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Contamination Limits for Real and Personal Property

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by

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II. PATHWAYS OF EXPOSURE

In order for a radiation dose to be delivered, it is necessary for an individual to be near the object or for the contamination to be transferred from the object to a position where the dose can be delivered. By analogy with the ecological experience of transfer of radioactive materials, these methods of exposure of the individual have been called the "pathways" whereby the contamination leads to a radiation dose. Obviously, the quantitative importance of any individual pathway depends upon the isotope and the use of the object. However, for purposes of discussion, we will, in this section, review only the pathways themselves and some of the interactions leaving the influence of use of the object on the pathway to a later section.

A. Direct Exposure

This has been referred to earlier in the discussion of dose. Any contaminated object will have a radiation field surrounding it with intensity dependent upon the radiations emitted, the distance from the object, any shielding, and, to some extent, the geometrical nature of the object and the contaminated area on it. The dose received by an individual will depend upon his position in the radiation field and the time he spends in the field. In general, this pathway should be minimal in importance as compared to others, although there can be specific situations where a significant dose can be visualized. These would include conditions where a large number of contaminated items are placed in one area, or where the contamination is well fixed with a low probability of transfer.

B. Contact Exposure

The radiation dose rate in contact with a contaminated object is higher than that in the radiation field surrounding the object. Thus, in situations where the object comes into contact with the body for a significant portion of the time, as in handling or sitting on an object, the dose to the skin could be of primary importance.

C. Contact Transfer of Contamination to Skin

Contact between the object and skin of the body can result in transfer of contamination from the object to the skin. The degree of transfer will depend upon the fixation of the contamination, the type of contact and, perhaps, the duration of

the contact. Considerations such as the part and area of the skin contacted and the size of the contaminated region of the object are also of importance.

Radiation doses will result from:

1) Direct irradiation of the skin.

2) Transfer from the skin to the mouth and ingestion.

3) Absorption through the skin.

4) Possible inhalation through localized resuspension to produce a concentration in the breathing zone.

D. Contact Transfer of Contamination to Clothing

Contamination can be transferred to the clothing by deliberate or casual contact with the object. Many of the considerations in the transfer to skin will apply here. Radiation doses will result from:

1) Direct irradiation of the skin near the clothing.

2) Transfer from the clothing to the mouth and ingestion.

3) Transfer from the clothing to the skin and subsequent absorption.

4) Localized resuspension in the breathing zone from movement of the fibers during normal actions or when removing the clothing.

E. Local Resuspension

High, localized air concentrations can be caused by the radioactive material leaving the object and being carried by the air. Localized resuspension is distinguished by high concentrations in the immediate vicinity of the object before they can be diluted by air currents. Generally, such concentrations will be caused by actions on the object which serve to dislodge the contamination. In specific cases, such as heating, the production of vapors or gases can result, and these are also classified as resuspension. In general, resuspension material will deposit on surfaces resulting in contamination of the objects on which deposition occurs. Radiation doses will result from:

1) Inhalation.

2) Deposition on clothing.

3) Deposition on skin.

4) Deposition on other objects resulting in possible pathways and doses from them.

In general, the inhalation pathway will be of primary importance, but in cases of long-term use of contaminated objects, the other pathways may become of importance.

F. General Resuspension

Air concentrations which are reasonably dispersed throughout an area are classed as General Resuspension. Usually, this will describe the effects of resuspension at some distance from the object after air currents have provided some dispersion and dilution. General resuspension may occur either from natural forces such as air currents or from actions on the object. The intent is to describe the general exposure of anyone in the area as opposed to the exposure of the individual close to the source as in local resuspension. The differentiation is primarily to permit the use of different sources of information and different methods of analysis of the problem. Radiation doses will result from:

- 1) Inhalation.
- 2) Deposition on clothing.
- 3) Deposition on skin.
- 4) Deposition on other objects resulting in possible pathways and doses from them.

Again the inhalation pathway will probably dominate, although the potential buildup on other objects may be of interest when long-term use of contaminated objects exist.

G. Liquid Transfer

In some cases, the pathway of transfer can occur in liquid rather than directly or in air. This can occur through solubilization of the radioactive material or the erosion of particles from the surface and will result in a contaminated liquid which can provide a means of contaminating individuals or dispersing the radioactive material to other areas. Radiation doses will result from:

- 1) Ingestion.
- 2) Skin contamination.
- 3) Clothing contamination.

H. Direct Ingestion

A potential pathway which has a relatively low probability of occurrence is direct ingestion of radioactive material from the object. This would occur primarily from the use of contaminated utensils used in preparing and eating food or from children placing contaminated objects in their mouths. Radiation doses will result from:

- 1) Ingestion.
- 2) Possibly local resuspension if the object is near the mouth.

