicant, at his expense, will make shipment of the recalled materials to a destination designated by the Commission.
9. The applicant shall permit the Commission to make such inspections of his facilities wherein byproduct materials are stored or used as the Commission may deem necessary, and shall make available to the Commission the records required to be kept by the provisions hereof.
10. The applicant will keep accurate and complete records showing the receipt, use, storage, delivery and disposal of byproduct materials,

APPENDIX 2 (Continued)

the disposal of waste or discard byproduct materials, and the safety measures used to protect health. The applicant will report to the Commission every delivery or transfer made to any person (as defined in the Atomic Energy Act of 1946), giving the name of the transferee, type and amount of byproduct material, and date of delivery or transfer.

APPENDIX 3

NUMBER OF RADIOISOTOPE SHIPMENTS AND AMOUNT
OF RADIOACTIVITY SHIPPED BY HALF-YEAR PERIODS

ISOTOPE	July 1, 1946 to Dec. 31, 1946		Jan. 1, 1947 to June 30, 1947		July 1, 1947 to Dec. 31, 1947		Jan. 1, 1948 to June 30, 1948		Total to June 30, 1948	
	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount	Ship- ments	Amount
Separated C ¹⁴	48	45 mc	41	84 mc	67	210 mc	67	260 mc	223	599 mc
Separated I ¹³¹	67	2053 mc	206	8243 mc	281	10945 mc	450	19765 mc	1004	41006 mc
Separated P ³²	35	1757 mc	180	8647 mc	293	11464 mc	361	13978 mc	869	35846 mc
Separated S ³⁵	--	--	10	63 mc	12	291 mc	13	212 mc	35	566 mc
Separated Ca ⁴⁵	--	--	--	--	4	0.017 mc	--	--	4	0.017 mc
Fission Products	10	1112 mc	15	467 mc	15	284 mc	28	461 mc	68	2324 mc
Irradiated Units	85	85 units	243	256 units	263	266 units	286	311 units	877	918 units
Service Irradiations	1	1 irra- diation	4	4 irra- diations	18	18 irra- diations	33	33 irra- diations	56	56 irra- diations
Total	246		699		953		1258		3136	

mc = millicurie

APPENDIX 4

DISTRIBUTION OF ISOTOPES CLASSIFIED ACCORDING TO DEGREE OF HAZARD,
AS SPECIFIED BY SUBCOMMITTEE OF THE NATIONAL COMMITTEE
ON RADIATION PROTECTION

(Period covered: June 1, 1947, to July 1, 1948.)

<u>Isotope</u>	<u>Total Amount of Isotope Shipped in Millicuries</u>
<u>SLIGHT HAZARD</u>	
Na ²⁴	4,521
K ⁴²	8,710
Cu ⁶⁴	2,800
Mn ⁵²	0
As ⁷⁶	25
As ⁷⁷	2.1
Kr ⁸⁵	0
Hg ¹⁹⁷	0
Total	<u>16,058.1</u>
Per cent of total millicuries shipped	9.65

MODERATELY DANGEROUS

Tc ¹²⁷	0
Te ¹²⁹	0
I ¹³¹	61,774
Cs ¹³⁷	7
Ba ¹⁴⁰	65
La ¹⁴⁰	80
Ce ¹⁴¹	200
Pr ¹⁴³	2
Nd ¹⁴⁷	1
Ar ¹⁹⁸	8,560
Ar ¹⁹⁹	10
Hg ^{203, 205}	250
H ²	0
P ³²	76,612
S ³⁵	1,227
Cl ³⁶	.05
Mn ⁵⁴	0
Fe ⁵⁹	21
Co ⁶⁰	690
Sr ⁸⁹	31.5
Cb ⁹⁵	1
Ru ¹⁰³	5
Ru ¹⁰⁶	1
Total	<u>149,537.55</u>
Per cent of total millicuries shipped	89.81

APPENDIX 4

(continued)

<u>Isotope</u>	<u>Total Amount of Isotope Shipped in Millicuries</u>
<u>VERY DANGEROUS</u>	
C ¹⁴	488.7
Ca ⁴⁵	177
Fe ⁵⁵	2.8
Sr ⁹⁰	0
Y ⁹¹	56
Zr ⁹⁵	174
Ce ¹⁴⁴	0
Cl ¹⁴⁷	0
Bi ²¹⁰	0
Total	<u>897.8</u>
Per cent of total millicuries shipped	0.54

APPENDIX 5-A

QUANTITY OF FOLLOWING ISOTOPES RECEIVED BY LISTED CITIES
 WITHIN A PERIOD FROM JUNE 1, 1947 TO JUNE 1, 1948

(MC)

Isotope	Dallas	New York	Boston	Chicago	Philadelphia	Cleveland
I 131	1,220	14,263	7,129	4,330	17,166	1,235
P 32	1,230	18,116	20,294	1,356	1,300	1,210
S 35	0	63	20	43	0	0
Na 24	0	330	720	0	0	400
K 42	0	2,080	4,680	0	0	0
Co 60	0	0	60	0	0	0
C 14	0	37	106	31.5	3	2
Sr 89	0	150	55	3	0	0
Au 198	1,920	80	0	0	0	0
Ag 110	0	0	0	0	0	0
Cl 36	0	0	0	0	0	0
Cs 45	0	.8	11.6	10	0	0
Fe 55, 59	0	0	6.6	11.4	0	0

