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NEW TRENDS IN THE INTERNAL DESIGN FOR RADIATION PROTECTION IN RADIOLOGICAL MEDICAL FACILITIES

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ABSTRACT

The incidence of cancer throughout the world is increasing with the prolonged life expectancy that has resulted from improvements in standards of living. About half of all cancer patients receive radiotherapy, either as part of their primary treatment or in connection with recurrences or palliation. For that The Safety Report 2015, was initiated result of increase in the construction of radiotherapy facilities, and in response to Member States that have requested practical guidance regarding the design and shielding of such facilities. The objective of this paper is to elaborate the requirements for the interior design and shielding of radiological facilities prescribed in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation, Safety Series No. 115. This report gives guidance on the design of diagnostic and radiotherapy facilities and describes how the required location of shielding should be determined, as well as shielding for brachytherapy units. The Design is used necessary for location shielding, for all types of radiotherapy facilities. So that, this paperexplains achieve the global trends in interior design for radiological facilities, and the extent to apply which the local situation.

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INTRODUCTION

The Internal design of radiological facilities has evolved dramatically in the past two decades. Through design new trends according to design professionals. Safety interior design is use in the first class by environmental engineering, and in the remodeling of existing facilities. Sections of the report will also be of interest to architects, civil engineers, hospital administrators and others who are concerned with the design of radiotherapy facilities. In addition, the guidance in this report will be useful to regulatory personnel responsible for the licensing and inspection of these facilities. Environmental engineering and internal designing are considered basic to the modern international requirements so as to establish functionality for institutions. The importance of its application increases especially for radiological facilities. The study of using shielding walls and directions and colors as well as lighting, are very important for changing the psychology for those living there.

They also help in responding to treatment, help in protecting Man and environment, and help in enhancing the safety competence for workers and patients. They do not affect the internal elements. It needs specialized study.
Elements of the interior design:

- Shielding walls.
- Direction.
- Lighting.
- Colors.
- Natural ventilation.
- Distribution.
- Flexibility of design and the ability of extension.
- Circulation paths.

Definition of the Interior Design: Interior Design is the art and craft of creating beautiful and functional environments. It is about finding harmony in a space. This harmony comes from the fusion of all the senses. Interior Design has become a crucial element in many fields. Interior Design enables us to create an environment to reflect a specific character.

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It has a long and rich history. Once understood, the rules can either be followed or broken with awareness.

Interior Design Considerations: The methods that can be used to enhance the interiors of Radiological facilities are endless! This introductory section can only offer a few basics to consider when design. A good piece of advice is to work closely with your designer. They will have the creativity, experience, and knowledge to help you choose from the countless materials that are available in today's design marketplace.

The Elements of Interior Design

- Space.
- Line.
- Shape.
- Light.
- Ventilation
- Color.
- Pattern.
- Texture.

The Principles of Interior Design

- Function
- Balance.
- Rhythm and Repetition.
- Emphasis.
- Proportion and Scale.
- Harmony.

Interior Design Considerations

Lighting: Indirect lighting to produce softer, subtler environments and the use of increased indoor lighting have been the revolutionary changes in terms of lighting in the radiological building, say design experts. Designers are also becoming more creative with lighting to produce relaxing, stress-free atmospheres by using intricate illumination designs. Windows allowing natural light to provide a psychological boost and a connection to nature is another way of reducing stress. Natural light can also be a source for cheap, high quality light if controlled properly. Today, it's easier than ever to get creative with natural light. Decorative windows, available in colored contemporary and natural outdoors scenes, are just as efficient as conventional windows. Generally, for the treatment room, ambient lighting should be evenly distributed, shadow free, have good color rendering and be concentrated at the patient's head. The doctor should use lamps with a high Color Rendering Index (CRI) (a CRI number of 100 shows the "truer" colors) to perform tasks such as tissue inspections, shade readings for colored restorations, and aesthetic evaluations. Doctor can reduce the amount of eyestrain during the day if the ambient lighting of the treatment room is high enough to prevent a large difference when moving the eye from internal task lighting to regular room lighting. Generally, overhead treatment room lighting from two banks of 2' x 4' four tube fixtures will be adequate room illumination.

Flooring: There is a myriad of flooring choices for the radiological units. Keep in mind that flooring choices are subject to applicable laws. Floors are available in vinyl composition tile (VCT), sheet vinyl, ceramic tile, slate, a combination of all of these, or others. With the variety of hard surface flooring and available today, they can be incorporated as way finding techniques and patterns to reinforce larger themes.

