LOW-LEVEL RADIOACTIVE WASTE MINIMIZATION

FOR

HEALTH CARE INSTITUTIONS[a]

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OVERVIEW

In recent years medical waste has been the subject of considerable public and governmental attention. This has been, in part, due to the media's attraction to unfortunate instances of environmental pollution caused by hazardous and medical wastes. While a considerable amount of information is currently available on the treatment and disposal practices for hazardous wastes, a shortfall of information exists on the subject of medical wastes. Such wastes are generated by various health care institutions. Medical waste is a wide and all encompassing term which refers to a variety of wastes. This presentation will address medical low-level (LLW) radioactive waste; its generation, recovery and handling. The development of generic waste minimization models and greater use of alternative technologies are part of the discussion.

MEDICAL WASTE TERMINOLOGY/DEFINITIONS

The definition of medical waste varies from state to state and can be referred to as "biohazardous," "pathological," "biological," "biomedical" and hazardous infectious." Despite the variety of definitions and multiplicity of subcategories, there is agreement on one issue: a portion of the solid waste

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generated at medical institutions must be subject to treatment prior to disposal. The waste requiring treatment is identified by a variety of means. The remaining medical waste is noninfectious (not capable of disease induction) and joins the solid waste stream for disposal at a landfill. An issue that does create a lot of misunderstanding when addressing medical waste is the relationship of medical waste and disease transmission. Infectious diseases occur as a result of interaction between an infectious agent (pathogen) and a susceptible host. Medical wastes are such a source of pathogens. In order for infection or disease to occur, certain factors must be present forming a chain constituting the process of disease/infection transmission. A break in any one of the links will inhibit the transmission of infection/disease. Refer to Figure 1. This should clarify the medical waste issue of disease transmission. Medical wastes are generated by hospitals, medical research institutions, and clinics. LLW can be generated at these institutions, but is regulated by the Nuclear Regulatory Commission (NRC), the Department of Transportation, the State Department of Health and the Environmental Protection Agency. It is not regulated as RCRA waste.

SOURCES OF RADIOACTIVE MEDICAL WASTES

Radioactive materials are used in therapy, diagnosis, and as nuclear pharmaceuticals. The form of the source material varies from vials and ribbons to beads. The waste streams generated can best be characterized by their origins, and are generally dictated by the procedure that produce them. Typical waste forms found in biomedical research and the medical waste streams are: liquid scintillation vials (to be discussed later in this presentation), dry solids, liquids, and biologicals and are briefly addressed in this portion of the discussion. See Figure 2.

The biomedical research waste stream objectives are to investigate the behavior, structure and kinetics of biochemicals and biological systems. In many of these studies, radionuclides are used in small quantities (mCi/uCi) of elements such as carbon, hydrogen, sulfur, phosphorous, or elements that are easily bound to biologically important compounds. The research stream can

HOW DOES INFECTION OCCUR?