APPENDIX 5-B

EXAMPLES BASED ON ACTUAL DISTRIBUTION

Equilibrium quantities of I^{131} and P^{32} in sewage system at the following institutions or cities, assuming that all material received was disposed of in sewer at the rate of $1/52$ of total millicuries each week (period July 1947 to July 1948):

<u>Institution or City</u>	<u>Isotope</u>	<u>Amount Received in Millicuries</u>	<u>Complete Disposal by Sewer Equilibrium Value in Millicuries</u>
Memorial Hospital	I^{131}	4,000	129.8
	P^{32}	1,400	79.6
Mayo Foundation	I^{131}	2,800	89.0
	P^{32}	1,200	67.8
New York City	I^{131}	14,263	517.0
	P^{32}	18,116	147.0
Cleveland	I^{131}	1,235	39.2
	P^{32}	1,210	68.6

APPENDIX 5-C

EQUILIBRIUM VALUE OF DISPOSED MATERIAL

Assume a disposal rate of 1 mc/week, then:

Isotope	$T_{\frac{1}{2}}$	Equilibrium Time (1)	Millicuries at Equilibrium (2)
C ¹⁴	5,100 y	30,600 y	383,735.3
P ³²	14.3 d	85.8 d	2.94
I ¹³¹	8 d	48 d	1.65
H ³	12 y	72 y	902.9
S ³⁵	87.1 d	522.6 d	17.96
Ca ⁴⁵	180 d	1,080 d	37.1
Au ¹⁹⁸	2.7 d	16.2 d	.556
Na ²⁴	14.8 h	88.8 h	.127

(1) Note: Transient radioactive equilibrium will be reached closely in about 6 half-lives of the daughter. For the purpose of these calculations, the activity is considered as growing in at the rate of 1 mc/week. Reference MDDC-763, page 45.

(2) Equilibrium value (Q) = $\frac{R}{\lambda}$

R = rate material is added/day

$\lambda = 0.693/T_{\frac{1}{2}}$ in days

APPENDIX 6

HALF-LIFE < 5 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Antimony 122	1.36, 1.94	0.57	50
Arsenic 76	1.1, 1.7, 2.7	0.57, 1.25	25
Arsenic 77	0.8	None	10.70
Bromine 82		0.547, 0.787	70
Cadmium 115	1.33, 0.6	0.65	20
Copper 64	0.58 B ⁻ 0.66 B ⁺ K	1.2 (weak)	100
Gallium 72	3.1, 0.8	0.84, 2.25	25
Gold 198	0.97	0.44	80
Gold 199	1.01	0.45	10
Iridium 194	2.07	0.38, 1.65	40
Lanthanum	0.9 (20%) 1.40 (70%) 2.12 (10%)	1.63 complex	40
Mercury 197	K, e ⁻ K, e ⁻	0.075 0.13, 0.16	95
Molybdenum 99	1.3	0.77, 0.815 0.84	40
Potassium 42	3.58 (75%) 2.07 (25%)	1.51 (25%)	130
Praseodymium 142	2.14	1.9	40
Rhenium 186	1.0	None	75
Ruthenium 97	K, e ⁻	0.22, 0.18	10
Samarium 153	0.73	0.1, 0.57 (weak)	16

APPENDIX 6 (CONT'D)

HALF-LIFE < 5 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Rhodium 105	0.5	0.3	10
Sodium 24	1.4	1.4, 2.8	20
Tungsten 187	0.6, 1.3	0.086 - 0.94 complex	40
Yttrium 90	2.16	None	100

HALF-LIFE - 5 - 10 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Bismuth 210	1.17	None	10
Iodine 131	0.6	0.367, 0.08	130
	I.T., e ⁻	0.055, 0.082	10
Silver 111	1.0	None	10

HALF-LIFE = 10 - 15 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Barium 131	K, e ⁻	1.2 (weak)	6.0
Phosphorus 32	1.69	None	1500
Phosphorus 32	1.69	None	350

HALF-LIFE = 15 - 30 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Cerium 141	0.55	0.21	50
Chromium 51	K	0.32	50
Osmium 193	0.35	Present	40
Palladium 103	K	None	Undetermined
Rubidium 86	1.60	None	100

APPENDIX 6 (CONT'D)

HALF-LIFE = 30 - 60 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Cadmium 115	1.85	~0.5	1
Hafnium 181	0.8	0.5	50
Indium 114	I.T.e ⁻ 1.95	0.19	10
Iron 59	0.26, 0.46	1.1, 1.3	1.0
Mercury 203, 205	0.3	0.28	135
Strontium 89	1.5	None	1.5

HALF-LIFE = 60 - 90 DAYS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Antimony 124	0.53, 2.25	1.72	4
Iridium 192	0.59	0.2 - 0.6 complex	40
Scandium 46	0.36	1.12, 0.90	750
Sulfur 35	0.17	None	1.0
Titanium 51	0.36	1.0	0.09
Tungsten 185	0.6, 1.3	None	10
Zirconium 95	1.0 (2%) 0.394 (98%)	0.73 0.92	12

HALF-LIFE = 90 - 180 DAYS (6 MONTHS)

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Selenium 75	K, e ⁻	<0.3 complex 0.5	65
Tantalum 182	0.53	1.13, 1.22 1.0 complex	40

APPENDIX 6 (CONT'D)

HALF-LIFE = 6 MONTHS (180 DAYS) -- 2 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Calcium 45	0.250	None	0.8
Silver 110	0.59	0.66 (44%) 0.90 (47%)	35
Zinc 65	0.4 B ⁺	1.40 (9%) 1.14	15

