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RESEARCH ARTICLE

# Radiation safety assessment of X-ray baggage scanners in a Metro Manila hotel and a port facility

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**ABSTRACT**

**Background:** The ionizing radiation produced by X-ray baggage scanners may cause harmful health effects to the health of occupational workers and members of the public. Hence, the International Commission on Radiological Protection recommends that radiation exposures from X-ray baggage scanners be kept as low as reasonably achievable.

**Objectives:** This study was done to assess the occupational risk from the measured ambient radiation from anti-crime X-ray scanners from a hotel and a port facility in Metro Manila. This was done by comparing the measured radiation levels with the acceptable limits required by the Center for Device Regulation, Radiation Health, and Research (CDRRHR) –Department of Health (DOH) – Food and Drug Administration (FDA).

**Methodology:** Ambient radiation of X-ray baggage scanners from Manila North Harbour Port Inc. (MNHPI) and Marriott Hotel Manila (MHM) were measured using RaySafe Xi survey detector while both machines were in operation. Measurements were done at a five-cm distance from the surface of the scanner console, front, back, left, and right sides. Peak measurements of ambient radiation were then obtained to overestimate the scattered radiation dose received by the worker assigned to the scanner. Values from the peak measurement were then compared with the limits set by the CDRRHR-DOH-FDA.

**Results:** The maximum measured ambient radiations at 5 cm from the surface of the machine were 0.590 µSv/hr and 3.519 µSv/hr from MNHPI and MHM, respectively. Both peak measurements were less than the 5.000 µSv/hr limit set by the CDRRHR-DOH-FDA.

**Conclusion:** Measurements from both facilities are within the required limit of the 5 µSv/hr at 5 cm distance from the external surface of the X-ray baggage scanner, set by the CDRRHR-DOH-FDA. It was also seen that the calculated annual occupation dose of the operator is within the limits set by ICRP. It is also recommended to study measuring at other distances from the surface of the scanner to determine whether safety protocols should be reassessed.

**Keywords:** *radiation safety, radiation protection, X-ray baggage inspection systems.*

## Introduction

There are facilities that use anti-crime X-ray scanners to provide higher security and better protection unlike other institutions that only use regular security procedures. The anti-crime X-ray baggage scanners are installed to inspect internally incoming products, parcels, and luggage through radiographic and fluoroscopic imaging [1]. Examples of this equipment are X-ray baggage scanners and cargo X-ray scanners. The X-ray baggage inspection system is also used for industrial quality control. Examples are food inspection for checking for foreign objects and circuit board inspection for finding manufacturing defects. Aside from its industrial uses, the X-ray baggage inspection system can be used for medical applications like analyzing tissue samples for tumor metastases [2].

Radiation exposures from X-ray procedures, which include the anti-crime X-ray scanners, are recommended to keep all exposures as low as reasonably achievable (ALARA) by the

International Commission on Radiological Protection (ICRP). This is to reduce the unnecessary radiation dose received by the workers and the public [3]. These unnecessary radiations are the secondary radiations generated by the X-ray generator namely the scattered and leakage radiations.

For the anti-crime X-ray scanners (Figure 1), the scattered radiation is coming from the primary beam that hits the target (baggage) and escapes through the lead curtains of the machine, while the leakage radiation is the stray radiation that escapes from the X-ray tube housing [4]. To prevent the leakage radiation from the X-ray machines, the tube housing is covered with lead that reduces the unnecessary exposure for both the worker and the public [5]. There are factors that affect the amount of scattered radiation. These are the intensity of the primary X-ray beam, field size, distance between the target and location of interest, and angle of X-ray scattering. A shielding barrier is used to reduce the exposure of the workers and public to the scattered radiation to the acceptable limit of the reference levels recommended by the IAEA [6].

Exposure to ionizing radiation may cause adverse health effects that fall into two general categories – the deterministic and stochastic effects. The deterministic effects are harmful tissue reactions caused by the killing of cells due to high dosages of radiation. The stochastic effects are cancer and hereditary effects caused by the mutation of somatic and reproductive cells, respectively [7]. Occupational exposure risks cancer induction, genetic mutation, and embryonic or fetal damage for pregnant workers.

Proper shielding in the facilities with X-ray machines is important to minimize radiation from escaping and to reduce the exposure of the workers and public. Safety requirements with regards to the radiation protection program of the facilities are established to comply with the International Basic Safety Standards (BSS) [6].

Unlike medical X-ray facilities where shielding rooms are installed, X-ray baggage scanners rely only on their built-in shielding protection. Since these scanners are more accessible to the public, there is a risk of possible exposure to ionizing radiation to the workers and the public within the vicinity of these X-ray machines.