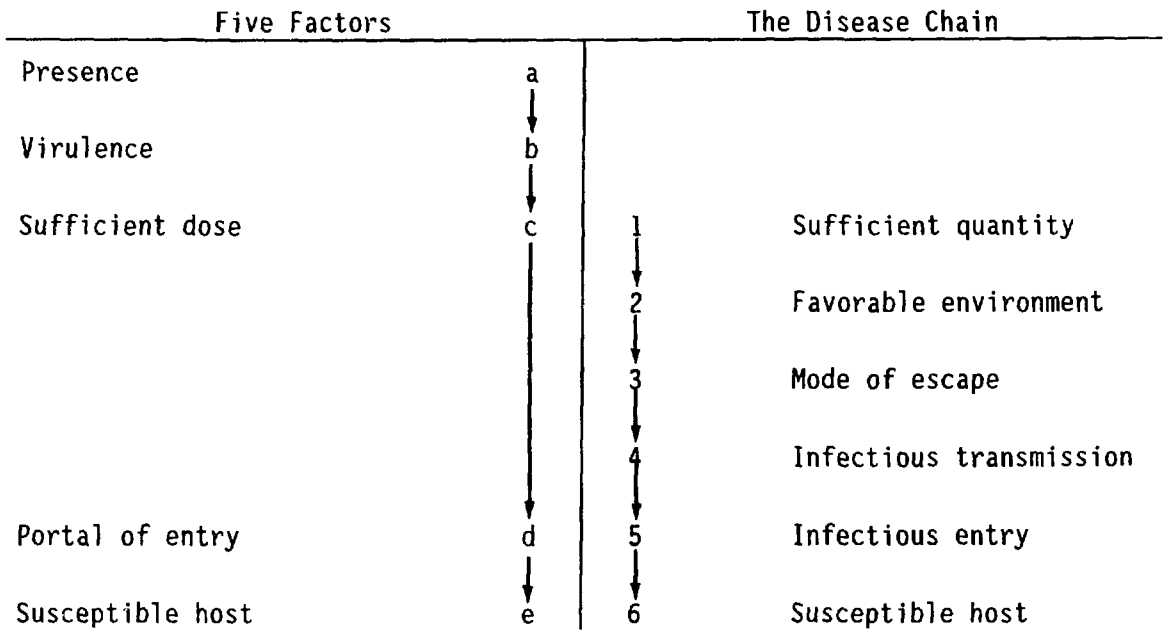

Figure 1.

TYPICAL WASTE FORMS FOUND IN BIOMEDICAL AND MEDICAL INSTITUTIONS

- Liquid Scintillation Vials
- Dry Solids
- Liquids
- Biologicals

Liquid Scintillation Vials

- Subtypes of organic liquid and/or dry solid institutional waste which require special consideration

Dry Solids

- Various articles (urinals, catheters) used in patient care
- Miscellaneous laboratory apparatus such as glass, tubing
- Contaminated instruments and tools
- Protective clothing, lab bench paper, and packaging materials

Liquids

- Most liquids associated with clinical use of radionuclides
- Washings from contaminated labware and other reusable articles in both medical and research facilities
- Culture media, dialysis fluid, buffers and some reagents

Biologicals

- Animal carcasses / parts / tissue / bedding / excreta
- Other patient wastes
- Wastes from surgery, autopsy, micro-organisms such as bacteria

Figure 2.

however, include any radionuclide in any amount and in any chemical compound. The waste associated with research can be any of those listed above. Chemical and pathogenic, as well as radioactive hazards can be components of the research waste stream.

The medical waste stream objectives of diagnostic studies are to investigate organ systems' functions and forms through measurements of uptake, dilution and excretion and object imaging and localization. This is accomplished by tracing the distribution or clearance of radiolabeled compounds in the body in vivo. The radionuclides used in diagnostic studies are characteristically short-lived gamma emitters of moderate energy (e.g., Technetium 99). The wastes associated with these uses are typically dry solids, syringes, vials absorbent pads and some liquids used for injection solutions. Pathogenic, as well as radioactive hazards can be components of the diagnostic waste stream. The clinical therapeutic waste stream, a part of the medical waste stream, objective is to deliver radiation to specific areas of the body, or "targets," to destroy diseased tissue. The introduction of radioactive material into the body usually involves relatively short-lived radionuclides such as Iodine 125 or Phosphorous 32. The wastes associated with these uses can include all those listed for diagnostic studies. The clinical laboratory waste stream objective is to measure the presence of very small amounts of various compounds (e.g. steroids, hormones) quantitatively in sample body fluids/tissue. The radionuclides used in clinical assays are usually medium to short-lived, low energy beta or gamma emitters (Iron 59 or Iodine 125). Typically wastes that result from clinical assays are test tubes, pipettes, absorbent paper and liquids. Infectious, and chemical, as well as radioactive hazards can be components of the clinical lab waste stream.

A SYSTEMATIC APPROACH FOR LLW MINIMIZATION FOR HEALTH CARE INSTITUTIONS

This part of the discussion addresses a generic and systematic approach for medical waste minimization. All health care LLW generators need to exercise control over the treatment and research methodologies to ensure

improved generation, recovery and treatment. Figure 3 identifies the LLW minimization techniques that would be most effective. Institutions will continue to generate some LLW. Access to existing disposal sites is far more restrictive and disposal is becoming very costly. Therefore, I believe this approach is both necessary and important.

PERSONNEL

Dedicated Waste Minimization (WMIN) Personnel With Authority - the first and most important action is for each medical institution to establish a Radiation Management Board. The Board should include members from the Nuclear Medicine Department, Pathology Department, Clinical Laboratory, Purchasing Department, the Radiation Safety Officer, and Environmental Engineering. The members of the Board will select membership dependent on type of health care services provided. For example, there may not be a Clinical Laboratory service.

The mission of the Board will be to institute a Radiation Management Plan which would assess, implement policies, and monitor the handling of all aspects of radioactive material entering the institution for patient care use.

