

## SELECTIVE RADIOGRAPHY OF $^{10}\text{B}$ DISTRIBUTION IN ORGANS USING COLD AND THERMAL NEUTRON BEAMS

JURE SKVARČ<sup>1</sup>, MARKO GIACOMELLI<sup>1</sup>, HIRONOBU YANAGI<sup>2</sup>  
and GUIDO KÜHNE<sup>3</sup>

<sup>1</sup>J. Stefan Institute, Jamova 39, SI-1001 Ljubljana, Slovenia, <sup>2</sup>Teikyo University  
School of Medicine, Ichihara Hospital, 3426-3 Anesaki, Ichihara, Chiba 299-  
0111, Japan, <sup>3</sup>Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

**Abstract:** The investigation of boron biodistribution by neutron induced autoradiography was performed using a CR-39 etched track detector. Calibration samples, made of boronated chicken liver, and freeze-dried mouse tissue samples were irradiated both with thermal and cold neutrons. Digital images were made on the basis of track densities, with the selection of tracks due to  $^{10}\text{B}(n, \alpha)^7\text{Li}$  reaction. A comparison of results obtained both with thermal and cold neutrons demonstrated that it is possible to obtain equivalent results with both neutron sources, although the background noise due to recoil protons from the fast neutrons of the thermal neutron source is 15 % higher than that of the cold neutron source.  $^{10}\text{B}$  concentrations in the range of 0.5 ppm to 150 ppm were determined, with a standard deviation of 13 % and 8 % for the mouse tissue samples and calibration samples, respectively.

**Key Words:** BNCT, Neutron Autoradiography.

### INTRODUCTION

The search for a suitable boron transmitting agent in Boron Neutron Capture Therapy (BNCT) studies requires the boron content in different organs and in the tumor to be determined for a variety of chemicals at different times after the injection was administered. Radiographic imaging with etched track detectors is a suitable method for this. It utilizes the same  $^{10}\text{B}(n, \alpha)^7\text{Li}$  reaction which is responsible for the cell-killing effect in the BNCT method. It was demonstrated that it is possible to digitally exclude background noise from protons to obtain good contrast images of boron distribution in organs, and to obtain quantitative results of relative boron concentrations in different organs from the same CR-39 plate [1]. We extended our investigations to irradiations with cold neutrons instead of thermal neutrons. The most important advantage of cold neutron beams is the complete absence of the fast neutron component which is difficult to remove from the thermal neutron beam of a reactor source.

## MATERIALS AND METHODS

The calibration samples made of chicken liver with  $^{10}\text{B}$  concentrations from 0.1 to 150 ppm were prepared at the University of Bremen. The mouse tissue samples were prepared at Tokyo University. After the injection of different boron-carrying compounds, the mice were killed, and the dried-frozen bodies were cut into slices by a microtome. All the samples were stuck on CR-39 plates. Irradiations were performed in the TRIGA Mark II reactor at the J. Stefan Institute and at the Cold Neutron Facility of the Paul Scherrer Institute [2]. The thermal fluences were from  $4.4 \times 10^9$  to  $4.6 \times 10^{10}$  neutrons /  $\text{cm}^2$ . CR-39 plates were etched in 6.25 N NaOH solution at  $70^\circ \text{C}$  for 2 hours. Plates were automatically analyzed by image analysis software [1]. On the basis of the track parameters, digital images of boron distribution in organs were made with pixel intensities corresponding to the local track densities. Based on the track sizes, it is possible to image boron-related tracks only, excluding tracks of protons from the  $^{14}\text{N}(n, p)$  reaction and those from the recoil protons coming from the fast neutron component present in the thermal beam.

## RESULTS

The responses to cold and thermal neutrons with selective radiography of the calibration samples showed uniformly proportional response in the  $^{10}\text{B}$  concentration range of 0.5 ppm to 150 ppm. The response in units of track/neutron is 3.8 times higher for cold neutrons, in accordance with the  $1/v$  dependence of the cross-section for the  $(n, \alpha)$  reaction (Fig.1 and 2).

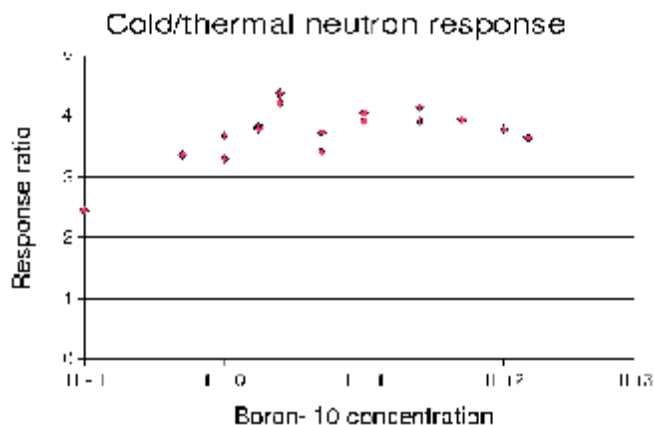


Fig. 1. Ratio of responses (tracks/neutron) to cold and thermal neutrons as a function of boron concentration in boronated liver samples.

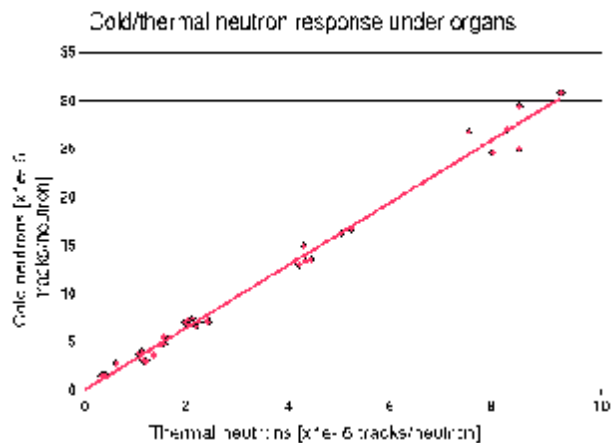


Fig. 2. Comparison of responses to cold and thermal neutrons for different organs in mouse tissue samples used for imaging of the boron biodistribution.

The selective radiography method allows quantitative radiography, even in the presence of proton background noise due to fast neutrons and the  $^{14}\text{N}(n, p)$  reaction for boron concentrations down to 0.5 ppm. Separation of tracks of the  $^{10}\text{B}(n, \alpha)$  reaction from other tracks is accomplished at the expense of a certain loss in absolute signal. For the purpose of treatment the cold beam is preferable due to the  $\sim 15\%$  lower proton background noise but the main source of the unwanted dose is due to the  $^{14}\text{N}(n, p)$  reaction.

## REFERENCES

1. Skvarč, J., Ilić R., Yanagič, H., Rant, J., Ogura, K. and Kobayashi, H. Selective radiography with etched track detectors, **Nucl. Instr. Meth. B** 152 (1999) 115-121.
2. Bauer, G. S. Operation and development of the new spallation neutron source SINQ at the Paul Scherrer Institut, **Nucl. Instr. Meth. B** 139 (1998) 65-71.