The Administrative Order No. 40 Series of 1996, otherwise known as the "Requirements for the control of radiation hazards from industrial and anti-crime X-ray facilities" was issued by the Department of Health on December 6, 1996. This administrative order was made to set a standard in industrial and anti-crime X-ray facilities to protect the health of the people by preventing substandard operation, improper management, and inadequately shielded facilities that use X-ray machines. It was mandated that all facilities should be staffed by operators with complete training in radiation protection for industrial and anti-crime work, and a radiation safety officer (RSO) who has undergone training in radiation protection for RSOs [8].

For an industrial fluoroscopic X-ray equipment, the administrative order imposed that X-ray tubes be enclosed in a tube housing with an aperture covered by a shutter, or a complete shielding on the enclosure. The radiation level at any accessible point 5 centimeters (cm) away from the surface of the tube housing should not exceed 25 micro-Sieverts (µSv) in an hour or 2.5 mR in an hour when the X-ray

**Figure 1.** *An anti-crime X-ray baggage inspection system which features leaded curtains, fluoroscopic image, and key control console. (Photo Credit: East Image Security)*

tube is operated. Also, the radiation level at any accessible point 5 cm from the external surface of the machine should not exceed 5 µSv in an hour when averaged over an area of 100 cm2 when the X-ray tube is operated [8].

Even though standards have been set with various machines emitting radiation, measured ambient readings are essential to clearly establish the radiation safety of occupational workers and the public. The reported average scattered radiations from X-ray baggage inspection machines from Mehrabad and Ihmam Khomeini airport in Iran were 2.07 µSv/hr and 3.03 µSv/hr respectively [9], while the reported peak scattered radiation from X-ray baggage inspection machine in Sharjah International Airport in United Arab Emirates was 1.02 µSv/hr [10]. Comparing the measured doses shows that radiation levels are within limits set following Philippine and international standards.

This study was done to evaluate the occupational risk of workers from measured scattered radiation from the anti-crime X-ray scanners from the facilities by comparing peak measurements with the acceptable limits required by the Center for Device Regulation, Radiation Health, and Research (CDRRHR)–Department of Health (DOH) – Food and Drug Administration (FDA) Philippines, that follows the reference levels of the International Atomic Energy Agency (IAEA).

## Methodology

This study was done to evaluate the risk from radiation coming from the X-ray baggage scanners to operators at one of the inspection gates of the Manila North Harbour Port, Inc. (MNHPI) and at the entrance of the Marriott Hotel Manila (MHM). The MNHPI terminal was equipped with Auto Clear 100100B X-ray scanners for the inspection of the baggage of the boarding passengers as shown in Figure 2 and MHM had an East Image 100100 X-ray inspection system at its entrance as shown in Figure 5. There were two to three operators who work around each of the X-ray scanners, the baggage handlers who assist the passengers in loading and unloading their luggage on the conveyor belt of the scanner, and a computer operator who monitors the screening process of the luggage.

In this study, the ambient radiation was measured from one of the X-ray machines at the MHM and MNHPI passenger terminal with the use of Unfors RaySafe Xi, a semiconductor-based survey meter with survey detector probes and their base units as shown in Figure 3. Measurements from the survey detector have an uncertainty of 5%.

The radiation levels were measured and recorded at the accessible points 5 cm and 15 cm in MNHPI, and 5 cm in MHM from the external surfaces of the machine for three times while the machine was in operation. The detector

**Figure 2.** *The Auto Clear 100100B X-ray scanners at the MNHPI passenger terminal with the railings and workstation for the computer operator.*

**Figure 3.** *The survey meter that was used is the Unfors RaySafe Xi base unit and its survey measurement detector probe. (Photo Credit: RaySafe [27])*