One of the chief responsibilities of the Board members would include a very early assessment of existing methods, testing, technologies, etc., currently in place which utilize radionuclides. Effort should be made to delete outdated methodology, methods which result in nonspecific results, and those which are rarely requested. This effort would also include some long term planning and assessment of new methods to be provided in the near future with a view to institute those which do not incorporate the use of radionuclides.

WMIN Training Programs

Details for WMIN training programs would be included in the Radiation Management Plan. Personnel training would consist of safe and proper radionuclide material handling from point of receipt, storage, during the

- Personnel
- Materials
- Processes
- Maintenance
- Decontamination
- Waste Handling

Figure 3.

testing phase, use of protective clothing, and treatment and disposal of wastes. The importance of integrating WMIN training in all areas of the work place is essential.

The training program would also address area preparation techniques, decontamination procedures, emergency handling procedures (spills,etc.), labeling of equipment and materials, and waste handling procedures.

Limited Access to Radiological Areas

To reduce LLW generation of worker exposure, the Board should enforce a policy that only personnel authorized to handle radioactive materials and testing would have access to the areas where radioactive material are used or stored. Personnel limitations should be in the form of an administration control such as a badge or form to perform work.

MATERIALS

WMIN Requirements for Purchases and Contracts - Vendor requirements should also be implemented by the Board. Volume reduction in the Purchasing Dept. is essential. This could be facilitated by the use of an index of the manufacturer/vender capabilities and matching the institutions requirements for the use of radioisotopes (volumes, short dates, use of mini vials, etc.). Policies should be in place for vendors to take back outdated test kits and radionuclide materials, pickup disposable shipping containers. There are vendors who will also offer a radioactive waste retrieval service. This may be costly upfront, but would be a cost savings in the long run. Some vendors use recyclable shipping containers so that the receptacles can be picked up for reuse. Purchase control should include the purchase of material volume based on anticipated need rather than price.

Material Substitution

This involves the replacement of any existing material with another material or process that would serve an equal function and result in the

generation of less waste volume. Reusable transport containers should be provided where ever possible utilizing the smallest volumes of packaging material. Glass and metal surfaces, and glass receptacles for laboratory testing should be used. Permeable surfaces which are difficult to decontaminate should be avoided.

More sensitive equipment should be selected for high detection and efficiency thereby allowing the use of considerably less radioactive material.

Isotope Substitution

There is limited potential for isotope substitution. In research studies, alternatives are more abundant than in the area of clinical procedures. Many procedures involving synthetic labeling of proteins and nucleic acids can use 14.3d 32P or 87.4d 35S in place of 12.3y 3H and 5730y 14C. Substitutions however, may introduce potential exposure to other types of radiation, e.g. a high energy gamma rather than a medium energy beta. Exceptions to the use of shorter-lived radionuclides are procedures which produce a significant percentage of their radioactive waste in the form of liquid scintillation fluids or in animal carcasses. In these cases the use of 3H or 14C might be recommended since LLW in these forms can be discarded as nonradioactive under certain conditions.

In the clinical laboratory, radioimmunoassays (RIA) sometimes can be replaced with acceptable or superior alternative procedures. Enzymes can be used in place of radiolabels to yield many varieties of enzyme-linked immunoassays. Fluorescent labels can turn immunofluorescent techniques into highly quantitative and sensitive fluorescence immunoassays. (Kaplan et al., 1981; Voller et al., 1981; and Pal, 1978). Automated enzyme immunoassay systems such as ELISA (enzyme linked immunosorbent assay) or EMIT (enzyme multiplied immunoassay technique) offer acceptable clinical/research results and possible cost savings. Although the use of RIA is somewhat hampered by difficulties in full automation of procedures and by limitations on kit shelf-life, imposed by the radiolabels, Schall and Tenoso (1981) state that no one

label or method has shown itself to be so successful as to surmount the shortcomings of radioassay. Nonradioactive labels, including enzymes, fluorophores and chemiluminescent compounds may ultimately replace radiolabels. Agglutination procedures using latex particles offer an additional approach to RIA nonradioactive methods.

In the research laboratory, nonradioactive methods which may be appropriate are:

- Nucleic acid hybridization techniques - Hapten-substituted nucleotides that can be unincorporated into DNA or RNA probes are commercially available. These probes can be detected using enzyme-linked antibody to the hapten-substituted nucleotide. This technique is useful in the detection of DNA and RNA in situ or after immobilization on a membrane.

- High-pressure/high performance liquid chromatography - High-pressure liquid chromatography (HLPC) methods which employ ultraviolet detection systems are available. These optical techniques analyze methylated purines from DNA hydorlysates using HPLC and fluorescence detection in place of radioactive methods.