HALF-LIFE = 2 TO 3 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Antimony 125	0.8, 0.3	Present	1
Cesium 134	0.645	0.584, 0.776 (95%) 1.35 (5%)	20
Thallium 204	0.58	None	7

HALF-LIFE = 3 TO 5 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
(61) 147 (illinium)	0.223	None	1.001

HALF-LIFE = 5 TO 10 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Cobalt 60	0.3	1.1, 1.3	20
Europium 154	0.34 (50%) 0.82 (50%)	1.4 et al	40

HALF-LIFE = >10 YEARS

Element	Radiation (Mev)		Estimated Quantity Per Unit (mc)
	Beta	Gamma	
Chlorine 36	0.66	None	0.005
Nickel 59	K, e ⁻		1
Technetium 99	0.3	None	0.00001
Carbon 14	0.154	None	

APPENDIX 7.

EQUILIBRIUM RETENTION OF ACTIVITY IN MAN
ON THE BASIS OF 4.15 ERGS/GM/DAY
OR 50 MR/DAY

Element	Total Content Gms/Man	Isotope	μc Present to Produce 50 mr/day (4)	<i>Marinelli</i> D. A. R. (5)	Permissible μc/man on Basis of D. A. R.	Permissible μc/gm of Element on Basis of D.A.R.	Minimum Permissible Dilution by Stable Element <i>gm/μc</i>
C	12,950	C ¹⁴	1100	1	1100	0.0849	62 11.76
		C ¹⁴	1100	10	110	0.00849	117.6
		C ¹⁴	34(3)	---	---	---	---
P	.670	P ³²	100	1	100	0.149	680 6.71
		P ³²	100	10	10	0.0149	67.1
S	112	S ³⁵	1010	1	1010	9.017	68 .1109
		S ³⁵	1010	10	101	0.9017	1.109
Ca	1,160	Ca ⁴⁵	678	1	678	0.584	202 1,713
		Ca ⁴⁵	678	16.6(1)	40.8	0.035	28.58
I	0.020	I ¹³¹	86	1	86	4300	787 .0002325
		I ¹³¹	86	1168(2)	0.0736	3.75	.2666
Fe	4.375	Fe ⁵⁹	21.3	1	21.3	4.868	3.22x10³ .2055-
		Fe ⁵⁹	21.3	10	2.13	0.4868	2.055-
Na	63	Na ²⁴	12.1	1(1)	12.1	0.192	5.68x10³ 3521
K	150	K ⁴²	39.5	1(1)	39.5	0.263	1.75x10³ 3:80

(1) Known D. A. R. value.

(2) Calculated D. A. R. value from Skohl, Mineral Metabolism.

(3) Dr. Austin Brues' value.

(4) Assuming equal distribution.

(5) D. A. R. for any tissue, this is the ratio of concentration of an isotope in that tissue to the average concentration in the body (neglecting excretion). Marinelli - "Dosage Determination with Radioactive Isotopes." The American Journal of Roentgenology and Radium Therapy, Vol. LIX, No. 2, Feb. 1948.

A COMPARATIVE SUMMARY OF SOME TOLERANCE VALUES*

Method of Body Intake	Organ Affected and Fraction of Amount in Body That is in Organ	Fraction Taken into Body that Reaches Organ	%c in Organ to Produce Tolerance Rate When t = 0	%c in Organ to Produce Average Tolerance Rate	One-Year Tolerance Concentration rate	One-Year Tolerance Concentration in Air	One-Year Tolerance Concentration in Water
					μc/sec.	μc/cc.	μg/cc.
Breathing	Lungs (0.5)	0.25	0.013	0.23	7.5x10 ⁻⁹	2.0x10 ⁻¹⁰	4.4x10 ⁻⁶
Ingestion	Bone (0.6)	0.05	0.155	0.16	5.1x10 ⁻⁹	2.0x10 ⁻¹⁰	4.4x10 ⁻⁶
Breathing	Lungs (0.3)	0.25	0.035	0.15	4.7x10 ⁻⁹	1.3x10 ⁻¹⁰	2.0x10 ⁻³
Ingestion	Bone (0.6)	0.0003	0.42	0.43	1.4x10 ⁻⁸	2.5x10 ⁻⁹	3.1x10 ⁻²
Breathing	Bone (0.6)	0.0375	0.42	0.43	1.4x10 ⁻⁸	4.0x10 ⁻⁸	
Breathing	Lungs (0.3)	0.25	0.041	0.17	5.5x10 ⁻⁹	1.5x10 ⁻¹⁰	
Breathing	Lungs (0.3)	0.25	0.039	0.16	5.1x10 ⁻⁹	1.4x10 ⁻¹⁰	
Breathing	Lungs (0.3)	0.25	0.037	0.156	5.0x10 ⁻⁹	1.3x10 ⁻¹⁰	
Breathing	Kidneys (0.05)	0.011	0.010	0.033	1.0x10 ⁻⁹	6.4x10 ⁻¹⁰	4.5x10 ⁻⁵
Ingestion	Kidneys (0.05)	0.001	0.010	0.033	1.0x10 ⁻⁹	1.4x10 ⁻¹⁰	1.0x10 ⁻⁸
Ingestion	Bone (0.5)	0.075	32	190	6.0x10 ⁻⁶		3.4x10 ⁻³
Ingestion	Bone (0.5)	0.075	88 (20)*	34	11x 10 ⁻⁶		6.2x10 ⁻⁴
Breathing	Lungs (0.3)	0.25	32	130	4.3x10 ⁻⁶	1.2x10 ⁻⁷	2.6x10 ⁻⁸
Breathing	Total Body (1)	0.25	2260	5.7x10 ⁴	1.8x10 ⁻³	4.8x10 ⁻⁵	1.1x10 ⁻⁵

