

Feasibility Study for Compton Computed Tomography (CT) for Radioactive Waste Drum Monitoring

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1. Introduction

In decommissioning of nuclear facilities, the amount of radioactive waste and its disposal cost can be significantly reduced by identifying and removing the hot spots in radioactive waste drums. A research of using the Large-area Compton Camera (LACC) [1] to image hot spots (i.e., emission imaging) in the waste drum and to estimate their activity is in progress, where the accuracy of the activity estimation can be improved by using the attenuation map of the waste drum. In the present study, the LACC itself, i.e., without using a separate CT system, was used to provide the attenuation map (i.e., transmission imaging). The performance of the imaging method, named Compton CT, was then evaluated through some experiments with phantoms.

2. Methods and Results

The LACC-based Compton CT consists of an external gamma-ray source, a rotation system for the waste drum, and the LACC. To reconstruct CT image, the Compton CT uses both single events, in which a gamma ray emitted from the external source is absorbed in the front detector of the LACC (i.e., scatter detector), and coincidence events in which a gamma ray is scattered in the scatter detector and then absorbed in the absorber detector. In addition to the energy window to select effective events, the scattering angle difference (SAD), a difference between geometrical angle of the external source and Compton scattering angle calculated from measured events, is considered to distinguish the origin of the gamma ray (e.g., external source or hot spots in the waste drum). The sinogram was generated from the effective events, and the CT image was reconstructed from the sinogram with the algorithm of cone beam CT image reconstruction.

The Compton CT was demonstrated with an IAEA industrial gamma CT phantom [2], a polypropylene cylinder with two holes which can be filled with pillars of different materials. In the present study, air, polypropylene, iron, and lead were used for the pillars. For the cone beam source of CT, a 20 mCi source of ¹³⁷Cs was located at 400 cm from the LACC. The phantom was placed at the isocenter (i.e., center of the drum rotation system), and the isocenter-to-detector distance was 36.4 cm. The phantom was rotated 360° at intervals of 5° (i.e., 72 projections), and the measurement time was set to 60 sec per projection. The energy window of 662±50 keV was used for single events and the SAD window of ±15° was used to select

the coincident events. The sinogram was reconstructed with the hybrid median filter. The attenuation map was then reconstructed by the filtered back projection with the Hann filter.

Fig. 1 shows 2-D attenuation maps of the IAEA phantom with different pillar materials in the X-Y plane and Y-Z plane, and 1-D profiles for the vertical (Y-axis) direction acquired from the Compton CT system. The results show that the map of linear attenuation coefficient can be estimated for both low-density material (i.e., air and polypropylene) and high-density material (i.e., iron and lead) with the Compton CT. The root mean square error (RMSE) of the attenuation maps of the phantoms with the pillar materials of air, polypropylene, iron, and lead were evaluated to be 5.7×10^{-6} , 5.1×10^{-6} , 2.3×10^{-6} , and 2.2×10^{-6} , respectively.

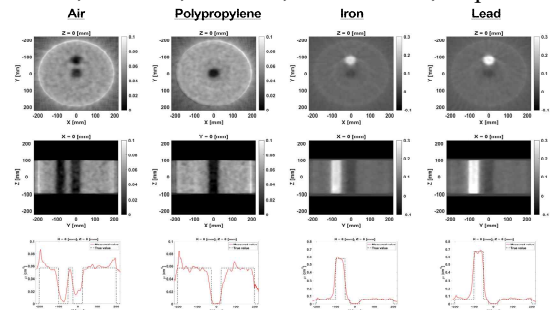


Fig. 1. Reconstructed 2-D attenuation maps for X-Y plane (upper) and Y-Z plane (middle), and 1-D profiles (lower) of linear attenuation coefficients for IAEA phantoms

3. Conclusions

In the present study, an LACC-based Compton CT was developed as a preliminary study to provide the attenuation map of the waste drum. The results show that the LACC can reconstruct the attenuation map for various materials. The attenuation map obtained in the present study is expected to be used for to estimate the activity of gamma emitters in the radioactive waste drum. In the future study, it is expected to be possible to identify other radionuclides, including pure beta or alpha emitters, by using scaling factor.

REFERENCES

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[2] International Atomic Energy Agency, Industrial Process Gamma Tomography, IAEA-TECDOC-1589, IAEA, Vienna, 2008