Walls: Interior designers can assist you in planning your wall preparations. Painted walls are usually inexpensive and easy to clean. New technologies are producing wall coverings or wallpaper with sharper and more sophisticated designs. Wallpaper is available in a wide variety of color combinations, designs, and textures — including natural grass cloths. In addition, these new products are meeting fire code requirements. One trend that is evolving with wallpaper is that more commercial spaces are using "residential" colors and patterns. Radiological buildings use the residential theme to help patients relax and feel more comfortable. Wallpaper also is a great way to "cover" imperfections in walls, which can be common in older buildings. Consider a combination of paint and wallpaper in certain areas to enhance the wall look. Alternating ceiling heights or placing a border along the ceiling can give an impression of more space or enhance the design. Along Inside the ceiling can be a good way to trap sound and reduce the noise level in the office. In addition, ceiling art such as painted murals, mobiles, even artifacts embedded in the ceiling, can provide positive distractions for patients.

Corridors: Use wide, spacious corridors and hallways – a minimum of five feet for two people to pass each other comfortably. This will also help your supplier with any equipment installation and servicing. Frequently, the doctors subtract space in the hallways to acquire space for another treatment room. This is usually a bad idea. Cramped quarters will increase the stress levels in your office. In regards to accessibility, corridors should be free of clutter and loose doormats. Doorways should be at least 32 inches wide, with thresholds no more than one half inch high. Ramps should be equipped with handrails that extend beyond the end of the incline. Elevators should be large enough for wheelchairs and the buttons should be accessible from a seated height.

Interior Materials and Finishes

Partitions: Interior partitions should be primarily painted gypsum wallboard on metal studs. Partitions enclosing physician offices, exam rooms, and treatment rooms should be provided with sound attenuation batts between the studs in accordance with H-18-03, VA construction standard CD 34-1, Noise Transmission Control. Partitions, windows and doors enclosing Nuclear Medicine rooms that require radiation shielding must have the shielding engineered by an appropriately certified Health Physicist. Refer to H-18-03 VA Construction Standard 64-1, X-Ray Radiation shielding and Special Control Room Requirements. Construction documents will require written certification by a registered Health Physicist.

Floors: Floors in offices, conference rooms and waiting areas should be carpet with a 4-inch-high resilient base. Floors in toilet rooms should be ceramic tile with a ceramic tile base. Floors in Imaging Units, Radiobioassay Units, and Radiopharmacy should have welded seam sheet flooring with an integral base. Floors in exam rooms and most other spaces should be vinyl composition tile with a 4-inch high resilient base.

Treatment rooms and other spaces where higher doses of radiation or longer lived isotopes will be administered should be of welded seam sheet construction. Floor assemblies enclosing Nuclear Medicine rooms that require radiation shielding must have the shielding engineered by an appropriately certified Health Physicist.

Ceilings: Ceilings should be primarily lay-in acoustic ceiling tile. Certain areas, such as procedure rooms and treatment rooms, should have lay-in acoustic ceiling tile with a washable sprayed plastic finish. Coordinate the ceiling height requirements with the equipment manufacturer. Pathways above ceilings for cable assemblies should be provided for specific equipment types. Ceiling assemblies enclosing Nuclear Medicine rooms that require radiation shielding musthave the shielding engineered by an appropriately certified Health Physicist. Refer to H-18- 03 VA Construction Standard 64-1, X-Ray Radiation shielding and Special Control Room Requirements. Construction documents will require written certification by a registered Health Physicist.

Wall Protection: Wall and corner guards should be used in corridors and all other areas where damage from cart and stretcher traffic is anticipated.

***Hospital Regulation Page 20 of 96 Ref. No.**

HRD/HRS/FRU001

- Wall finishes shall be washable, moisture-resistant and smooth, wall finish treatments shall not create ledges or crevices that can harbor dust and dirt.
- Joints for floor openings for pipes and ducts shall be tightly sealed
- .- Floor drains shall not be installed in delivery rooms. If floor drain is installed in Cystoscopy, it shall contain a non-splash, horizontal-flow flushing bowl beneath the drain plate.
- Wired glass; or plastic, break-resistant material that creates no dangerous cutting edges when broken shall be used in certain areas such as glass doors and sidelights
- Highly polished flooring, walls or finishes that create glare shall be avoided.
- All doors between corridors, rooms, or spaces subject to occupancy shall be of the swing type or shall be sliding doors.
- Patient’s room door swings should be oriented to provide patient privacy.
- Curtains used throughout the hospital shall be washable/cleanable, fireproof and maintained clean at all times.
- Each patient shall have access to a toilet room without having to enter a corridor.