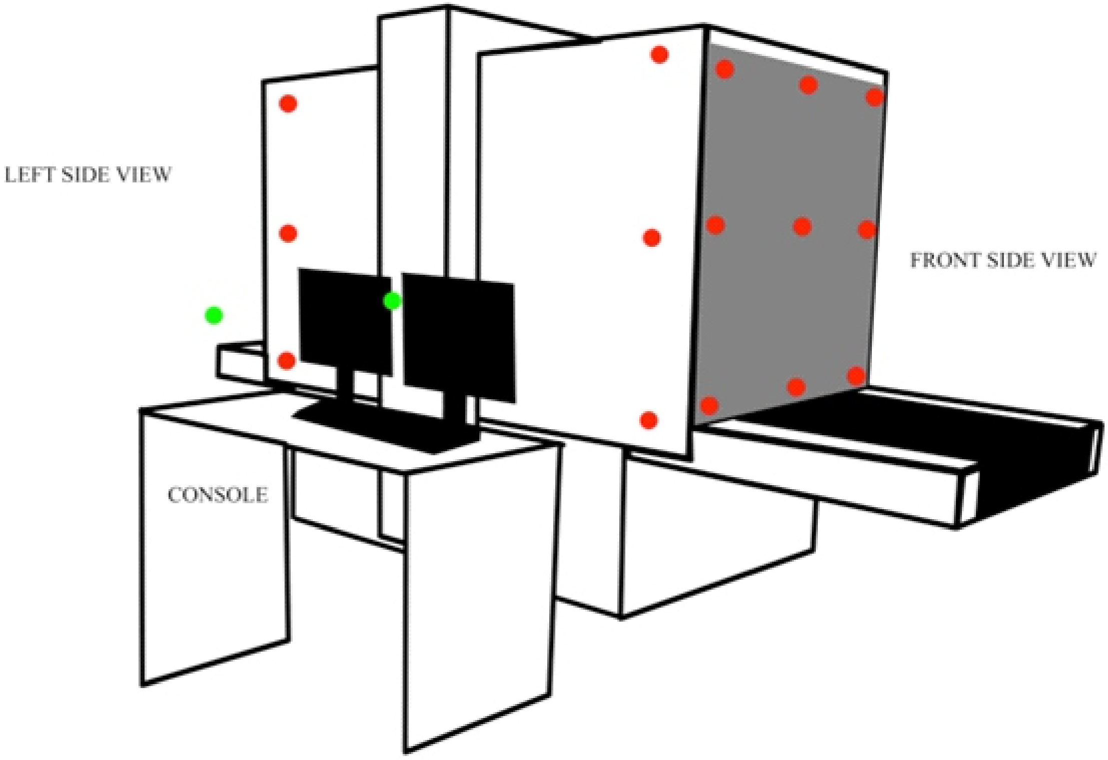

**Figure 4.** *The ambient radiation levels were measured 5 cm and 15 cm away at the following points from the external surfaces of the Auto Clear 100100B machine of MNHPI, while the machine was in operation. The front and back side views have the same location for the points; and at the console area (green dots), the radiation was measured 5 cm and 80 cm away from the machine.*

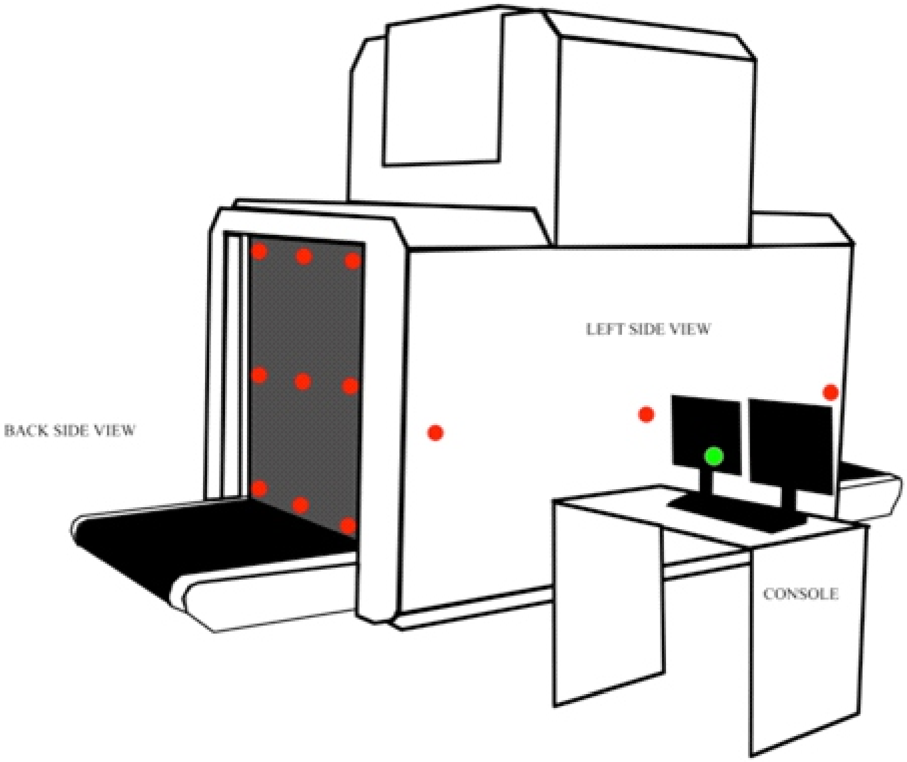

**Figure 5.** *The ambient radiation levels were measured 5 cm away at the following points from the external surfaces of the East Image 100100 machine of MHM. The front and back side views have the same location for the points as well as for the left and right sideview; and at the console area, the radiation was measured 50 cm away from the machine.*

probes were used to measure the radiation exposures at the entrances and exits of the X-ray baggage scanner and as well as from the console of the machine operator. These accessible points gathered from MNHPI and MHM are shown in Figures 4 and 5 respectively.