I. Transfer to Other Objects

The transfer of contamination from the initial object to other previously uncontaminated objects will result in potential pathways from the newly contaminated object to people. In general, intuition would indicate that in most cases the secondarily contaminated object would result in lower doses since only a fraction of the contamination will be transferred. However, there are cases where the secondarily contaminated object will be in closer contact, used for a significantly longer period of time, or used in conditions where resuspension or ingestion may be more probable. In addition, in cases where large numbers of contaminated objects pass through a given area, the continued transfer of a small portion from each object will result in a buildup in the area.

Such secondarily contaminated objects should result in pathways similar to those noted for the initial object. Thus, definition of the quantitative aspects of the pathways for the initial object should permit assessment of the importance of such secondary, tertiary, etc., pathways by definition of the use factors for the objects. However, it is noted that this adds tremendous complexity to the overall problem, and the information available will probably not warrant pursuing these pathways to any length except in special cases.

The above pathways describe the flow of contamination from the contaminated objects to individuals. Consideration must also be given to the eventual dispersion of the material over wider areas where any individual deposit may be well below limits but the accumulation on many surfaces will result in a general increase in background with transfers in the ecological chains or

accumulations by physical concentration mechanisms possibly becoming of importance. An example of this type of consideration would be the disposal of contaminated liquids to the sewage system with possible accumulation on sludges.

III. USAGE MODELING

A. Classification of Objects

The objects which can be released for public use range widely in complexity and potential utility. For purposes of initial study, we have classified these materials into eleven categories. These include:

1. Scrap

Those items which are intended for recycle of the component materials by melting, shredding, or otherwise reprocessing. This would include all types of waste metal, including precious metals, as well as glass, paper, rubber, and plastics.

2. Movable Buildings

Those buildings which can be moved essentially intact to a new location or those buildings in which the entire structure and land are to be released to the public. It is to be noted that components removed during the demolition of a structure are not included here but are classed in the appropriate category.

3. Furnishings

Items normally considered as furnishings for offices, homes, or shops. They would include such items as desks, chairs, file cabinets, or bookcases.

4. Office Equipment

Portable or transportable items normally used in offices but which can serve similar or different purposes in homes or other locations. This would include items such as typewriters, recorders, transcribers, telephones, staple guns, etc.

5. Laboratory Equipment

Devices or objects used in the laboratory for measurement or manipulation of objects. This would include electronic devices, specialized manipulators, glassware, or built-in furnishings such as fume hoods.

6. Hand Tools

Portable items used in shaping or forming materials. These include normal hand tools and power tools such as drills or saws.

7. Heavy Tools

Fixed items used in shaping or forming materials. These include lathes, power presses, heavy drills, or metal casting equipment.

8. Light Machinery

Equipment designed to convert forms of energy for use in buildings or to power other equipment. These include small motors of less than 3 hp and equipment associated with motors such as rectifiers, blowers, or pumps.

9. Heavy Machinery

Large equipment designed to convert forms of energy for use in buildings or to power other equipment. These include electrical generators or turbines, motors >3 hp, or equipment associated with such motors.

10. Components

In all of the above categories, equipment can be released which is not operable and the intended use is for removal of parts for use in repair or construction of another device. Such items would be electronic gear containing resistors or transistors, scrap from which usable wire or sheets are obtained, or vehicles from which parts are obtained. Components such as transistors, wire, or screws are in this category.

11. Vehicles

Equipment used for moving people, material, or other items from place to place. This would include automotive equipment, earth-moving equipment, or such speciality items as snowmobiles.

While the above classifications are not exhaustive in their inclusion of all objects, they do serve to indicate the types of categories in which some differentiation of use patterns after release to the public can be defined. For example, furnishings and office equipment can be expected to be used by the public in much the same way as other items of these types, although the environment of use and frequency of use can differ. Heavy tools will be primarily used outside of home and commerce but will be found in repair shops, light industry, and perhaps in educational institutions. Light machinery,

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such as motors or blowers, can be used in the home for shops or for installation as a part of the heating, cooling, or plumbing; but heavy machinery will usually be used in larger structures, or only as installed equipment with little direct contact with people. Scrap will normally enter commerce for recovery, or if the economics are not proper, for disposal. Components can be used in a large variety of applications limited only by the materials available and the needs of the buyer.