A COMPARATIVE SUMMARY OF SOME TOLERANCE VALUES*

Element	Grams per Curie	Assumed Effective Half-Life	Method of Body Intake	Organ Affected and Fraction of Amount in Body That is in Organ	Fraction Taken into Body that Reaches Organ	Organ to Produce Tolerance Rate When t = 0	µg in Organ to Produce an Average Tolerance Duration	µCi/
Ra 226 pdts	1	~2 weeks	Breathing	Lungs (0.5)	0.25	0.013	0.23	7.5
Ra 226 pdts	1	~10 yr.	Ingestion	Bone (0.6)	0.05	0.155	0.16	5.1
Pu 239	16	2 months	Breathing	Lungs (0.3)	0.25	0.035	0.15	4.7
Pu 239	16	10 yr.	Ingestion	Bone (0.6)	0.0003	0.42	0.43	1.4
Fu 239	16	10 yr.	Breathing	Bone (0.6)	0.0375	0.42	0.43	1.4
Natural U	1.47x10 ⁶	2 months	Breathing	Lungs (0.3)	0.25	0.041	0.17	5.5
Enriched U U233	2.7x10 ⁴	2 months	Breathing	Lungs (0.3)	0.25	0.039	0.16	5.1
Po 210	2.24x10 ⁻⁴	82 days	Breathing	Kidneys (0.05)	0.011	0.010	0.033	1.0
Po 210	2.24x10 ⁻⁴	82 days	Ingestion	Kidneys (0.05)	0.001	0.010	0.033	1.0
Sr 89	3.7x10 ⁻⁵	43 days	Ingestion	Bone (0.5)	0.075	32	190	6.0
Sr 90 → Y90	7.74x10 ⁻³	Sr-197 days Y-2.49 days	Ingestion	Bone (0.5)	0.075	88 (20)*	34	1.2
C14 (graphite)	0.23	2 months	Breathing	Lungs (0.3)	0.25	32	130	4.4
C14 (CO2)	0.23	10 days	Breathing	Total Body (1)	0.25	2260	5.7x10 ⁴	1.8

APPENDIX 8

(Continued)

Method of Body Intake	Organ Affected and Fraction of Amount in Body That is in Organ	Fraction Taken Into Body that Reaches Organ	μc in Organ to Produce Tolerance Rate when $t = 0$	μc in Organ to Produce an Average Tolerance Rate during Year	One-Year Tolerance Concentration rate	One-Year Tolerance Concentration in Air	One-Year Tolerance Concentration in Water
				$\mu\text{c}/\text{sec}$	$\mu\text{c}/\text{cc}$	$\mu\text{E}/\text{cc}$	$\mu\text{E}/\text{cc}$
Breathing	Lungs (0.02)	0.25	320	1.3×10^{-3}	3.5×10^{-5}	9×10^{-9}	
Ingestion or Breathing	Thyroid (0.2)	0.20	2.0	2.6×10^{-6}	8.5×10^{-8}	6.8×10^{-13}	5.5×10^{-4} 4.4×10^{-9}
Submersion	Body Blood (0.25)	0.25	2.2	3.0×10^{-5}	6.3×10^{-7}	7.1×10^{-14}	4.9×10^{-4} 5.5×10^{-11}
Ingestion or Breathing	Lungs (0.037)	0.037	0.5	8.2×10^{-6}	1.5×10^{-6}	1.7×10^{-13}	9.5×10^{-3} 1.1×10^{-9}
Submersion	Body				4.2×10^{-6}	1.5×10^{-11}	3.2×10^{-3} 1.1×10^{-8}
Ingestion or Breathing	Bone (0.9)	0.09	39	2.4×10^{-5}	1.8×10^{-6}	6.2×10^{-12}	0.011 4.0×10^{-8}
Ingestion or Breathing	Bone (0.6)	0.06	48	5.3×10^{-6}			3.8×10^{-3} 5.1×10^{-8}
Ingestion or Breathing	Skin (0.2)	0.05(0.1)**	150	4.7×10^{-5}	3.1×10^{-6}	7.3×10^{-11}	0.041 9.4×10^{-7}
Ingestion or Breathing	Bone (0.99)	0.15(0.4)**	190	1.3×10^{-5}	2.1×10^{-7}	1.3×10^{-11}	3.6×10^{-3} 2.2×10^{-7}

$5 \times 10^{-23} = \sqrt[3]{R} \text{ rad}$

APPENDIX 8
(Continued)

