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# A feasibility study on reactor based fission neutron radiography of 200-l waste packages

T. Bücherl[a]*, O. Kalthoff[b], Ch. Lierse von Gostomski[a]

[a]*Technische Universität München, ZTWB Radiochemie München RCM, Walther-Meißner-Str. 3, 85748 Garching, Germany*
[b]*Hochschule Heilbronn, Fakultät für Informatik, Max-Planck-Strasse 39, 74081 Heilbronn, Germany*

**Abstract**

This feasibility study investigates the applicability of fission neutrons for the non-destructive characterization of radioactive waste packages by means of neutron radiography. Based on a number of mock-up drums of different non-radioactive matrices, but being typical for radioactive waste generated in Europe, radiography measurements at the NECTAR and the ITS facility using fission neutrons and $^{60}$Co-gamma-rays, respectively, are performed. The resulting radiographs are compared and qualitatively assessed. In addition, a first approach for the stitching of the fission neutron radiographs to visualize the complete area of 200-l waste drums is performed. While the feasibility of fission neutrons is demonstrated successfully, fields for further improvements are identified.


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*Keywords:* fission neutron, radiography, radioactive waste, non-destructive characterisation, stitching

## 1. Introduction

In the frame of non-destructive characterization of radioactive waste packages for the declaration or verification of their radioactive inventory well established passive and active methods are applied, mainly based on gamma-spectroscopic emission measurements (segmented gamma scanning (Bücherl 1998)), gamma-transmission measurements (radiography and tomography using radioactive sources (Martz 1996) or accelerators (Rizo 2000)), neutron emission counting (with time correlation analysis to distinguish between neutrons originating from

* Corresponding author. Tel.: +49-89-289-14328; fax: +49-89-289-14347.
*E-mail address:* Thomas.buecherl@tum.de


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spontaneous fission or (α,n) reactions, respectively (Bücherl 2001)) and neutron interrogation techniques (to induce fission events (DeSimone 2010)). Radiography using neutrons is not applied successfully on radioactive waste packages, yet.

Results of a R&D project on neutron imaging of radioactive waste packages using a portable accelerator based neutron source did not show convincing results, yet (Kettler 2014). This might be caused by both, the low neutron flux at the detection area and the low spatial resolution. To investigate the general applicability of fission neutron radiography for the non-destructive characterization of radioactive waste packages a feasibility study was initiated using the fission neutron facility NECTAR (Heinz Maier-Leibnitz Zentrum 2015) at the FRM II of the Technical University of Munich (TUM). This facility offers a neutron flux of up to 4.7E+07 $cm^{-2}s^{-1}$ at sample position and a L/D of up to 235 (Bücherl 2011) depending on beam filtering and collimation.

## 2. Samples

At Radiochemie München (RCM) of TUM a number of predominantly 200-l mock-up drums of different non-radioactive matrices, but being typical for radioactive waste generated in Europe, is available. These drums are originally used for calibration and verification measurements in segmented gamma-scanning. Their matrices are made out of light materials like PE grains or bitumen (ca. 1 $g/cm^3$), medium dense materials like concrete (ca. 2.5 $g/cm^3$), or dense materials, like supercompacted pellets, lead-shielding containers and heavy concrete (up to 4.6 $g/cm^3$), respectively (Fig. 1).

Fig. 1 Some of the mock-up drums used in the measurements. From top left to bottom right: Drum filled with supercompacted pellets, with a shielding container, with bitumen, with a shielding container and a cylinder on top, with PE grains and with supercompacted pellets, respectively.

Based on first results of neutron imaging an additional mock-up drum simulating raw waste was purpose-built for fission neutron radiography (Fig. 2). Aluminum profiles form a frame on which different other objects are fixed: a block of wood, gear wheels made of Iron, a synchronous belt, a caster, Iron and Aluminum cylinders etc. A bag is