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Dose inspection and risk assessment on radiation safety for the use of non-medical X-ray machines in Taiwan

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ABSTRACT

The subject of this study is the on-site visits and inspections of facilities commissioned by the Atomic Energy Council (AEC) in Taiwan. This research was conducted to evaluate the possible dose and dose rate of cabinet-type X-ray equipment with nominal voltages of 30–150 kV and open-beam (portable or handheld) equipment, taking both normal operation and possibly abnormal operation conditions into account. Doses and dose rates were measured using a plastic scintillation survey meter and an electronic personal dosimeter. In total, 401 X-ray machines were inspected, including 139 units with nominal voltages of 30–50 kV X-ray equipment, 140 units with nominal voltages of 50–150 kV, and 122 open-beam (portable or handheld) X-ray equipment. The investigated doses for radiation workers and non-radiation workers operating cabinet-type X-ray equipment under normal safety conditions were all at the background dose level. Several investigated dose rates at the position of 10 cm away from the surface of open-beam (portable or handheld) X-ray equipment were very high, such X-ray machines are used by aeronautical police for the detection of suspected explosives, radiation workers are far away (at least 10 m away) from the X-ray machine during its operation. The doses per operation in X-ray equipment with a 30–50 kV nominal voltage were less than 1 mSv in all cases of abnormal use. Some doses were higher than 1 mSv per operation for X-ray equipment of 50–150 kV nominal voltage X-ray. The maximum dose rates at the beam exit have a very wide range, mostly less than 100 μSv/s and the largest value is about 3.92 mSv/s for open-beam (portable or handheld) X-ray devices. The risk induced by operating X-ray devices with nominal voltages of 30–50 kV is extremely low. The 11.5 mSv dose due to one operation at nominal voltage of 50–150 kV X-ray device is equivalent to the exposure of taking 575 chest X-rays. In the abnormal use of open-beam (portable or handheld) X-ray equipment, the effective dose of 3.92 mSv/s is equivalent to taking 196 chest radiographs within 1 s. This work assessed the annual doses (equivalent and effective doses) and risks of X-ray operator staff as reasonably as possible. The results of this research are helpful to the AEC (competent authority of ionization radiation) to improve the management and perform the safe control of X-ray equipment.

1. Introduction

X-ray machines are the most widespread application of radiation sources, in Taiwan. There are approximately 9000 X-ray machines in industry, including in the manufacture of semiconductor components, electronic component quality control tests, analysis/judgment of material elements, etc. The Atomic Energy Council (AEC) is the competent authority for ionizing radiation sources. The AEC asks that radiation safety testing be carried out for each radiation source at least once every five years, and test reports should be retained for future reference. A certain percentage of X-ray machines are selected by the AEC each year, for radiation safety inspection testing. This is to compel facility operators to implement the self-management of radiation safety to protect both their workers and the general public (IAEA, 2011, 2014; ICRP, 1997). The characteristics of X-ray machines are usually indicated based on their nominal voltage or radiation energy. In some cases, although X-ray machines have the same nominal voltage or energy output, X-ray machines designed in different manners, used for different purposes, and produced by different manufacturers may create the different radiation doses and thus present different safety risks to radiation workers. Therefore, by means of on-site visits and surveys, investigating X-ray machine types and performance data could help assess the causes of radiation doses and risks. Based on the dose limitation requirements of "as low as reasonably achievable"(ALARA) for occupational and public exposures recommended by the International Commission on Radiological Protection (ICRP) (ICRP, 1991, 1997, 2007), many national

