CHARACTERIZATION OF MOROCCAN TRIGA MARK II REACTOR NEUTRON BEAMS USING NEUTRON ACTIVATION DETECTORS AND SAND II CODE

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ABSTRACT

The Triga Mark II research (TMRII) reactor is equipped with four horizontal channels and one thermal column. Tangential (NB1) and Percy (NB2) channels, subject of this work, are dedicated to PGAA&NI (Prompt Gamma Activation Analysis and Neutron Imaging) and ND (Neutron Diffraction) facilities respectively. A preliminary neutron characterization is primordial for each channel. Basic beam parameters including neutron flux and spectra were measured with activation detectors for the two channels (NB1, NB2). Activity measurement by spectrometry gamma was made with HPGe detector. SAND II code was used for evaluation of neutron spectra from multiple activation detector analysis and compared with the spectra obtained with Monte Carlo simulations. Comparison between experimental and simulated results shows good agreements regarding thermal and fast fluxes; otherwise, a small difference between the two methods has been detected in the epithermal component.

1. Introduction

TMRII reactor is located at Nuclear Centre of Energy, Science and Nuclear Techniques (CNESTEN), Morocco. It was installed to contribute in development of socio-economic sectors in the country such as environment and geochemistry, agriculture, health, industry, cultural heritage and human sciences.

TMRII reactor is dotted with four lateral beam channels (NB1, NB2, NB3 and NB4) to make possible the installation of nuclear facilities around the reactor such as Prompt Gamma Activation Analysis (PGAA), Neutron Imaging (NI) and Neuron Diffraction (ND)… Concretization of these facilities implies a preliminary neutron flux characterization. This characterization will contribute effectively in the optimization of these facility's performances and shielding.

Neutron beam Characterization is a crucial step before any nuclear facility implementation around nuclear reactors or neutron sources. This characterization gives a clear idea about the suitable quality of the neutron beam for a specific facility or experience. Many laboratories around the world characterize their beam facilities and validate with Monte Carlo model to achieve this clarity for neutron source specifications either for spectra determination or for spatial neutron distribution. For instance, Tehran Research Reactor (TRR) performed, as a new experience in the year 2016, the first beam characterization for their NRAD facility [1]. At the HRPT Instrument at the Swiss, V. Talanov et al. [2] validated their MCNP model by detector foils irradiation in the spallation neutron source. L. VIERERBL et al. performed a neutron beam characterization for the LVR-15 research reactor using detector foils and validated with MCNP model. For all cited laboratories the results show a good agreement with the Monte Carlo models. It is under the frame of these experiences that our work was based on. Detectors foils were irradiated in the NB1 and NB2 beam channels of the TMRII reactor to characterize neutron flux and MCNP model was used for the validation.

For nuclear analysis techniques as PGAA, NI and ND precise spectral characteristics of neutrons and neutron flux are with a great interest for the evaluation of the impact on the experiment and the accuracy of the methods used. Same experiments were performed by K Tiyapun et al. [3] with an accuracy ranging from 2 to 23 % between experiment and calculation results.

An ongoing effort to characterize neutron beams at TMRII reactor for radio isotopes production and neutron activation analysis has been occurring for the past several years using detector foils. Bounouira et al. [4]. The most recent efforts consisting on using the unfolding code, SAND II [6] and k_0 method with foil detectors measurements. Monte Carlo code was also used to generate neutron spectra to be compared with SAND II results. These characterization concerns NB1 and NB2 beam channels, which is the subject of this paper.

2. Material and methods

- Preparation of flux monitors used

Neutron activation experiments were carried out on-site using four available high purity activation detector foils with threshold reactions that cover a majority of the expected neutron spectrum. Table 1 resumes the type and specification of each activation detector foil used in this experiment.

