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Optimized Safety Management for X-ray Irradiators with Various Levels of Potential Exposure Risk Used for Researches

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This paper introduced one example of optimized safety managements for X-ray irradiators with various levels of potential exposure risk used for researches. How to manage X-ray irradiators and workers using them under the consideration of reasonable radiation protection in the case of The University of Tokyo has been shown. Japanese regulation on usage of X-ray as well as important ideas of optimization of radiation protection by International Commission on Radiological Protection (ICRP) is explained. To achieve an optimized safety management of X-ray usage in The University of Tokyo, the following two categorizations have been developed: (1) categorizing X-ray irradiators into five groups based on the potential risk on radiation exposure to workers using them, and (2) categorizing workers into two groups based on the information on the category class of the irradiator which they use. After starting the new safety management system in the university, without decreasing safety management quality and safety culture of workers, related management cost could become downsized. In addition, a load such as health surveillance etc. of lots of the workers using irradiators with comparatively lower risk has been also decreased.

Key words: safety management, X-ray irradiators, optimization, potential exposure risk, categorization, graded approach

1. Introduction

Lots of types of X-ray irradiators has been developed and used for researches in universities or institutes. Safety system of newer commercial irradiators used in Japan becomes better and better. Possibility of exposure accident on X-ray irradiators of present standard model is considered much lower. The risk of accidental exposure to workers is estimated nearly zero. On the other hand, old model irradiators without effective safety system or of open face type without effective shielding, which we still use as the main devices for researches, should be taken care of. To realize reasonable management on risk, The University of Tokyo enforced a new management system for X-ray irradiators for research uses in the budget year of 2012. The university has a history to manage all irradiators and all workers using them as the same before 2012. This paper introduces our discussion contents through the changing process of the management. How to manage X-ray irradiators and workers under the new system based on a consideration for reasonable radiation protection has been shown.

This safety management research and consideration

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Table 1. Main requests to workers of X-ray irradiators by regulations and regulators in Japan on the safety of X-ray

No. of Article		Request Contents
ISHA[a]	No. 3, 15, 18	- specifying radiation controlled area, radiation device room, and keep-out area
	No. 3	- notice on prevention of health disorder
	No. 8, 9	- measurement, confirmation and record of external exposure of workers
	No. 17	- installation of alarm device
	No. 46, 47	- appointment and duty of a chief for workers using X- ray
	No. 54	- measurement, record, preservation, notice of dose equivalent on external exposure in controlled areas
	No. 56, 57, 58	- enforcement, record, preservation, and report to the Labor Standards Inspection Office on health surveillance
	No. 60	- installation of radiation survey meters in facilities
OPIRH[b]	No. 253	- safety education (human effects on radiation exposure, safety handling of radiation and related devices, etc.)
	No. 253	- appointment of a chief for X-ray management
NCLSB[c]	No. 85, 86	- report of plan using X-ray to the Labor Standards Inspection Office

[a] Industrial Safety and Health Act (Rou-An-Hou)
[b] Ordinance on Prevention of Ionizing Radiation Hazards (Denri-Soku)
[c] Notification by the Chief of Labor Standards Bureau (Tsutatsu)

are mainly based on the activities of Working Group activity among radiation safety specialists and Informal Meeting on radiation safety under the Radiation Control Division in The University of Tokyo. The division received a special prize of the president of The University of Tokyo in 2013, by the reason on its excellent business reform based on the new management system for X-ray irradiators to be introduced here. This paper rearranges our former documents or presentations[1-3] to timely introduce the discussion process of changing on the management system in the university.

2. Regulation on X-ray usage in Japan

Definition of 'X-ray irradiator' in Japanese regulation is an irradiator to emit X-ray under the status to positively use the X-ray. This definition is under the Industrial Safety and Health Act (Rou-An-Hou) and the Ordinance on Prevention of Ionizing Radiation Hazards (Denri-Soku), regulated by the Ministry of Health, Labor and Welfare (HLW) of Japan. Especially, we call an X-ray irradiator with 10 kV or more of tube voltage as 'a specified X-ray irradiator'. The irradiator should be installed with some specifications determined by HLW. X-ray irradiators are categorized into two by their purpose of 'for industrial use' and 'for medical use'. Use of X-ray irradiators for researches is considered as one of industrial uses. Here, we are focusing on the safety management of X-ray irradiators used for researches. These Japanese regulations and related regulators on the safety of X-ray requests the users to keep and act the items listed in Table 1.