Interior Doors

Interior doors should be 1 ¾ inch thick solid core flush panel wood doors or hollow metal doors in hollow metal frames. Doorjambs, except in rooms with radiation shielding, should have hospital type sanitary stops that stop 8 inches from the floor to facilitate mopping.

Doors in wall assemblies that require shielding must be rated to provide the same shielding level as that in adjacent partitions. Hollow metal doors should be used where high impact is a concern and where fire rated doors are required. Kick / mop plates should generally be applied to both sides of the doors. Handicapped accessible hardware should be used throughout. Refer to VA Handbook PG-18-14, Room Finishes, Door and Hardware Schedule, for additional information. Doors leading to radionuclide receiving and storage area and radiopharmacy are required to be steel security doors that may in some areas need to have proper lead shielding. Refer to VA Handbook PG-18-14, Room Finishes, Door and Hardware Schedule, for additional information.

Definition of Radiological Facilities: That Facilities which include Radiation facilities, irradiation facilities, mining and milling facilities, waste management facilities and any other place where radioactive materials are produced, processed, used, handled, stored or disposed of – or where generators are installed – on such a scale that consideration of protection and safety is required. Activities include the production, use, import and export of radiation sources for industrial, research and medical purposes, the transport of radioactive material, the mining and processing of radioactive ores and closeout of associated facilities, cleanup of sites affected by residues from past activities and radioactive waste management activities such as discharge of effluents.

What is Radiology?: Radiology or radiography is a photographic process used to image anatomic structures. Instead of visible light, radiography utilizes X-ray energies which penetrate the body. These energies are absorbed at different rates by different tissue densities and are particularly effective for imaging bone and dense tissues. By varying the frequency and intensity of the X ray energies different tissue structures can be imaged. Many different applications of X-ray imaging technology have been developed over the years. In addition to the direct imaging technologies originally developed to print images on film, new computerized detectors have largely replaced film to produce electronic versions of the radiographic image. By using X-ray images of a volume acquired from different angles, three-dimensional reconstructions of the object can be created. This is the technology used for Computed Tomography (CT) scanners which can create acutely detailed volumetric models of anatomy. X-ray energies are a form of ionizing radiation that does have known health risks. However, the level of exposure from diagnostic imaging examinations, when appropriately proscribed, does not present significant health risks. The VA Radiology service also includes ultrasound which uses non-ionizing sound waves instead of X-rays to produce images for diagnosis or to guide treatment. Design guidance for Magnetic Resonance Imaging (MRI), often co-located with radiology services, is addressed in a separate VA Design Guide.

Radiological Facilities types

- Hospitals
- Laboratories
- Factories
- Research Centers

Classification of radiological facilities: The design of the facility should take into consideration the type of work and the radionuclide and their activities intended to be used. The concept of 'categorization of hazard' should be used in order to determine the special needs concerning ventilation, plumbing, materials used in walls, floors and work benches. Registrants and licensees shall ensure that a multilevel (defence in depth) system of sequential, independent provisions for protection and safety that is commensurate with the likelihood and the magnitude of the potential exposures is applied to sources for which the registrants and licensees are authorized. Registrants and licensees shall ensure that if one level of protection were to fail, the subsequent independent level of protection would be available. Such defense in depth shall be applied for the purposes of:

- Preventing accidents;
- Mitigating the consequences of any accidents that do occur;
- Restoring the sources to safe conditions after any such accidents.

Defense in Depth nuclear medicine:

- Source
- Shielded container
- Work area
- Laboratory
- Department
- Hospital

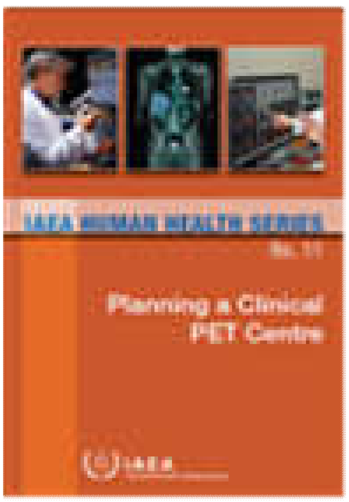
Categorization of Hazard Based on calculation of a weighted activity using weighting factors according to radionuclide used and the type of operation performed.

High hazard: Room for preparation and dispensing radiopharmaceuticals, temporary storage of waste. Room for administration of radiopharmaceuticals Examination Room Isolation ward.

Medium hazard: Room for storage of radionuclide. Waiting roomPatient toilet.