Table 1: Flux monitors used in the experiment and specifications

Type of detector	Shape	Thickness (mm)	Purity (%)
Au	Wire	0.00125	0,1
Ni	Foil	0.00025	99,95
Ti	Foil	0.00025	99.99+
Zn	Foil	0.00025	99.99+

Eighteen sets of these four labelled activation detectors were prepared and packaged each in polyethylene vial. Nine sets were positioned and welded on a cylindrical shaped Plastic Support (PS) at the locations presented in Figure 1 to form a single package for one experiment. These locations were selected in order to be able to measure an integrated flux along the cross section of the beam tube. The PS has been attached to a PVC tube with a sufficient length in order to achieve the bottom of the beam tube. Both the device and the insertion PVC tube are in house manufactured to make the device fit with the actual dimensions (diameter and length) of the beam tube.

Figure 1: On the right PS with front sealed nine PE vials used to position activation detector foils; on the left the experimental assembly for the insertion of the PS inside the beam tube

- Activation and measurement

The activation of all activation detector foils used has been performed by introducing the whole assembly (Figure 1) inside the beam tube. Each package of nine detector sets was irradiated for 30 and 60 minutes and under 10 and 50kW respectively in NB1 (A position) and NB2 (B position) (See Figure 2). The various reactions considered in this experiment are presented in Table 2.

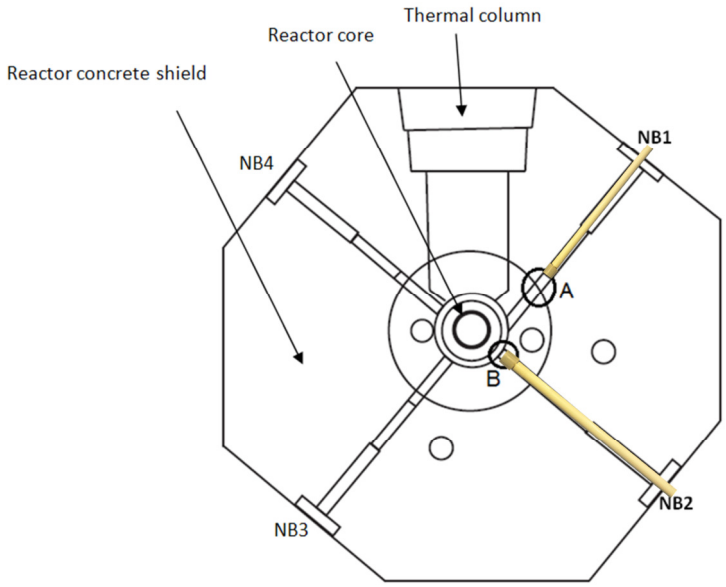


Figure 2: Top view of the TMRII reactor and irradiation positions
(A position in NB1 and B position in NB2)

Table 2: Threshold reactions used in this experiment

Foil	Reaction	Half-life
Gold	$^{197}Au(n,\gamma)^{198}Au$	2.6952 d
Nickel	$^{58}Ni(n,p)^{58}Co$	70.88 d
Nickel	$^{64}Ni(n,\gamma)^{65}Ni$	2.517 h
Nickel	$^{60}Ni(n,\gamma)^{60}Co$	5.271 y
Titanium	$^{46}Ti(n,p)^{46}Sc$	83,83 d
Titanium	$^{47}Ti(n,p)^{47}Sc$	3,351 d
Titanium	$^{48}Ti(n,p)^{48}Sc$	1,8208 d
Zinc	64Zn(n,g)65Zn	244,26 d
Zinc	$^{64}Zn(n,p)^{64}Cu$	12,7 h
Zinc	$^{68}Zn(n, \gamma)^{69m}Zn$	13,76 h

After irradiation, each individual detector foil was removed from the nine PS vials and was counted using the HPGe detector. Counting time depends upon the induced activity and the time scale of the half-life of the specific reaction being measured. This was required in order to minimize detector dead-time, while maximizing the total counts and obtaining the best possible statistics.

- Methods

After irradiation induced activity is measured. Neutron fluence rate is determined based on measured activities and the calculated neutron spectrum. The latter is constructed for thermal, epithermal and fast neutrons spectra respectively from a Maxwellian (350K), an "1/E" low and a Watt-spectrum from the neutron fluence rate experimentally determined. For this purpose SAND II [6] code was used.