Element	Grams per Curie	Assumed Effective Half-Life	Method of Body Intake	Organ Affected and Fraction of Amount in Body That is in Organ	Fraction Taken Into Body that Reaches Organ	μc in Organ to Produce Tolerance Rate when $t = 0$	μc in Organ to Produce an Average Tolerance Rate during Year	One-Year Tolerance Concentration rate	On an anti-
H^3 (water)	2.59×10^{-4}	2 days	Breathing	Lungs (0.02)	0.25	320	4×10^4	1.3×10^{-3}	1.
I^{131}	8×10^{-6}	6.3 days	Ingestion or Breathing	Thyroid (0.2)	0.20	2.0	81	2.6×10^{-6}	3. 8.
Na^{24}	1.13×10^{-7}	14.8 hrs.	Submersion	Body	0.25	2.2	960	3.0×10^{-5}	6. 8.
Na^{24}	1.13×10^{-7}	14 hrs.	Ingestion or Breathing	Blood (0.25)	0.25	2.2	960	3.0×10^{-5}	6. 8.
Na^{24}	1.13×10^{-7}	11.5 hr.	Ingestion or Breathing	Lungs (0.037)	0.037	0.5	258	8.2×10^{-6}	1.
P^{32}	3.48×10^{-6}	14.3 days	Breathing or Submersion	Body	0.09	39	750	2.4×10^{-5}	4. 1.
P^{32}	3.48×10^{-6}	13 days	Ingestion or Breathing	Bone (0.9)	0.09	39	750	2.4×10^{-5}	1.
Ba^{140}	1.33×10^{-5}	Ba-11.75 days	Ingestion	Bone (0.6)	0.06	48	170	5.3×10^{-6}	3.
La^{140}	1.51×10^{-5}	La-1.51 days	Breathing	Bone (0.6)	0.06	48	170	5.3×10^{-6}	3.
S^{35}	2.3×10^{-5}	25 days	Ingestion or Breathing	Skin (0.2)	0.05(0.1)**	150	1500	4.7×10^{-5}	3.
Ca^{45}	6.15×10^{-5}	150 days	Ingestion or Breathing	Bone (0.99)	0.15(0.4)**	190	400	1.3×10^{-5}	2.

APPENDIX 8
(continued)

Table: A Comparative Summary of Some Tolerance Values. (Continued)
Explanation of contents of table.

The tolerance values in columns 9, 10, 11, 12 and 13 are for continuous exposure. If the exposure is for a 40-hr. week, multiply these values by 4.2.

Column 9 is the tolerance concentration rate, in $\mu\text{c}/\text{sec.}$, to the body organ that will produce a tolerance rate of exposure after 365 days of consumption.

It should be noted that the values given in column 6 depend on the chemical form and in the case of inhalation they depend upon the size of the particles. Until the most likely forms of these elements in a given laboratory are known, it is difficult to assign typical values of tolerance concentration in columns 10, 11, 12 and 13.

Values in column 9 can be obtained by dividing values in column 8 by the seconds in a year.

Column 8 is the $\mu\text{c.}$ in the lung, bone, kidney, or blood required to irradiate the organ with 3.65 roentgens of α or 36.5 roentgens of $\beta\gamma$ in a year. It is the $\mu\text{c.}$ in the thyroid required to irradiate it with 365 roentgens of β in a year.

*The Sr-Y activity reaches a maximum after 15 days. The 88 $\mu\text{c.}$ is required to produce tolerance exposure rate soon after Sr reaches the bone. Only 20 $\mu\text{c.}$ is required to produce tolerance exposure rate on the 15th day. The 34 $\mu\text{c.}$ produces an average yearly tolerance dose.

**It is assumed that the fraction reaching the skin by way of the gut is 0.05 and by way of the lungs is 0.1 in the case of S^{35} . For Ca^{45} it is assumed that 0.15 reaches the bone by way of the gut and 0.4 by way of the lung.

APPENDIX 9

EXAMPLE OF DATA ON CITY SEWAGE

Report on the Pollution of Tennessee River in and
Near Knoxville and Sewage Treatment for Knoxville

Chemical analysis of city water based on 6 months average for 1945:

pH	7.6	p.p.m.	Carbonate Alkalinity	0	p.p.m.
SiO ₂	5.0	"	Total Alkalinity	70.0	"
Fe	0.02	"	SO ₄	31.0	"
Al ₂ O ₃	0.85	"	Cl	24.0	"
Ca	40.0	"	Dissolved Solids	180.0	"
Mg	5.0	"	Soap Hardness	120.0	"

Waste from Tennessee Packing Company:

Annual average waste of 24,000 would contain 3,200 pounds of suspended solids and 2,560 pounds of B.O.D.* per day.

In 1944: Per Capita
 Industrial Use 38 gallons Domestic Use 49 gallons Population 160,000

Water pumped per capita for Knoxville = 88 gallons per 24 hours

The total load of suspended solids and 5-day B.O.D.* in the raw sewage for 1945 is estimated to be as follows:

<u>Year</u>	<u>Pounds per 24 hours suspended solids 5-day B.O.D.</u>	
1945	42,000	49,500

Average sanitary sewage flow is 24.7 million gallons per day.

There are 32 sanitary sewer outlets into the river at Knoxville.

*Biological Oxygen Demand

APPENDIX 10 .

RADIOISOTOPE ADULTERATION

ELEMENT DILUTION WHICH WILL ACHIEVE ADULTERATION
TO 4.15 ERGS/GM/DAY IN THE ADULTERANT

Isotope	Total Absorbable Energy per Disintegration	Kilograms of Adulterant per mc of Isotope	Liters of Element Time = 0	Liters of Element Time = 30 days	Liters of Water Time = 0	Liters of Water Time = 30 days	Liters of Earth Time = 0	Liters of Earth Time = 30 days
C14	5.08×10^{-2}	62	17.6	17.6	62	61.9	11.2	11
P32	.558	680	309	72.5	680	159.5	123	28.9
I131	.645	787	159.3	11.8	787	58.5	142.5	10.6
H3	4.95×10^{-3}	6	66.8	66.5	6	5.97	1.1	1.09
S35	5.61×10^{-2}	68	34	26.8	68	53.49	12.4	9.75
Ca45	.083	101	65.7	58	101	89.6	18	16.2

Note:- 4.15 ergs/gm of tissue is considered a safe permissible daily dose.