Low hazard

- Room for measuring samples Radiochemical work (RIA) Offices.
- Premises frequented by patients.



***Planning a clinical pet centre international atomic energy agency vienna, 2010, iaea human health series no. 11**

Design of the Radiological Facilities: The design of the facility has to suit the functional program, which defines the activities of the facility and will be reflected in the layout. It is crucial for the success of the facility to organize a design team that can work in a coordinated way. That includes the facility director, physicians, architects, engineers, radiation protection experts, and equipment vendors. The next step is to develop a floor plan taking into account how the rooms and the space will be distributed according to functions to be performed in each area the flows and radiation protection measures. A suggested layout is described below. According to the risk and level of radiation exposure, in the following, different functions will be allocated to areas with either a low risk (Section 6.3.1) of significant radiation exposure (so called 'cold' or 'uncontrolled areas'), or with high risk (Section 6.3.2) of radiation exposure (so called 'hot' or 'controlled areas'). Activities listed under Section 6.3.1 could be shared with other facilities (e.g. if the PET centre is set up in an already existing nuclear medicine and/or diagnostic imaging department).

Stages in Safety in Design

There are essentially stages in the design process that may be affected by the principles of SiD as follows:

Functional Design this may include preliminary design. At each stage of the design process risk identification should take place to eliminate risk or where this is not possible reduce risk as low as reasonably practicable through the implementation of control measures

Low risk areas

Reception: As patients arrive they are received and logged in by the administrative staff. Brochures and leaflets with general information about the PET/CT technique and any specific recommendations that apply to their particular scan should be provided and available to read while waiting. Typically, the reception is located at the front of the facility, normally with the *secretarial room* to its rear. Both areas need between 10–20 square meters, depending on the workload.

Waiting room: The appointment schedule should allow for a waiting time of no more than 30 minutes and if any delay is likely patients should be informed. It should be taken into account that oncological outpatients frequently come with an accompanying person, and so the waiting room should be constructed accordingly. An area of no less than 16 square meters is advised for a department with a single scanner. A location close to the reception is recommended.

Consulting room: In this room the request and clinical records are analyzed and the patient is interviewed and physically examined, if necessary. The patient is informed about the nature of the specific examination he/she is undergoing. This room should be close to the waiting room and adequately equipped. A supply of oxygen gas for medical use and vacuum for aspiration and all other services as per local regulations should be provided. An area of not less than 12 square meters is necessary.

Cleaning utilities room and store: A small room or cabinet should be available for the storage of QC phantoms, supplies and other materials.

TABLE 7.1. SPACE REQUIREMENTS FOR A TYPE 1 FACILITY

Function	Classification	Area (m^2)	No. of air changes (h^{-1})	Room pressure (Pa)
Entrance for personnel	Uncontrolled area	4	—	—
Offices for staff	Uncontrolled area	50	—	—
Quarantine storage room	Uncontrolled area	5	—	—
Material entrance	Uncontrolled area	3	—	—
Corridor	Uncontrolled area	24	—	—
Janitorial room	Uncontrolled area	2	—	—
Kitchen	Uncontrolled area	9	—	—
Data centre (archive)	Uncontrolled area	7	—	—
Toilets	Uncontrolled area	12	—	—
Storage room for released raw materials	Uncontrolled area	12	—	—
Storage room for technical gases	Uncontrolled area	2	—	—
Personnel airlock for entering the controlled area	Controlled area	9	5–10	−5
Corridor	Controlled area	34	5–10	−10
Preparatory laboratory	Controlled area	7	5–10	−10
Radiopharmaceutical handling	Controlled area, GMP class 'C'	16	10–20	+20
Storage for radioactive waste, recalled products andretention samples	Controlled area	3	5–10	−25
Janitorial room	Controlled area	2	5–10	−10
QC laboratory	Controlled area	25	5–10	−10
Material airlock/emergency exit	Controlled area	4	5–10	−5

*Radiation Protection Dosimetry (2013), Vol. 155, No. 3, pp. 351–363 doi:10.1093/rpd/nct005,Advance Access publication 20 March 2013

There should also be a dedicated space allocated to the cleaning utilities. Those can be located at one end of the facility and 5 square meters each would be sufficient.

Offices: In addition to the reporting room, a certain number of rooms should be available for clinical, scientific and technical staff, and for meetings and teaching activities, the number depending on the size and aims of the unit.