The adjustment procedure is designed in accordance with ASTM (American Standard Test Method). The standard spectrum for the horizontal channel at the LVR-15 research reactor was selected as an input parameter for SAND II code.

All Mont-carlo calculations were made through the transport Monte Carlo code MCNPX 2.6.0. [5] and data libraries ENDF 7.1 V2013.

An approximated MCNP model for the TMRII reactor has been created. This model (Fig. 3), including the reactor core, without thermal column, contains 96 fuel rods, 5 fuel followers and 17 graphite bars, graphite reflector, light water moderator and four horizontal channels (NB1 tangential and NB2, NB3 and NB4 radial). The model was subjected to test KCODE criticality mode with fresh fuel loaded reactor core. The Effective Multiplication Factor Keff = 1.00126 ± 0.00015 was obtained.
In order to make the comparison between experimental and calculated results accurate, we calculated the neutron spectra at approximately the same position as the experiment (see figure 3) and the flux was also averaged to be compared with SANDII results.

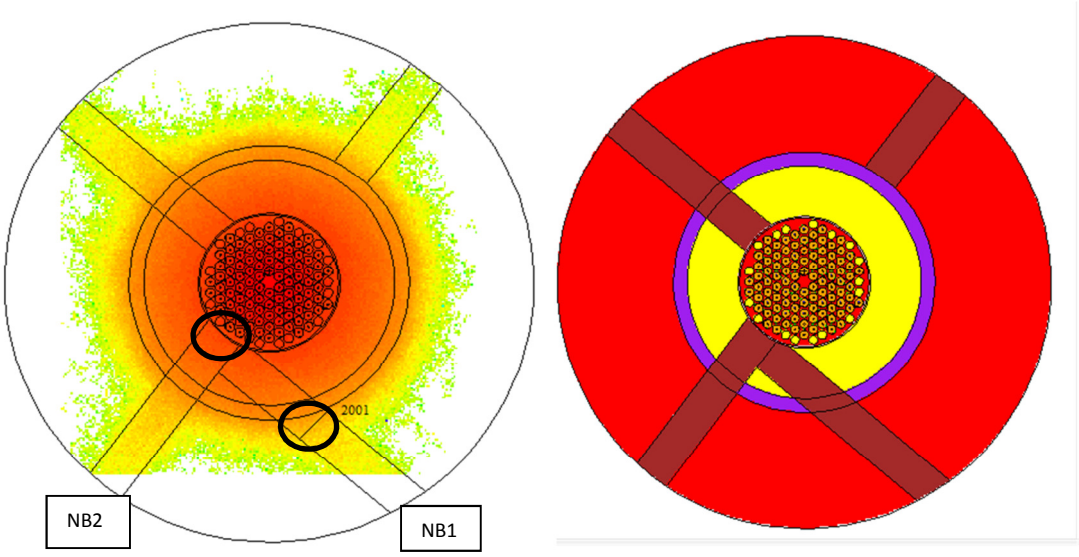


Figure 3: MCNP model for TMR II with calculation positions and particle source distribution

