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Investigation of activation for decommissioning of accelerator facilities

Currently, there are over 1,700 accelerators in Japan, and the number of accelerators older than 30 years increases rapidly. As a result, the number of accelerator facilities to be decommissioned is also estimated to increase rapidly. Activation of accelerator facilities considerably impacts the effort and cost invested to decommission them. For reasonable planning of decommissioning, an advanced zoning of activated/non-activated area (region) is very important. In addition, in the decommissioning field, a method to easily determine the specific activity for accelerator materials is required. Therefore, in this study, the activated zone for various accelerator facilities was clarified, an easy determination method of the specific activity for concrete walls and floors was established, and the visualization of activated accelerator components was examined [1, 2]. This work was performed as one of the priority research areas in Radiation Safety Research Program and supported by Radiation Safety Research Promotion Fund.

In the zoning of activated area for accelerator facilities, we focused on five types of accelerator facilities in Japan: electrostatic accelerator facility (4 facilities), proton therapy accelerator facility (2 facilities), heavy ion therapy accelerator facility (1 facility), synchrotron radiation experimental accelerator facility (5 facilities), and cyclotron facility for positron-emission tomography (PET) (3 facilities). The typical facilities were selected based on the accelerator type, beam energy, facility size, and beam usage.

The activated zones were identified directly by measuring the gamma rays emitted from the accelerator components (Fig. 1) and indirectly by measuring the neutron fluxes generated during operation. The activated zone was identified around the beam loss location on the beamline. However, a few of the very large accelerator components (the terminal container of the electrostatic accelerators and electromagnet gantries of the proton and heavy ion therapy accelerators) were not activated. The floor and wall concrete of the accelerator room have very large volume as well. The activation of the concretes was evaluated by two different methods (direct determination of long-lived radionuclides after core sampling and indirect estimation from measured neutron fluxes in concretes). The potential to activate accelerator facilities using a cyclotron was indicated. On the other hand, any activated concrete area was not identified in other accelerator facilities. For example, in proton therapy, there are facilities using a synchrotron and those using a cyclotron as an accelerator. This difference in the accelerator facilities clearly appeared in the activation of the floor and wall concretes. In many of the facilities using a cyclotron, separation of the activated concrete as radioactive waste will be required at the decommissioning stage.

The method to determine the specific activity for concrete wall and floor was examined using a cyclotron facility for PET radiopharmaceutical production (the Medical and Pharmacological Research Center Foundation in Hakui, Ishikawa, Japan) as a case study. It was found that two radionuclides, which are ^{152}Eu and ^{60}Co, should be considered to decommission concrete. Other radionuclides can be ignored as minor. A method to easily determine specific activity of ^{152}Eu and ^{60}Co in the concrete was established. In this method, the contact dose rate on the concrete is measured using a specially customized survey meter equipped with a small probe. The specific activity can be obtained from the calibration curve to convert the contact dose rate into the specific activity, which is shown in Fig. 2. The specific activity in concrete could be measured easily and quickly using the survey meter.

The gamma-ray imaging technique was expected to help with the rapid identification of the activated parts in accelerators. The separation of the activated parts after rapid identification allows us to reduce the activated waste in decommissioning. Although gamma rays over 1 MeV from ^{60}Co, which is a major radionuclide in activated accelerator materials, must be detected, current devices are not designed to detect such high-energy photons. Therefore, to examine visualization of the activated accelerator components, activated electromagnets in KEK were measured with three different types of commercially available gamma-ray imaging devices (pinhole, Compton scattering, and masked types) and the results were compared. Fig. 3 shows an example of a contour figure of activation for an electromagnet of the 12-GeV proton accelerator. The strongly activated parts were evident in images observed using the devices of the pinhole and Compton scattering types. Further examination, we will take images in more difficult imaging conditions using these devices.

The results of this study contribute to standardize the decommissioning procedure of accelerator facilities.

References

[1] H. Matsumura *et al*., Report for radiation safety research program in FY2018 (2019), in Japanese.

[2] H. Matsumura *et al*., Report for radiation safety research program in FY2017 (2018), in Japanese.

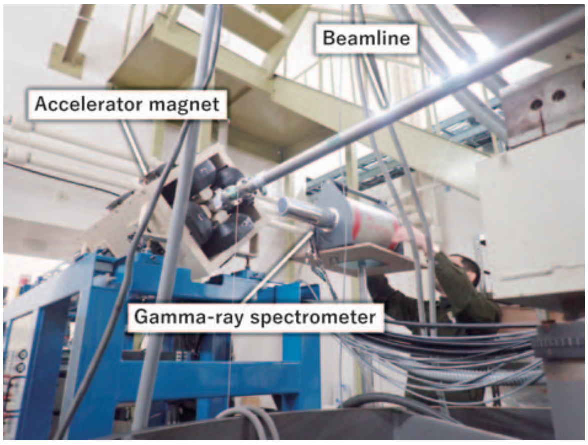

Fig. 1. Activation measurement for an accelerator magnet at the 6 MV tandem accelerator in University of Tsukuba.

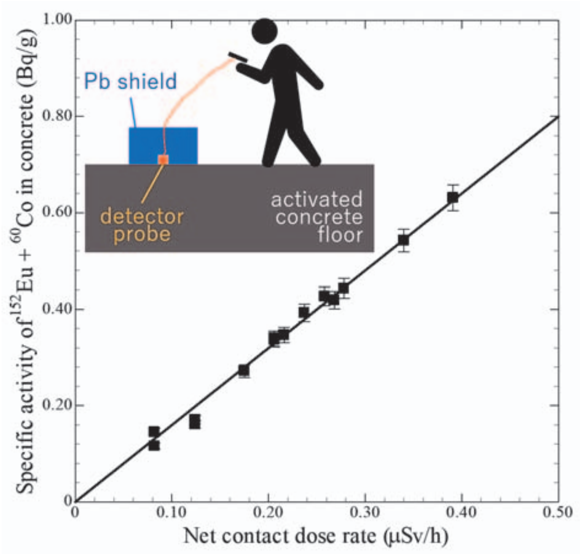

Fig. 2. Calibration curve for converting contact dose rate on the activated concrete into the specific activity.

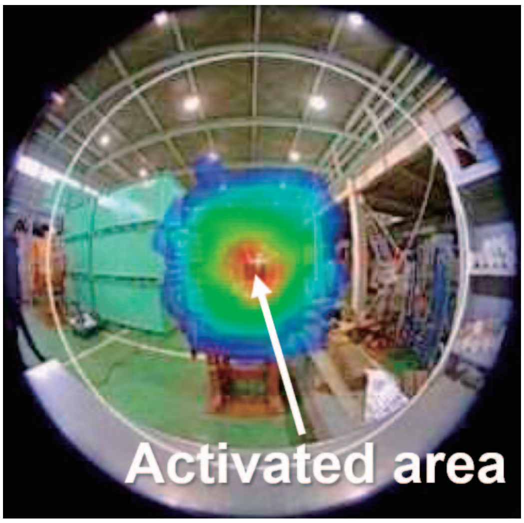

Fig. 3. Contour figure of activation for an electromagnet of the 12 GeV proton accelerator in KEK, using Gamma-Catcher, Chiyoda Technol (Compton scattering type).