High risk areas

Small hot lab: Normally, PET radiopharmaceuticals can be delivered to the injecting room in two ways: either in a monodose syringe or in a vial. When it is in a vial, the radioactivity may be very high, depending on the number of patients, and each dose has to be dispensed from the vial; in this case, a small room, designed as a basic hot lab with shielding for positron emitters and near the injecting room, is needed. The IAEA's Operational Guidance on Hospital

Radiopharmacy: A Safe and Effective Approach [6.3] should be consulted for proper guidance on setting up this laboratory. The most favorable situation applies when the PET imaging facility is part of a PET/CT center with its own production unit (cyclotron and radiochemistry lab). This allows for mono-dose syringes to be delivered to each injecting room in lead containers.

Preparation, injection and uptake room: When procedures start, patients are asked to lie on a bed or to sit on a reclining chair. They might be medicated or otherwise treated according to the protocols followed in the unit before being injected with the FDG dose. If there is no specific changing room, a locker or small wardrobe should be provided in the preparation room for safekeeping of patient belongings. Position and size are crucial for smooth operations in a busy PET center. These rooms should be located close to the scanners room; an adequate work place/station should be available for the nursing personnel. Injection/preparation rooms should be available to host three to four patients (not less than roughly 12–16 square meters) for each PET/CT scanner installed. Patients after injection are a relatively intense source of radiation (of the order of 30–50 μSv/h per patient at 100 cm just after the administration). The assembly of several patients in the uptake room areas is a radiation protection problem that should not be overlooked; proper positioning and shielding of the uptake rooms need particular attention [6.4].

Toilet: After injection and an uptake period dependent on the protocol, before starting the actual PET scan procedure, patients are asked to void their bladder. The toilet must be located adjacent to the preparation rooms so that it can be easily accessed from any one of them. Within the facility, the toilet and preparation rooms are like an independent block that accomplishes specific functional and radiation protection requirements. About 30 square meters is sufficient for the entire block.

Control and scanning room: This is the core of the facility. The scanning room must be easily reached from the preparation rooms and the toilet. The door is normally just in front of the preparation block. Although the area needed for proper installation of a PET/CT scanner can be as small as 7 m -5 m, some extra space will ease diagnostic as well as maintenance operations. Vendors' prerequisites and installation guidelines should be considered in the planning phase. Also, careful consideration should be given to the fact that PET/CT scanners are somewhat demanding in terms of site prerequisites: the gantry of a multi-modality scanner could weigh in excess of 3000 kg. The corridors and angles should allow the biggest single package to be moved until its final position. Most parts of the scanners are air cooled; since the power consumption can reach 30 kW/ h, proper air conditioning is mandatory. For scanners that are water cooled, some extra space may be necessary for the water chiller.

Post-examination waiting room: Patients should wait in the post-scan waiting room while their scans are checked.

They will also need to change clothes if they are wearing a hospital gown. This allows faster patient throughput. Patients are released from the post-scan waiting room and leave the facility.

Reporting room: When the scan is finished the examination is checked and the images transferred for reporting. There should be space for at least one processing and fusion workstation, one for visualization, a desktop, and the typical furniture for diagnostic imaging. The area should be not less than 10 square meters and it should be located in the same area as the offices. Since studies could be transferred through the PACS system, this room does not necessarily need to be in the 'controlled area'.

Waste disposal room: The materials used for the dispensing of the FDG and anything which could be contaminated (clothes, linen, etc.) should be stored in a dedicated area to let the radioactivity decay before being disposed. The whole space required for a facility adhering to the above description is about 170–200 square meters, of which about half will be 'controlled/restricted' areas, including the PET/CT block and the tracer administration block, while the other half will host activities which do not imply the use of any radioactivity, such as offices and the reception block. Therefore, should the facility be located in a nuclear medicine department, about 40% of the space required could be considered as being for common use, which would account for a considerable saving in the budget allocated for construction. The bare minimum will be a space to process, and a separate space with the facilities to do QA on the final product before injection.

- Legal and Ethical Issues in Medical Practice, Including HIPAA
- *Radiation protection in the design of radiotherapy facilities international atomic energy agency, vienna, 2006, safety reports series no. 47

General Considerations for Interior Design FEATURES

General Regulations: General work area laws restrict eating, drinking, smoking, applying cosmetics or lip balm, and handling contact lenses in the work area. These laws also forbid storing food or drinks in refrigerators that are used to store blood or other potentially infectious material. Refrigerators must have working thermometers to ensure proper cooling temperature (see Figure 3-4). There are also required procedures for various specific on-the-job injuries. For instance, for eye injuries such as burns and chemical splashes, OSHA requires flushing the eye(s) for 15 minutes with a constant water flow.