APPENDIX 11

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIALS

from

Dr. J. J. Nickson, Director, Medical Division,
Argonne National Laboratory,

to

Philip S. Owen, M.D., National Research Council,

concerning

"Protection Against Radiation Hazards"

Disposal of Waste Radioactive Materials

Wastes which contain less than 0.1 mc/liter in a clear alkaline solution are classified as radioactive wastes which may be discarded into the usual city sewer system. Acid solutions should not be discarded in this fashion because of the danger of precipitation of the radioactive material when the activity comes in contact with the organic material in the sewer. Animal carcasses and excreta are here discarded by collection and storage in a suitable monitored guarded area. Should incineration be considered as a means of disposal of organic wastes containing radioactive materials it is obvious that monitoring of the content of activity in the air should be done at all times.

Perhaps a brief description of our waste disposal system here might be in order. We have set up a system whereby all material contaminated with radioactive material is placed in special containers which are to be used only for such materials. At least one container is present in every room in which radioactive material is handled in the laboratory. In addition suitable containers (usually stainless steel) for solutions containing radioactive materials in excess of the 0.1 mc/liter figure given above are placed in several of the laboratories in each building so that the solutions which are not to be dumped down the sink can find a suitable resting place. Both the dry active waste containers and the liquid active waste containers are collected at intervals dictated by their use; the material transferred to large containers are taken to a guarded monitored area and there held.

It is recognized that such a system is expensive. However, we do not feel justified in allowing dry active wastes or liquid active wastes to enter the normal channel of waste disposal if we can humanly avoid it. Even with this system it has been necessary to routinely monitor all ordinary dry active wastes leaving the project because, on occasion, through error or through indifference, dry wastes contaminated with radioactive materials are placed in the non-active waste containers.

It cannot be too strongly recommended that all these wastes should be placed in a holding area under the control of the institution in

APPENDIX 11 (Continued)

question. It is desirable that the holding containers be of such a nature that they can be readily transported without over-exposure to the personnel involved. It is hoped that the national policy will be decided within an interval which will not necessitate too large local holding areas.

It is my feeling that any local decisions by any given institution to make definitive disposal of radioactive wastes should be discouraged. Although we do not ordinarily consider it so, the sea is a finite body. Should all countries decide to use the ocean as a dumping ground for radioactive materials, it is possible to foresee a condition in not too many generations in which plant and animal life within the ocean (which are capable of concentrating many fold the activity present in the water) would contain a radiation level which on a long term basis would be harmful to humans.

APPENDIX 12

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIALS

from the

Argonne National Laboratory manual,
"Radiation Hazard Control"

1. Contaminated Dry Objects

1.1 Dry Active Waste Cans. Contaminated dry objects such as glassware, used kleenex, and contaminated apparatus should be placed in the Dry Active Waste Cans for disposal by the Safety Section. The Health Physics group should be contacted before attempting to dispose of any appreciable activity in this manner.

When alpha active material in an amount greater than microgram levels is placed in a Dry Active Waste Can, the scientist is responsible for notification of the Health Physics Division. This is important because it is very difficult or even impossible for the surveyor to tell how much alpha activity may be present in the Dry Active Waste Can.

Under no circumstances should active solutions be placed in these cans.

1.2 Material which cannot be placed in the Dry Active Waste Cans. Articles which are too large to be placed in these cans, such as: ring stands, tripods, pieces of masonite, transite, plaster boards, pipes, etc., should be checked by Health Physics, labelled, and arrangement for their disposal by the Safety Section made through the Health Physics Division.

2. Active Solutions.

Active solutions should be retained for disposal by the Safety Section. Such solutions should be placed in bottles small enough to be easily handled (if possible, the size should be kept below 2 1/2 liters), and in the case of beta-gamma active materials to prevent excessive exposure to those removing the material. The Health Physics group will make the necessary arrangements for their disposal. All bottles should be carefully and completely labelled before being removed from the laboratory.

EXCERPT ON DISPOSAL OF RADIOACTIVE MATERIAL

from

"Safe Handling of Radioisotopes"

(Provisional Draft of a Report Prepared for the
National Committee on Radiation Protection)

Disposal of Contaminated Wastes

(1) Absorbent papers, wipes, etc.

Waterproof disposable containers to hold the discarded absorbent bench paper and wiping papers should be provided at each laboratory station. Regular collections of these disposal vessels from the laboratory should be made. The eventual disposal of such items is conditioned by the half-life and toxicity level of the isotopes involved. With short half-lives, retention of the materials in a controlled area, until their residual activity is insignificant, is a preferred method. With long-lived isotopes, the laboratory management is committed to a prevention of contamination of the public domain. The association of groups of laboratories to provide a single controlled and economical disposal area may be feasible.

(2) Active solutions

The disposal of active solutions to the public sewers can only be considered safe when the possible subsequent chemical, physical, and biological concentrations will still leave the material at safe concentrations. Disposal to a water system should include consideration of the accumulation of activity in soil or mud, and in algae and similar organisms. Concentration of the order of 100,000 fold may occur. Whenever possible, the principal activity in the waste solution should be precipitated, and discarded as active solid material.