- Silver staining and kodavue - There are a number of nonradioactive methods that can be used for certain bioassays in which 125I or 51Cr have been used, respectively Detection methods for the proteins in polyacrylamide gels (PAGE) include silver staining (Merril et al., 1981) and the Kodavue Electrophoresis Visualization Kit. These two methods will detect 5 to 25 mg of protein in a band on PAGE. Utilization of these methods prevent the modification of the protein such as might occur in labeling conditions with 125I.

- Cytotoxic assays -This dye staining assay replaces the use of 51Cr or other radiolabeled compounds normally used in cytotoxic assays. This method makes use of a dye that can be read by a Flow Titertek

Multiskan Plate Reader. The assay can use different dyes and allows longer incubation times with more sensitivity than with radiolabeled compounds.

- Magnetic resonance imaging (MRI/NMR) -This method has been used for biomedical research tracer studies but is now widely used in the nuclear medicine field. MRI is the clinical equivalent technique which generates images through the use of radiowaves that stimulate transitions between spin states of nuclei in a magnetic field. By means of computer reconstruction, images can be obtained from signals produced. NMR/MRI does not require the use of radionuclides and is becoming a method used by most health care institutes.

Nuclear medicine employs imaging called positron emission tomography which utilizes compounds that are labeled with accelerator-produced short-lived (half-lives are typically only a few minutes) positron-emitting radionuclides. Special cameras designed to record the annihilation radiation produced by positron emitting are used. Positron imaging is demonstrating clinical utility in the early diagnosis of Alzheimer's disease, as well as in epilepsy. It does have one major obstacle and that is the requirement for a nearby nuclear particle accelerator (cyclotron). The current cost is prohibitive. Isotope substitution in the area of nuclear medicine does have limited potential as radionuclides have specificity for particular body tissues. Diagnosis, treatment, and therapeutic monitoring must be conducted in a timely, efficient and as accurately as possible.

Material Restriction in Radiological Areas

Only materials required for the actual testing should be in the area. These includes glassware, protective clothing and the radionuclides required for the analysis.

Reusable, Hardy, Easily Decontaminated Materials

In all areas where testing and analysis using radionuclides, glassware on other materials which can be easily decontaminated should be selected. Glass, large volume (25 ml, 50 ml, etc) pipetters/dispensers can be selected on basis of need and can be reused as needed. Use designated shoes instead of disposable booties and reuse disposable lab coats until decontaminated or damaged. Investigate various clothing materials for durability.

PROCESS

The first step in the establishment of a waste minimization program is to identify each LLW generator within the institution. Each LLW generation point, regardless of volume or technique, is required to register with the Radiation Safety Officer. Some medical institutions do medical research, have a nuclear medicine department, and have clinical laboratories, so institutions may have several generation points. Most LLW generation is research related.

Thorough Process Characterization

Each LLW generator, after it registers with the Radiation Safety Officer, should undergo a thorough process characterization. This process should include all materials consumed, the volume, curie content and toxicity of wastes produced.

Process Modifications

There is limited potential for process modification in the area of research because research programs, once initiated and funded cannot be altered without severe impact to research program intent and purpose. The Board can institute policies for careful review, scrutiny, and approval for all new research proposals. Analysis of the new programs waste stream should be an integral part of this initial review. Proposals for new research programs must demonstrate that alternative methods have been considered and are not adequate or available.

Process Controls

The board should request LLW generators to include waste minimization strategies and waste stream projections. Board review would be able to assess adequate and appropriate procedural steps from the information provided. This could involve the elimination of unnecessary processes or process steps.

Cost/Benefit Analysis of the Process

The Board should institute a computerized direct billing to user groups to eliminate hidden costs. This feedback will also include waste handling records/costs. Information should be provided on a regular basis regarding volumes, types, and costs, thus providing an incentive for each user to reduce the amount of materials used and the amount of waste requiring treatment and handling. The Board should institute stringent review and RSO control over radionuclides ordered.

Waste Stream Segregation Within the Process

The most important step for the LLW generator is to avoid mixing uncontaminated waste with radioactive waste, infectious and chemically hazardous waste. Radioactive waste must be isolated at the point of origin.

Micro Techniques

Nuclear medicine departments and chemical laboratories are utilizing micro techniques where possible. In the area of medical research, the use of equivalent analytical results, with reduced sample size and lower waste volume generation then the original procedure is highly recommended.

Periodic Process Audits

After a process characterization, audits should be used on a periodic basis to monitor the success of each WMIN technique to promote newly identified technologies.