Location: Several factors should be considered when determining the location of Radiology Services within a facility. This service should be strategically located to maximize efficiency in usage. As technology is constantly changing and new methods of Imaging Services are being developed, consideration should also be given to the high probability that the area will require renovation, expansion and / or equipment replacement in the future. It is frequently more cost effective to expand an existing Imaging Service than to relocate the service completely. Thus, it is desirable to locate the service on the perimeter of a facility and where future expansion is possible. This location also provides for ease of service of existing equipment and equipment replacement as new technologies are developed. Soft space such as administrative offices and support space should be located adjacent to the high technology / diagnostic equipment areas to facilitate ease of expansion for the equipment areas. Radiotherapy departments are usually located on the periphery of the hospital complex to avoid radiation protection problems arising from therapy rooms being adjacent to high occupancy areas. As pointed out in NCRP 49 [2], operational efficiency, initial cost, as well as provision for future expansion and/ or increased workload, should be considered when locating a therapy installation. Proximity to adjunct facilities, ready access for in-patients and outpatients, and consolidation of all therapeutic radiological services, however, may be more important than construction cost. For rooms below ground level, the reduction in shielding costs for floors and outside walls should be weighed against the expense of excavation, watertight sealing and of providing access. For rooms on or above ground level, the outside walls always require shielding; and additional structural support may be required for heavy equipment and for the additional weight of the shielding barriers. The amount of shielding required in each of the barriers of the treatment bunker will depend to some extent on the use of the surrounding areas. Areas with high occupancy levels will require greater shielding. Wherever possible the treatment bunker should be surrounded with rooms that have low or controlled occupancy. For example locks or signs prohibiting unauthorized entry could control access to the roof space above a bunker.

Access: The main Radiology Service should be readily accessible to both inpatients and outpatients, and in proximity to the central vertical transportation system serving other areas of the medical facility. It should be located near Ambulatory Care, Nuclear Medicine, Outpatient Services, and the Emergency Department. Access to the room for the delivery and replacement of the treatment unit and subsequently by patients must be considered. Patients may arrive in wheelchairs or on trolleys or beds. Entrance to the room may be through a shielded door or via a maze. It is necessary to include in the room design an open access conduit for dosimetry equipment cables. This dosimetry duct should always be through a secondary barrier so that the primary beam can never strike it. Ideally it should run at an angle through the barrier to the treatment control area. Also, for security purposes, radiotherapy facilities using radioactive sources should be located in areas where access by members of the public to the rooms where sources are used and stored can be restricted. Further, the proximity of source storage facilities to personnel that may respond in the event of a security breach should also be considered.

Room Size: The machine manufacturer's pre-installation manual should provide the minimum room dimensions (length, width and height). The room should be large enough to allow full extension of the couch in any direction, with room for an operator to walk around it. The desirable size depends upon the type of treatments; for example, a total body irradiation (TBI) procedure will require a larger treatment distance to one wall. For intra-operative procedures (IORT) that require extensive support staff and equipment, the room may need to be larger. The accessory equipment such as electron applicators, breast positioning boards, etc., are usually stored within the room, and should be located to minimize the walking distance for each patient set-up.

Mazes: In order to reduce the radiation dose near the entrance, a restricted access passageway leading to the room may be incorporated in the design. This passageway is termed the maze. Ideally this should be as long and with as small a cross-section as possible. The minimum width may be determined by the dimensions of the treatment unit to be delivered by this route or by access for a hospital bed. A maze ensures that photon radiation can only exit the room after scattering has attenuated it. A maze reduces the need for a heavy shielding door. If the length of the maze is sufficient, or if there are enough bends, there may be no need for a radiation protection door at the maze entrance. However, it is recommended that a physical barrier such as a normal door(s) or gate be installed to discourage entry to the maze during patient treatment if a shielded door is not required. Linear accelerators normally only require a gate to prohibit entry during treatment times and/or motion detectors to detect unauthorized entry if a shielded door is not required to reduce dose rates.Another advantage of a maze is a route for ventilation ducts and electrical conduits without compromising the shielding.

Treatment control area: The treatment control area is where the operators control the machine. This area should be close to the entrance to the treatment bunker so that the operators can view the entrance area. The control area should be sufficiently large to accommodate the treatment unit control console and associated equipment. There may be computer terminals for record and verification, electronic portal imaging, hospital information system and dosimetry equipment, as well as closed circuit TV monitors.