However, it must be borne in mind that the human imagination in the use of such items is wide ranging. Thus, items of scrap can end up in an artist's studio and eventually in an art gallery. The frame from a heavy piece of machinery can provide a unique planter for flowers in the home or a playground for the children. Thus, any usage modeling of given items or classifications of items must be based on the more probable types of use but with sufficient conservatism that unexpected uses will not constitute a unique hazard.

B. Uses and Actions

The purpose of investigating and classifying the use of an object is to permit a description of the actions on this object with the ultimate goal of describing the radiation exposure resulting from such actions. An attempt to prepare a comprehensive listing of uses and actions for all objects would seem to be prohibitive at this time because of the large numbers of objects, uses, and actions and the lack of information which would permit detailed relation of the use and action to the resulting radiation exposure.

In studying the uses of the various categories of objects, it was noted that many of the actions which could result in exposure were common to many of the uses, and one can, therefore, presume that the pathways of exposure from these actions have some similarity. Thus, in installing a motor, it is necessary to handle it; in using a piece of office equipment the equipment is touched with the hands, and a hand tool is used in the hands. It is true that the character and frequency of the action is different in each of the cases so that the usage model will require consideration of the influence of these factors. However, one pathway of exposure in all of these actions is the transfer of

contamination to the hands (or other part of the body) where it can then provide a source of internal or external dose.

In this manner the use of an object can be related to the pathway through a series of defined actions. Each action will produce an exposure pathway resulting in the delivery of a radiation dose to the user. The overall use and pathways can then be examined as the sum of the effects of all actions with a reasonable probability that a few will be predominant.

The following listing provides examples of the types of actions to be considered and the resulting primary pathways of exposure. An attempt has been made to separate the actions and pathways to include only those pathways resulting from the defined action even though other actions are involved. Thus, touching of the object is involved in many of the uses and is implied in many of the actions, but transfer of contamination is considered only in the "touching" action.

Actions to be considered and the associated pathways of exposure are:

1. Touching

This involves any action such as handling, brushing against, or sitting on where the object comes in contact with the body or clothing. Potential pathways of exposure are:

- a) Transfer of contamination to the skin.
- b) Transfer of contamination to clothing.
- c) Localized resuspension.
- d) Direct exposure.
- e) Contact exposure.

2. Loading

Placing object into or removing from a vehicle or other device intended for transport. Potential pathways of exposure are:

- a) General resuspension.
- b) Local resuspension.
- c) External radiation.

3. Storage

Placement of an object or series of objects not in use in a location where they will remain undisturbed until use is desired. Pathways of exposure are:

- a) External radiation.
- b) General resuspension.

4. Repair or alteration

Any action which requires assembly or disassembly or mechanically alters the form of the object. This category will include a wide number of actions such as hammering, driving screws, welding soldering, and grinding. While the pathways of exposure will vary widely in quantitative degree depending upon the specific action, they will be:

- a) External radiation.
- b) Local resuspension.
- c) General resuspension.

5. Cleaning

Actions involving the removal of surface films or the surface itself for the purpose of removing foreign materials. This could include actions such as washing, chemical treatment, grinding, or abrading. Again, the quantitative aspects can vary with the action, but the general pathways of exposure will be:

- a) Local resuspension.
- b) General Resuspension.
- c) Liquid transfer.

6. Melting or Dissolving

Any action which converts the solid state of the object to a liquid, either as a melt or a solution. This action will occur immediately with scrap but must be anticipated as an eventual possibility for most metals and some plastics. Pathways of exposure are:

- a) Local resuspension.
- b) General resuspension.

7. Crushing

Any action which is undertaken to reduce volume by compaction or to reduce the item to finer particle state. Pathways of exposure are:

- a) Local resuspension.
- b) General resuspension.

IV. DISCUSSION

The work to date has indicated the feasibility of providing a simplified model based upon four concepts: 1) a use sub-model based upon categories of items; 2) an action sub-model describing the types of actions encountered by the objects while in use; 3) a pathway sub-model describing the ways in which contamination reaches humans under the

influence of the actions; and, 4) a dose sub-model describing the radiation doses resulting when the contamination reaches the body. All four parts of the model are interrelated so that, in the final utilization, feedback from one sub-model to another will be required to define the overall problem for a given category of object. However, these sub-models permit relatively independent investigation of each facet in defining and assembling available information and then permit the information to be applied to the overall model. It is recognized that the final model will be only a crude approximation to reality but it also provides a framework for iterative improvements once a better understanding of the interactions is obtained.

Since the chief area of uncertainty appears to be in the definition of the pathways, we plan to investigate each of the postulated pathways in some detail in order to provide a basis for quantitative analysis. At the same time, we will continue development of the conceptual model incorporating additional details on the action and pathways sub-models.

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