When the energy of X-ray is 1 MeV or higher, the X-ray is defined as one type of radiations under The Law Concerning Prevention of Radiation Hazards Due to Radioisotopes, etc., (Shogai-Boushi-Hou) regulated by the Nuclear Regulation Authority (NRA) of Japan. In this case, the irradiator is controlled by two Japanese regulators of HLW and NRA. Here we are focusing only on the irradiators emitting X-ray with the energy less than 1 MeV because optimization of safety management of these devices is the target of discussion in universities or institutes in Japan. The University of Tokyo owns and operates about 250 irradiators of X-ray with various levels of potential exposure risk used for researches as of in August of 2013.

3. Optimization on radiation protection and management

"Optimization of protection" is one of the three keywords for the radiation protection system established by International Committee on Radiological Protection (ICRP)[4]. The other two are "Justification" and "Dose limitation". According to the ICRP description, "The principle of optimization of protection, with restriction on the magnitude of individual dose or risk, is central to the system of protection and applies to all three exposure situations: planned exposure situations, emergency exposure situations, and existing exposure situations. The principle of optimization is defined by the ICRP as the source-related process to keep the likelihood of incurring exposures (where these are not certain to be received), the number of people exposed, and the magnitude of individual doses as low as reasonably achievable, taking economic and societal factors into account." Then strategy of graded safety management depending on risk level of target is important for optimized safety control. In order to establish the safety strategy in real-sites under the regulation system in Japan, to analyze risk status and

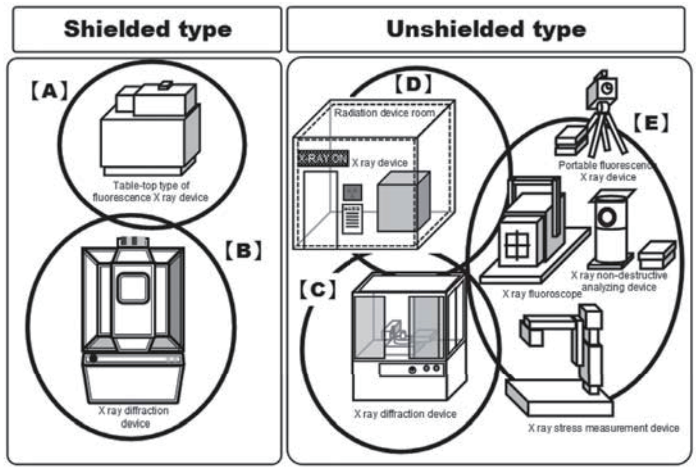
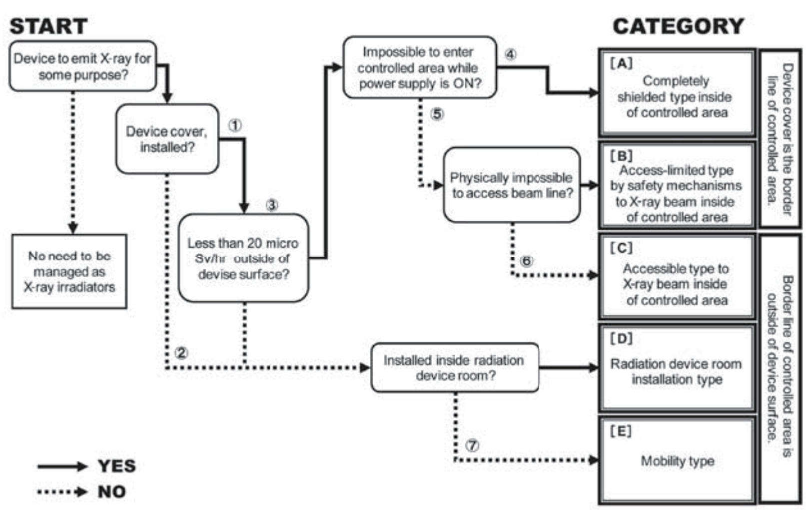


Fig. 1. Outlook of Categorization for X-ray irradiators based on their potential risk of exposure to workers.