Patient observation and communication: The operator should be able to visually monitor the patient during treatment with closed circuit TV. Two cameras are recommended. These should be situated 1- 1.5 moff and above the gantry rotation axis for optimum observation of the patient on the treatment couch. The cameras should be located far away from the radiation source, consistent with tele-zoom capabilities, to minimize degradation of the image receptor by scatter radiation. There should also be provision for two-way audio communication between the treatment control area and the room. A patient activated alarm may be required for patients unable to give an audible call.

Penetration of ducts: Ducts and conduits between the treatment room and the outside must be adequately shielded. This includes ducts for cables necessary to control the treatment unit, heating and ventilation ducts, ducts for physics equipment and other service ducts. It is recommended that ducts should only penetrate the treatment room through secondary barriers. No duct with a diameter greater than 30 mm should penetrate the primary shielding. The ducts should be placed in such a way that radiation passing through them will require the least amount of compensation for the barrier material it displaces. No duct should run orthogonally through a radiation barrier. It could either run at an angle through the barrier or have one or more bends in it so that the total length of the duct is greater than the thickness of the radiation barrier. If required, lead or steel plates are suitable materials to compensate for the displaced shielding. To shield the scattered radiation that passes along the duct, it is better to place the additional shielding outside the treatment room, where the radiation has a lower average energy and therefore, less shielding material is needed. Treatment machine cables are usually run below the floor level under the primary or secondary barriers, before bending up to reach the treatment control area. Provided there are no rooms below, additional shielding is not usually required unless the treatment control area is directly behind a primary barrier, and the cable passes beneath the same primary barrier. Water pipes and narrow electrical conduits are usually placed in groups inside a larger duct. It is recommended that they also should not penetrate through barriers, but follow the maze to exit the treatment room as described above or follow a route beneath the shielding barrier. Heating and ventilation ducts should not penetrate through primary barriers because of their large cross-sectional area, which makes it costly to compensate for the shielding material they displace. If the ducts must pass through a secondary barrier, the cross-section of the duct should have a high aspect ratio to decrease the radiation passing through the duct as a result of multiple scattering interactions with the duct/shielding walls. The axis of the duct and the longer side of the duct cross-section should be as orthogonal as possible to the direction of the leakage radiation from the target towards the duct.

Ceilings: The recommended placement of these ducts is above a false ceiling along the path of the maze, to exit the maze at or near the external maze door where the photon and/or neutron fluency are lowest. For accelerators of energies up to 10 MV, usually no additional shielding around the duct is required, for higher energies. If it is necessary for the ducts to pass through the secondary barrier, they should be placed as high as possible to minimize the scattered radiation to personnel outside the room. Conduits are required for dosimetry cables, beam data acquisition system control cables, quality assurance (QA) equipment cables, and in vivo dosimetry equipment cables. The conduits are usually PVC pipes of 80–100 mm diameter included in the concrete formwork. They should be inclined at an angle (in the vertical and horizontal planes), and penetrate through the secondary barrier but not through the primary barrier. If the openings are at least 300 mm above floor level they are more convenient to use. Ideally, the opening in the treatment control area should be at the counter top level and the opening in the treatment room side should be at a different level but within easy reach.

International trends in interior designing of radiological facilities.

- The importance of the interior design in distribution, direction, and identify the shielding, that is Leads to a doubling the efficiency.
- A detailed study of internal elements such as: doors, windows, floors, ceilings, walls, finishing material and warning signs.
- Establishment of modern management systems for different units' functionality and usage, with the ability of extension and usage flexibility.
- Programs and codes to analyze study and improve interior blanks and it is considered one of the most important, and recent instrument internationally in the field of environmental engineering and internal design facilities, such as:
- Thermal analysis.
- Radiation analysis.
- Ventilation flow.
- Faluk.
- Monte Carlo.

- Daylight design.
- 3D Max - AutoCAD.

A detailed study for water and ventilation circulation mechanisms to create a safe and healthy environment.

Earthquake protection mechanism: Making use of some international programs (geographic information system GIS) to study the environmental design to direct the building and thus study the lighting and internal natural ventilation and the aesthetic appearance and the psychology of colors to increase healing capacity.

Recommendation

Our recommendation is the: Establishment of a relationship between an entire modeling design with thermal analysis and protection design, in addition to the enhancement systems for radiological facilities by environmental internal design.

- The merger between international trends of internal design elements and the requirements of radiological facilities building.
- Using the most recent technologies for studies and analysis, along with enhanced building and finishing material for radiation protection (protection barriers) in order to achieve international trends milestones:
  - Enhancing treatment efficiency.
  - Better radiation protection for employees, patience and surrounding environment.
  - Expenses minimization.