Measurement of WMIN Progress and Trends

The Board should provide waste minimization information to new and current users and schedule periodic reviews of user minimization results. Measurements should be used to establish a baseline waste generation rate to quantify waste reduction. Documented measurements are essential to receive credit for WMIN to effectively transfer techniques among generators.

MAINTENANCE

Strict Equipment Calibration and Maintenance Program

In the clinical laboratory, all equipment must be calibrated and maintained according to manufacturer's recommendations. Quality control and preventive maintenance programs are an essential part of routine operations. Hospitals, in particular must comply with state and federal regulations in these areas. Hospitals may not be eligible for Medicare/Medicade payments if such programs are not instituted and implemented. The Joint Commission for Accreditation of Hospitals may not grant licensure if such programs are not part of the routine testing process. Nuclear medicine must also adhere to manufacturer's recommendations for preventive maintenance, calibration and quality control. The requirements for these activities are an essential part of the routine testing and analysis methods.

DECONTAMINATION

Mechanical Decontamination

Several methods are available to decontaminate glassware for reuse or disposal as nonradioactive waste. Commercially available freon systems are designed to decontaminate surfaces such as glass and metals. It can also be used to decontaminate articles that range from tools to protective clothing (Capella, 1978; McVey et al., 1981). Commercially available decontamination agents and laboratory glassware detergents can also be used. McElroy et al., (1982) report a 50% saving in disposal costs using a conventional laboratory

dishwasher. Hildalgo et al. (1982) report that a 50% household bleach solution is an effective decontamination agent for plastic beads and tubes used in Iodine 125 radioligand assays. This technique can also be used for other labware. Other decontamination processes currently being developed are: ultrasonic cleaning, vibratory finishing, and electropolishing. Each institution should evaluate the practicality of decontaminating its glassware or recycling for disposal as nonradioactive waste. Costs must be considered for personnel, equipment, decontamination agent, and disposal of resultant wastes (usually small compared to the disposal of original materials as radioactive waste).

Selective Removal of Surface Layer

Absorbent liners should be monitored and reused if not greatly contaminated. Avoid automatic disposal if not needed.

WASTE HANDLING

Release Limits for Uncontaminated Materials

Effort should be made to handle all radionuclides and kit material under the lab hoods. The amounts of material contained are usually so small that, if spills do occur, they can usually be allowed to evaporate, thus there is little opportunity for releases.

Waste Segregation After Generation

All LLW waste generated should be segregated at the point of origin. The first step is to assure that radioactive waste is indeed radioactive. The segregation of generated waste will isolate wastes that can be disposed of as nonradioactive, without prior treatment.

Under certain conditions (10 CFR 20), disposal of scintillation fluids and animal carcasses containing less than 0.05 microcuries of ^{3}H or ^{14}C per

gram are such wastes. All generators need to check with their RSO to verify that certain exemptions are permitted by the institution's policies.

The use of LSV in the medical setting and also in medical research seems to pose a major area of concern. It is a mixed waste issue and there seems to be differences in opinion in how to adequately handle this problem. More research and an indepth study needs to be conducted to resolve this problem.

Optimum Container Size, Shape, and Weight

It is essential that all waste be packaged in leakproof, adequately labeled containers. Only amounts of waste appropriate to the size should be packaged in each container. Avoid overpacking and excess bulk as all this can contribute to added costs and possibly problems.

Storage for Decay

The treatment of radioactive waste is less extensive than is currently practiced for other forms of medical waste. In the case of wastes with half-lives less than 65 days, they may be stored in a secure area for 10 half-lives or more. The waste may then be disposed along with the noninfectious, nonradioactive medical wastes (solid waste) at a solid waste disposal facility. Isotopes which are suitable for this form of treatment include:

Technetium 99	6.0 hr	half-life
Gallium 67	3.0 days	half-life
Iodine 131	8.0 days	half-life
Thallium 204	5-6 days	half-life

It is common practice for medical institutions to store isotopes with half-lives of 24 hr. or less for a 30 day period, far exceeding the required storage time. It is not common for hospitals to store isotopes with half-lives greater than eight days, since the resulting waste might require a substantial storage facility. Storage for decay should be regarded during isotopic substitution consideration.

SUMMARY

Waste minimization is a new concept and process for the health care facilities, but it needs to be institutionalized as one of the important criteria by which the health care systems evaluate their future business plans. Important decisions in process evaluation, services provided, new equipment purchases, and facility design should all include potential waste minimization techniques and opportunities.

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