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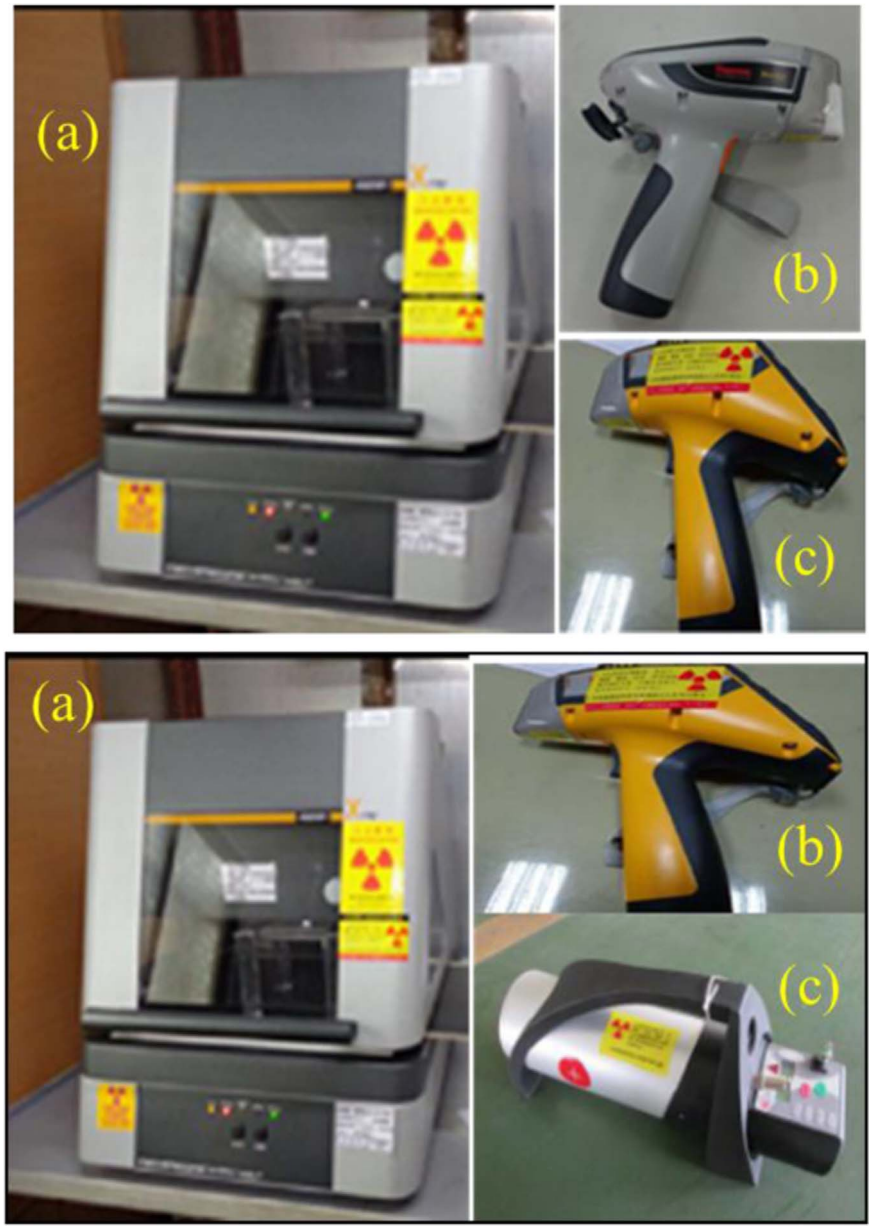

Fig. 1. Example photos of (a) cabinet-type X-ray equipment and (b) and (c) portable X-ray devices.

surveys regarding annual occupational exposures have been conducted by national governments (Colgan et al., 2008; Economides et al., 2006; Sanaye et al., 2010). This study subject is the on-site visits and inspections of facilities commissioned by the AEC. The subjects of visits and inspections were focused on non-medical-used cabinet X-ray machines with nominal voltages between 30 and 150 kV, and open-beam (portable or handheld) X-ray devices.

2. Materials and methods

This study was conducted to evaluate the possible occupational dose and dose rate (IAEA, 1999; UNSCEAR, 2008) of cabinet-type X-ray equipment with nominal voltages of 30–150 kV and open-beam (portable or handheld) equipment (see Fig. 1), taking into account normal operation and possible abnormal operation conditions.

2.1. Dose evaluation

The inspected X-ray machines, the radiation doses of which were evaluated in this work, were selected according to the roster provided by the AEC in Taiwan.

2.1.1. Dose evaluation for the normal use of equipment

Dose evaluations for cabinet-type X-ray machines and open-beam (portable or handheld) X-ray equipment were performed on-site, under the most commonly used operation conditions (tube voltage, tube current and exposure time). Doses and dose rates were measured using a plastic scintillation survey meter (manufactured by Atomtex, module number: AT1121, see Fig. 2). Dose and dose rates were measured for body and hand positions where radiation workers stand while operating the X-ray equipment. This study assumed that the hand dose and the body dose measured by the detectors represent the equivalent dose for limbs, and the effective dose for the whole body. The dose and dose rate results were compared with the dose limits of 500 mSv/y equivalent dose for the limbs and 50 mSv/y effective dose (ICRP, 1991, 2007).

2.1.2. Dose evaluation for abnormal use of equipment

Assessing the possible doses and dose rates for radiation workers,