Urine from isotope-injected animals or patients, and liquors from equipment or clothing decontamination, may require attention as active solutions.

(3) Tools

Tools and other miscellaneous equipment used in handling long-lived isotopes should be regarded as contaminated and should not be released for other work until proven otherwise.

APPENDIX 14

EXCERPTS ON DISPOSAL OF RADIOACTIVE MATERIALS*

from

Isotopes Branch Circular B-1,
"General Rules and Procedures Concerning Radioactive Hazards"

1. Storage and handling of plutonium or similar hazardous substances
 - a. Quantities of plutonium greater than 1 microgram shall be securely covered during storage and kept in a hood equipped with doors, or in other spaces specifically accepted by the Health Division Director, or his representative, as suitable under the given circumstances. (Such as shelves constructed in an out-pocketing from existing hoods or separate boxes equipped with doors and vented to a proper exhaust.)
 - b. All transfer of materials between hoods and storage devices must be done in such a manner as to avoid the possibility of spillage or breakage. Double containers to eliminate contamination and breakage danger should be used.
 - c. Any work with materials susceptible to atmospheric distribution of plutonium** (that is, dusting, spillage, vaporizing, effervescence of solution, etc.) shall be done in an "adequate hood."
2. Disposal of materials contaminated with plutonium or similar hazardous substances. All discarded material which has been liable to plutonium contamination is to be buried. Distinctive cans are to be provided, and these handled with proper discretion. If a dust hazard is involved, a Health-Physics representative shall accompany the can when it is taken to be buried to see that respirators and protective clothing are used when needed. In rooms where large (1 to 2 microgram) amounts of plutonium are handled, a small red closed can should be provided with a paper lining to receive waste of known contamination, so that the closed paper lining may afford some measure of protection against spread at the time of disposal.
3. Disposal of active trash, unwanted active materials or equipment
 - a. Two trash cans painted entirely red (both top and can) are to be provided at each desired location for trash which is contaminated.

*From AEC Regulation Safety No. 3, "Standard Safety Requirements"

**This rule applies to other radioisotopes which present a similar health hazard. (1 microgram approximately 1/16 microcurie)

APPENDIX 14 (Continued)

- b. Only one of these two cans should be used at a time and the one in use should be tagged by Supervision of the Area - "Use This Can."
 - c. It shall be the responsibility of supervision to see that these cans are monitored at sufficiently frequent intervals to prevent active materials from accumulating to such an extent that radiation levels of greater than 12.5 mr/hr occur.
 - d. Once a can has been labeled "Driver, O.K. to Pick Up," no more contaminated trash shall be put in that can. When the can has been emptied and returned, Maintenance should remove the tag so that it may be held in reserve while the second can is in use.
4. Burying ground - All contaminated material and equipment that is to be discarded shall be thrown only in the trenches provided for that purpose.
- a. Sufficient earth must cover active materials in a trench to keep the level of radiation at the top of the trench below 12.5 mr/hr.
 - (1) Keep sufficient earth over trash to prevent trash from being blown or floated outside the trench.
 - (2) Keep an adequate record of all equipment taken to the burial ground for burial or for storage.
 - b. The burial ground will be periodically surveyed.

APPENDIX 15

EXCERPTS ON DISPOSAL OF RADIOACTIVE MATERIALS

from

Atomic Energy Project,
University of California at Los Angeles,
"Health Physics Regulations"

by Stafford L. Warren, M.D., Project Director

DISPOSAL OF RADIOACTIVE WASTES AND CONTAMINATED MATERIALS:

The disposal of radioactive wastes must be carefully regulated so that the permanent or long-time high contamination of areas or disposal systems outside the control of this project or at the project does not occur.

I. Radioactive Wastes:

- a. In all laboratories where radioactive materials are handled no solutions are ever discarded into a sink or sewer unless the lack of activity or the approximate activity of the solution is known to be within the safe limit for disposal. (See I b 2 below for safe limit.)
- b. Usually the activity of a solution which has been used or involved in an experiment is known, thus when the disposal of one of these solutions is desired it will depend upon the nature of the active solution as to which method of disposal to follow:
 1. If the solution is highly active, then transfer to the "Solution Containers for Sea Burial."
 2. If the solution is of low or medium activity then, if practical, precipitate the activity out of the solution and the clear, alkaline solution of less than 1 microcurie per liter and not in excess of 10 liters per day may be discarded down the sewer with proper flushing.
 3. Active solids precipitated out of the active solutions or other active solid wastes shall be placed in the "Solid Waste Container for Sea Burial."

II. Contaminated Materials:

- a. Contaminated items of clothing or protective devices will be placed in large clean paper bags and turned into the Health Physics Section for disposal. The paper bag should

APPENDIX 15 (Continued)

be labeled with the nature of contents, degree of contamination (low, medium or high), date and name of person turning the item in.