Definition of important terms

- Device cover; Exposure box of X-ray installed with irradiators
- Controlled area; an area which has possibility to exceed 1.3 mSv per three months as the effective dose of external exposure
- Radiation device room; a room installs an irradiator or irradiators whose dose equivalent (1cm) could exceed 20 micro Sv/hr outside of device surface.

Example of explanation on each arrow mark

① Shielding by device cover
② Target sample for research to be exposed is outside of device cover, etc, including the hand-held type
③ Dose equivalent (1 cm) outside of device surface is estimated by specification catalog or in-situ measurement.
④ Device cover can be opened only when the power supply of the X-ray irradiator is off.
⑤ X-ray can be cut-off by a beam shutter, or target sample for research to be exposed is loaded and installed automatically by a device arm.
⑥ Beam shutter can be lifted, or interlock system can be intentionally lifted while irradiator emits X-ray.
⑦ The irradiator could not fix in a radiation device room, or the irradiator is designed for mobility use.

Fig. 2. Flow-chart to determine the category of an X-ray irradiator.

cause of risks is strongly needed through the discussion among real-site managers and workers.

Here X-ray irradiators are selected as target with a risk of radiation potential exposure. X-ray irradiator is a "source" in the system of radiation protection, and planned exposure situation is the target situation for discussion.

4. Categorization for optimized management

1. Five categories for irradiators

Five categories [A] to [E] were defined in The University of Tokyo to manage X-ray irradiators from the view point of accidental radiation potential risk to expose workers. From category [A] to [E], potential risk is generally from lower to higher. [A] is comparatively safe, and [E] has

Table 2. Definitions of five categories for X-ray irradiators and two categories for workers based on their potential risk of exposure

<table>
<tr><th colspan="4">Category</th><th>Specification and examples</th></tr>
<tr><th colspan="2">Users</th><th colspan="3">Irradiators</th></tr>
<tr><td rowspan="5">[b]</td><td rowspan="2">[a]</td><td>[A]</td><td>Completely shielded type inside of controlled area</td><td>- No possibility of accident exposure to workers.
- The irradiator could not emit X-ray because the power supply is automatically cut when workers try to enter the controlled area of the device.</td></tr>
<tr><td>[B]</td><td>Access-limited type by safety mechanisms to X- ray beam inside of controlled area</td><td>- No possibility of accident exposure to workers.
- The X-ray automatically is cut-off by a safety beam-shutter of the device when workers try to enter the controlled area of the device.
- Interlock system operates constantly.</td></tr>
<tr><td rowspan="3">—</td><td>[C]</td><td>Accessible type to X-ray beam inside of controlled area</td><td>- Potential risk of accident exposure to workers is comparatively low.
- The X-ray might not be cut-off or not be down when users try to enter the controlled area of the device.
- Beam-shutter could be lifted, interlock system could be lifted, interlock system is not installed, or adjustment of beam is possible while the irradiator emits X-ray.</td></tr>
<tr><td>[D]</td><td>Radiation device room installation type</td><td>- Higher potential risk of accident exposure to workers
- Dose equivalent (1cm) could exceed 20 micro Sv/hr outside of devise surface.
- Border line of controlled area is outside of device surface.
- The irradiator should install inside of a radiation device room.</td></tr>
<tr><td>[E]</td><td>Mobility type</td><td>- The highest potential risk of accident exposure to workers
- The irradiator could not fix in a radiation device room.
- The irradiator is designed for mobility use.</td></tr>
</table>

higher possibility of exposure accident to workers. Figure 1 shows an outlook image of categorization for X-ray irradiators based on their potential risk of exposure to workers. Figure 2 shows the flow-chart to determine the category of an X-ray irradiator based on the new rule in The University of Tokyo. Table 2 shows the definitions of five categories for X-ray irradiators.