The ambient radiation dose rates that were received from the survey meters were used as the reference for the different locations around the machine, which includes its entrance, exit, both sides, and at the console. The reference levels from the X-ray scanner were evaluated if the radiation exposure levels follow the BSS for exposures for the public and occupational worker as per required by the CDRRHR-DOH-FDA. The measured ambient radiation dose rates overestimate the actual radiation associated with scattered radiation from the X-ray scanner.

## Results & Discussion

Table 1 summarizes the measured ambient radiation from X-ray baggage scanner in MNHPI. The peak measured value was 0.590 µSv/hr which is significantly lower than the regulatory limit of 5 µSv/hr required by the CDRRHR-DOH-FDA.

Around the East Image 100100 X-ray security inspection system in MHM, the maximum level was located at the entrance of the machine with a value of 3.519 µSv/hr; while its minimum level of 2.590 µSv/hr was located at both the left side and console area of the machine.

Based on Tables 1 and 2, both facilities are within the regulatory limits set at 5 µSv/hr. This means that the machine passed the standards set by CDRRHR-DOH-FDA.

### *Comparison of Ambient Radiation Dose at 5 cm and 15 cm from the Surface in MHNPI*

The comparison between the average ambient radiation doses at the five locations around the X-ray baggage scanners is shown in Figure 6 for MHNPI. The figure also exhibited that the ambient dose rates measured at the distance of the survey detector probe 15 cm away from the external surface of the machine were considerably higher than the dose rates measured at 5 cm in MHNPI.

The increase in ambient measured radiation may call for a possible re-examination of where to measure when obtaining ambient radiation with respect to regulatory radiation safety limits. It is also possible that there are other sources of radiation when the detectors were placed 15 cm from the surface. Although the measurements were still below the safety limit, it is recommended to continue doing more measurements to re-examine existing protocols.

### *Occupational Risk*

The International Commission on Radiological Protection (ICRP) recommendation for the annual effective dose limit for individuals with occupational exposure to ionizing radiation is 20 mSv averaged over 5 years with no exposure greater than 50 mSv per year [13]. Measurements from the console where the operator is located were 0.217 µSv/hr and 2.590 µSv/hr, respectively, for MHNPI and MHM. Ideally, an operator should wear a device (a radiation dosimeter) that can track the radiation dose they receive in the course of their work. Measurements from individual dosimeters are better estimates of actual human exposure than depending on overestimates from console measurements. Assuming 40-hour work weeks, the calculated annual exposure for MHNPI and MHM were 0.451 mSv and 5.39 mSv, respectively. Both calculated doses are within the limits of the annual dose for occupational exposure (20 mSv per averaged over 5 years with no exposure greater than 50 mSv). These estimates assume a constant exposure of radiation to the workers at the respective peak measurements. The annual exposure estimates of 0.451 mSv and 5.39 mSv are conservative estimates being compared with limits for annual dose for occupational exposure.

**Table 1.** *Maximum Radiation Exposure Levels 5 cm from the External Surface of the Auto Clear 100100B X-Ray Scanner in MNHPI.*

| Position | Maximum Value in (µSv/hr) |
|---|---|
| Front Side | 0.590 |
| Left Side | 0.476 |
| Right Side | 0.224 |
| Back Side | 0.267 |
| Console | 0.236 |

**Table 2.** *Maximum Radiation Exposure Levels around the 5 cm away from External Surface of the East Image 100100 X-Ray Security Inspection System in MHM*

| Position | Maximum Value in (µSv/hr) |
|---|---|
| Front Side | 3.519 |
| Left Side | 3.332 |
| Right Side | 2.876 |
| Back Side | 3.405 |
| Console | 2.590 |