- b. Contaminated glass or other discarded equipment, contaminated with long-lived activity, which are impracticable to decontaminate shall be placed in special container marked "Contaminated Glass and Other Waste for Sea Burial."
- c. Animal carcasses and organic materials containing short half-lived (one month or less) active materials may be disposed of by incineration, provided the total activity does not exceed 0.1 mc. per incineration.
- d. The disposal of animal carcasses and organic materials containing active materials of half-lives of longer than one month will be accomplished by placing these materials in the special containers that are labeled ("Contaminated Animal Wastes for Sea Burial").
- e. All laboratories where active materials are handled will have a special waste can containing paper bag lining and painted completely red for contaminated paper coverings, wipes and tissues. Although these red cans will be marked "Radioactive Waste Only," laboratory personnel should be reminded by their supervisor of the above regulations on the disposal of the various contaminated items and these cans reserved for contaminated papers, etc., only.

500 gal / bed / day

APPENDIX 16

REMARKS FORWARDED BY DR. EDITH H. QUIMBY

In patients receiving radioiodine therapy, unless it is desired to keep a record of excretions, it seems desirable not to preserve the urine at all, but to have it flushed away as voided. However, if it is desired to determine the total volume and measure a small part, it is usually possible to obtain the patient's own assistance in handling the material during the measurement, and afterward disposing of it. Here, of course, we come directly into collision with the various formulated rules concerning flushable waste, and I want to consider the situation in some detail, as it has been studied by the group of New York hospital physicists concerned with this problem.

General recommendations have been of the order of not more than 100 μc per flush, and not more than 5 mc per week down any particular drain. On the other hand, the Provisional Draft of the Report for the National Committee on Radiation Protection on Safe Handling of Radioisotopes sets a permissible level for water contamination as 0.1 μc per liter. According to information received from Mt. Sinai and Presbyterian Hospitals, a large hospital flushes into the sewage system about 1800 liters per day per person; thus for a 300 bed hospital, assuming two people per bed, - one patient and one employee, - this would be about a million liters. One hundred millicuries dispersed in this amount of water is 0.5 μc /liter. On this basis each hospital of this size could flush away 100 mc of ^{131}I weekly without bringing the sum total of sewage contamination from its own drains above the permitted level. And evidently such hospitals represent a very small part of the total sewage water.

Of course questions immediately arise as to the rate of removal of the material from the individual drain to the general sewage system; how rapidly it gets diluted to this level, and whether it may be caught in traps or interact with material of the pipes to form an insoluble compound. The ordinary toilet uses about 10 liters per flush, and in a bathroom used by a number of patients would be flushed several times per hour. Thus the material would be quite rapidly pushed along into main sewers and into the general system. It is very unlikely that any stoppage or accumulation in traps would occur. In institutions where this type of disposal has been practiced, monitoring of the sewage lines has not shown appreciable activity. In one reported instance, following a large disposal, the background near a trap was appreciably raised for a time, but not to anything like tolerance level. In selecting drains for the disposal of such active material, precautions should be taken to assure that they do not run in the vicinity of any room where any Geiger-counting apparatus may be used. Where possible, a direct outlet to the main sewer is highly desirable. In a large hospital, where bathrooms are usually located in a tier, it is not likely that a bathroom drain will pass through or near a room in which measurements are being made.

APPENDIX 16

(continued)

If this type of disposal is practiced, it should always be borne in mind, however, that if any plumbing repairs are necessary in a sewage line containing possible contamination, traps or joints should be monitored upon opening, and so should waste removed from them, or water discharged at the time of the opening. This necessitates an understanding on the part of hospital personnel that the laboratory should be notified in the case of such repairs.

In the matter of disposal of radioactive wastes, it is the community at large that must be considered. No user of isotopes can consider his disposal problems as though he were the only one in the community working with them. Disposal measures adopted by any group at the present time in the light of its own uses and the known situation in the community, must be reviewed at frequent intervals.

APPENDIX 17

REMARKS FORWARDED BY DR. ALBERT H. HOLLAND, JR.

Submitted herewith are a few tentative proposals for the off-project disposal of isotopes.

It is not unreasonable to expect isotope users to retain short-lived isotopes, say, those with a half-life of thirty days or less, until the activity decreases to a safe level for disposal in city sewage systems. Therefore, in effect, we are concerned with the disposal of long-lived isotopes. This can be accomplished in the following ways:

- a. Calculated dilution and controlled disposal into city sewage systems.
- b. Burial in controlled university or institutional burial grounds. This, in my opinion, is not a safe procedure, at least for the present. We are currently studying some of the agricultural and geological problems associated with this procedure. Perhaps in a matter of six months to a year we will be able to draw valid conclusions concerning the advisability of this procedure.
- c. Disposal at sea. This probably is a satisfactory interim procedure for those institutions located near the oceans, but ~~is~~ the final analysis does not constitute a fool-proof approach.
- d. Concentration and return of long-lived materials to the regional laboratories of the Atomic Energy Commission. I do not believe we are particularly interested in operating a garbage disposal system. However, procedures could be worked out requiring the packaging of such material in disposable containers which would require a minimum of handling on our part. Pending the development of satisfactory information concerning local burial, this method of disposal appears to me to be the only one which we could publicly support and recommend.

APPENDIX 18

REMARKS FORWARDED BY DR. HYMER L. FRIEDEL

1. Disposal of material by off-Commission users should be the responsibility of these users with guidance only from the Atomic Energy Commission.
2. The individuals who are responsible for the disposal must have a clear understanding of the problem. This provides a greater safeguard than specific rules and regulations formulated by an outside agency.
3. If unusual means of disposal are required by off-Commission users, the whole project should be carefully studied at its inception - in other words, at the time that the allocation of the isotopes is made.
4. Emphasis should be placed on simple procedures such as dilution or addition of non-radioactive elements in rendering the materials non-toxic.