Conclusion

The international trends and standards pertaining to environmental internal design in Egypt have been applied after studying the extent of its adaptation and appropriate implementation to domestic field for new radiological facilities; The following have been implemented:

- The most recent international designs for protection barriers.
- Implementation of good module management systems that leads to the enhancement of efficiency, design flexibility and extension capacity.
- The implementation of the most recent systems for motion paths in order to reduce exposure to radiation between the hospital units (floor color planning to facilitate movement and guarantee protection).
- Environmental design to study natural orientation and lighting.
- The use of the latest finishing material.
- Implementation of the latest international trends in children injection units and waiting rooms.
- The latest doors' systems, alarm systems and children-friendly warning signs.
- Addressing the current case for best results and least costs:
- Change of module generation design by changing the units' orientation, redistributing the motion paths for better isolation and reducing the need for protection barriers and reducing its costs.
- Using local lead sheets (equivalent to international production) or types of lead bricks or Gibson board, and the choice must be based on the easiness of construction and replacement optimizing protection and cost.

REFERENCES

Beyer, T., et al. 2000. Combined PET/CT Scanner for Clinical Oncology, J. Nucl. Med. 41, 1369–1379.

CCR, Title 24, Part 2, Table 16A-OCCR. Title 8, 3241

CDC-NIH Biosafety in Microbiological and Biomedical Laboratories, 3 rd Edition Guidelines for Research Involving Recombinant DNA Molecules (NIH Guidelines), January 1997.

Colour and lighting in hospital design,Hilary Dalkea,b,_, Jenny Littlea, Elga Niemanna, Nilgun Camgoza,,Guillaume Steadmana, Sarah Hilla, Laura Stottb,aColour Design Research Centre, London South Bank University, Borough Road, London SE1 OAA, UK,bColour Design Research Centre, Kingston University, Knights Park, Kingston KT1 2QJ, UK Available online 19 October 200

IAEA Safety Guidance on Occupational Radiation Protection (RS-G-1.1 & RS-G-1.3).

Iaea Tecdoc Series-17, The Information System on Occupational Exposure in Medicine, Industry and Research(ISEMIR):Industrial Radiography.

International atomic energy agency, Operational Guidance on Hospital, Radiopharmacy: A Safe and Effective Approach, IAEA, Vienna (2008).

International atomic energy agency, Quality Assurance for PET and, PET/CT systems. IAEA Human Health Series No. 1, IAEA, Vienna (2009).

International atomic energy agency, Radiation Protection in Newer, Medical Imaging Techniques: PET/CT, Safety Reports Series No. 58, IAEA, Vienna(2009).

Legal and Ethical Issues in Medical Practice, Including HIPAA

NBS Handbook 92 IAEA, Safe Handling of Radionuclides Guide for the Preparation of Applications for Medical Programs (RH 2010 4/90) CDC-NIH Biosafety in Microbiological and Biomedical Laboratories (BSL 2, D.3) Guidelines for Research Involving Recombinant DNA Molecules (NIH Guidelines) App. G-II-B-4-b

Performance evaluation of natural ventilation strategies for hospital wards e A case study of Great Ormond Street Hospital,Z.A. Adamu*, A.D.F. Price, M.J. Cook,School of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU, United Kingdom

Planning a clinical pet centre international atomic energy agency vienna, 2010, iaea human health series No. 11

Radiation protection and safety of radiation sources: international basic safety standards, iaea safety standards series No. GSR Part 3 (Interim) "Safe Handling of Radioactive Materials", National Council on Radiation Protection (NBS Handbook 92)

Radiation Protection Dosimetry 2013. Vol. 155, No. 3, pp. 351–363 doi:10.1093/rpd/nct005,Advance Access publication 20 March 2013

Radiation protection in the design of radiotherapy facilities international atomic energy agency, vienna, 2006, safety reports series No. 47

Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide, Federal Emergency Management Agency: FEMA-74, 1994 EH&S Design Guide General Requirements for Stanford Laboratories, Version 2.0/ 13-02 Section 1 Page 3,Optimization of protection and safety, IAEA Basic safety standard (BSS).

Safe Handling of Radionuclides", International Atomic Energy Agency, Safety Series No. 1, (1973 ed. is still current as of 1999) (IAEA)

Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part3 No.GSR Part 3.

Wall color of patient’s room: effects on recovery by kortney jo edge. a thesis presented to the graduate school of the university of florida in partial fulfillment, of the requirements for the degree of master of interior design, university of florida 2003.

****