2. Two categories for workers using X-ray irradiators

Two categories, groups of [a] and [b], were defined in The University of Tokyo to appropriately manage X-ray workers from the view point of radiation safety. A key factor to categorize X-ray workers into two groups is the safety rank of [A] to [E] of irradiators. Which type of irradiators they use is the determination parameter for worker category. Workers who use irradiators categorized into [A] or [B] only could be categorized into the group [a]. Workers who use irradiators categorized into [C], [D] or [E] should be categorized into the group [b]. Workers categorized in the group [b] can use [A] and [B], of course. Workers of the category [b] should be more taken care of on their radiation use and safety.

Workers categorized in the group [b] should be received special education on radiation safety and features of X-ray irradiators. All chiefs for X-ray management of all types of irradiators should also follow the education rule as the workers categorized into the group [b]. In The University of Tokyo, the related education is classified into three steps; whole university's common education (2–3 hours), faculty's education (0.5–1 hour), and research team education (0.5–1 hour). From common education contents (basis of radiation, radiation effects, radiation safety, and regulation) to more precise or concrete information (local rules and on-site training), they would be effectively educated using step-wised education system. To make workers to receive related education before their first use and once a year after starting to use X-ray irradiators is one of the important duties of site managers. Implement of personal dosimetry and medical surveillance for requested workers are also duties of site managers.

Workers categorized into the group [a] should also be received special education on radiation safety and features of X-ray irradiators. However, because their risk to be accidentally exposed is too low, then annual education would not be needed except for the first education before their first use. Neither implement of personal dosimetry nor that of medical surveillance for workers of the group [a] is duty of site managers. Table 2 shows of two categories for workers based on their potential risk of exposure as well as categories for irradiators.

Special mention and future tasks

1. Special mention

At the beginning of our discussion on categorization of workers, we planned as follows. "Exceptionally, some of the [b]workers who use the [C] irradiators could be categorized as the [a] workers, depending on the judgment of the chief manager of the instrument. Feature of the irradiator and/or how to use it in practice became effective information for his judgment. Reasonable and optimized management is our goal depending on the level of potential risk."[3] However, we experienced some near-misses in the university. A worker who used a [C] irradiator was almost exposed to X-ray beam on his fingers while changing and installing a target sample inside of the device cover. Interlock of the device was intentionally lifted by him and X-ray beam could be emitted through an open window of the beam shutter. Without checking the open/close status of the beam shutter by him, the worker inserted his arm and hand inside of the device cover while beam emitted.

We determined to cancel this exception rule for the [a] workers who use the [C] irradiators after this risky experience. It was determined that all workers who use the [C] irradiators should be categorized into the [b] workers.

2. *Future discussion and tasks*

Some discussions are still continuing to achieve more optimized safety management in the university. Here we would like to introduce two main discussion items.

How to manage and control some devices with extremely low exposure risk, such as "X-ray Photoelectron Spectroscopy Device", is one of the important discussion items. This type shows zero risk of exposure to workers. Necessity of report on installing and using this kind of devices to the Labor Standards Inspection Office should be discussed. Some workers, chiefs of management of irradiators, and stakeholders insist that both report to the Office and management of the device are not reasonable and not needed.

Even after starting our new safety management system, safety education is still extremely important. Now we started to develop new safety education system on X-ray usage as well as on the other radiation or radioactive materials usages. Time schedule, items and contents of education are now under revision status. Especially we are focusing on the development of new graded education system for both workers and managers.

The related discussion would also take a great part in the achievement of reasonable and optimized radiation management and protection.

5. Conclusion

This paper introduced one example of optimized safety managements for X-ray irradiators with various levels of potential exposure risk used for researches. How to manage X-ray irradiators and workers using them under the consideration of reasonable radiation protection in the case of The University of Tokyo has been shown. To achieve an optimized safety management of X-ray usage in The University of Tokyo, the following two categorizations have been developed; (1) categorizing X-ray irradiators into five groups based on the potential risk on radiation exposure to workers, and (2) categorizing workers into two groups using the information on the category class of the irradiator which they use. After starting the new safety management system in the university, without decreasing safety management quality and safety culture of workers, related management cost could become downsized and a load such as on health surveillance etc. of lots of the [a] workers has been also decreased.

Under the limited situation of human resources or budget on radiation management, reasonable and optimized safety management based on the careful discussion should be realized. We continue to discuss the related items, to revise existing safety systems, and to develop a next generation safety system in order to go toward the best safety management of radiation.

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