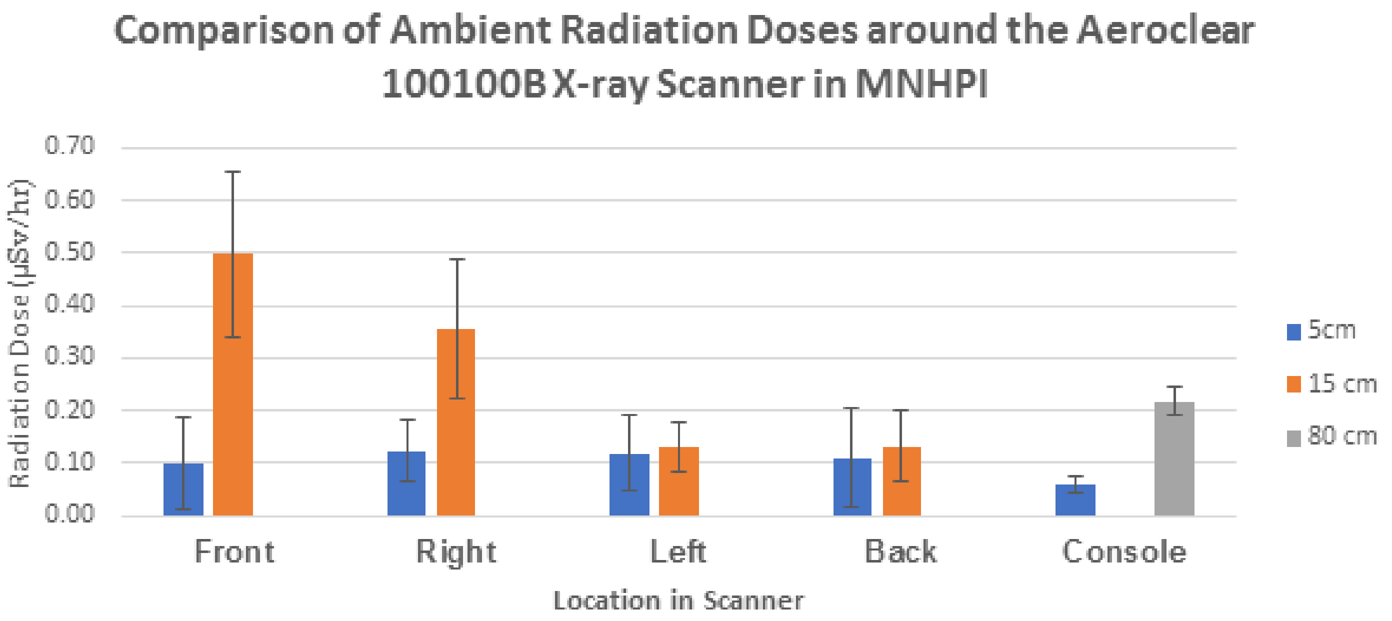

**Figure 6.** *The comparison of ambient radiation doses around the AEROCLEAR 100100B X-ray scanner in MNHPI at the distances of 5 cm, 15 cm, and 80 cm away from the surface. (Measurement at 15 cm further from the surface of the machine is higher than the measurement at 5 cm)*

### *Possible Factors Affecting Differences in Measured Scattered Radiation between MNHPI and MHM*

Some readings at 15 cm away from the surface of the scanners have shown larger measured radiation than the distance 5 cm away from the surface for the MNHPI X-ray scanner. It is possible that there are other sources of radiation being detected by the instrument. Differences in measured radiation levels between the MNHPI and MHM X-ray scanners might have also come from different operating voltages of 140 kV and 160 kV, respectively.

The tube location of the scanner may also have affected the difference between the two X-ray scanners. The X-ray tube of the East Image 100100 of MHM was located at the top of the machine's body, while the Auto Clear 100100B was located at the bottom due to its elevated design. We recommend simulations of these two set-ups to have a better understanding on how the tube position might have an impact on the scattered radiation.

The operating times of both machines might also be a factor. The Auto Clear 100100B from MNHPI was operated eight hours a day while the East Image 100100 from MHM was being operated 24 hours a day. The differences in hours of operation might impact the quality of the device and later the ability to efficiently image and scan baggage.

## Conclusion and Recommendations

The ambient radiation doses from the Auto Clear 100100B in MNHPI and East Image 100100 in MHM are within the acceptable limit as recommended by the ICRP and as required by the CDRRHR-DOH-FDA. The annual occupational doses computed from measurements were also within the limits set by ICRP.

Future studies are encouraged to review personnel and workplace monitoring, and the radiation protection training and programs of the facilities. It is also recommended to conduct more studies on scattered radiation of X-ray baggage scanners at different distances from the surface of the scanner to determine which position would be optimal for future regulatory procedures.

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