3. Results and discussion

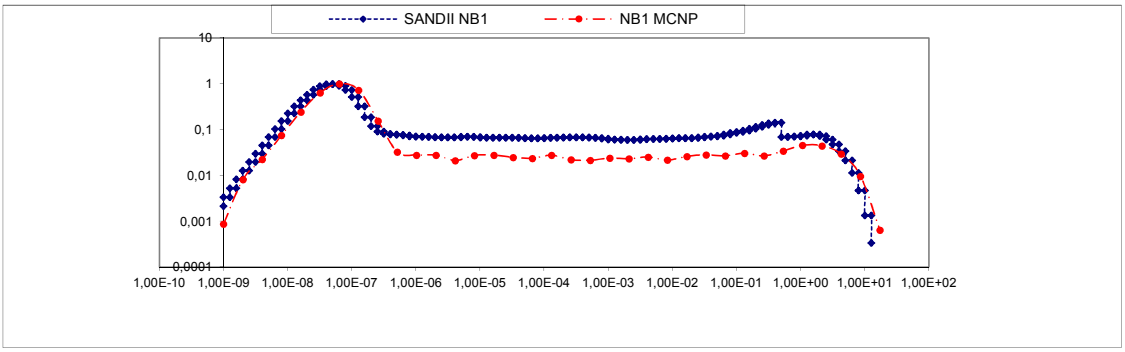
The isotope's total activity was calculated as the area under the associated gamma peak and calculated using a non-linear least-squares algorithm provided by the detector software to remove background effects. The measured activity was then extrapolated to saturation, and was used as input for the SAND-II unfolding routine. Neutron flux averages were calculated using SAND II and MCNPX code

for NB1 and NB2. The measured averaged values of thermal, epithermal and fast fluxes for both channels, under respectively 10 and 50 KW operational core power, linearly extrapolated to 2 MW are shown in Figure 4. The measured neutron flux components for the NB1 and NB2 channels agreed with the calculated ones with a maximum standard deviation of respectively 10% and 57% (See Table 3). The reason of this deviation can be attributed to experimental limitation: i- the difference between measurement and calculation position; ii- the low number of activation monitors available for the experiment and iii- the very low reactor power used for the activation. It can also be resulted from the use of fresh fuel or to calculation approximations. An attention should be focused on these results even by re-measuring the flus components for NB2.

	Neutron flux (cm-2.s-1)			
Channel	NB1		NB2	
Results / Flux components	MCNP	Measured	MCNP	Measured
Φ_{th}	1,88E+12	1,79E+12	5,77E+12	7,85E+12
Φ_{ep}	4,83E+11	5,95E+11	2,65E+12	1,49E+12
Φ_{fast}	4,15E+11	4,53E+11	3,55E+12	1,53E+12
Total	2,77E+12	2,84E+12	1,197E+13	1,09E+13

Table 3: Measured and calculated neutron flux at the NB1 and NB2 beam channel

The normalized spectra generated with SAND II and calculated with MCNPX code fit with each other, with a light difference in the epithermal part for NB1 channel (Figure 4). The flux hardness is visible in the piercing channel (NB2).



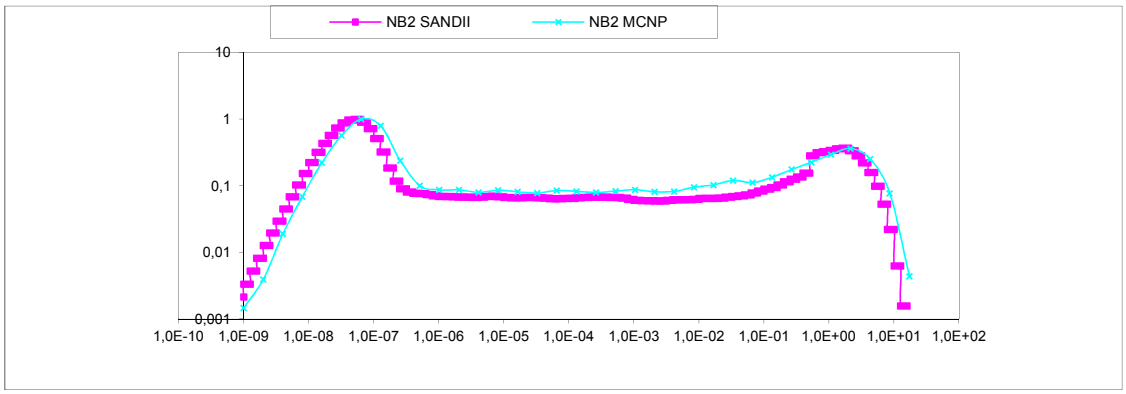


Figure 4: Spectra comparison for NB1 and NB2 determined by SAND II and MCNPX

Acknowledgment

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