STUDY OF THE DOSE FIELDS ON THE THERAPY BEAM OF REACTOR BR-10

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ABSTRACT

Studies of the physical characteristics of filter beam B-3 BR-10 reactor for boost therapy were carried out in the tissue phantom. Aluminum and nickel isotopes were used as filter materials. Filters were placed in the neutron channel of 5cm diameter of the BR-10 reactor. Experimental studies for fast flux density were carried out with using the Rhodium detector on the reaction Rh(n,n'). The detector was placed on the outlet of channel. The deposit of epithermal flux to the total flux was defined by calculation. To estimate the dose from fast neutrons and boron capture dose the calculation data and measured density fluxes were used. The calculations were performed by Monte Carlo MMKFK code.

Key Words: Fast neutrons, neutron therapy, reactor BR-10, tumors, cancer, Monte Carlo method, BNCT.

1. INTRODUCTION

Now neutron therapy is recognized by one from priority directions in a medical radiology, use it in a combination with traditional gamma – therapy increases efficiency of treatment of cancer tumors. About 70% cancer patients are needed in various forms of radiation therapy. Among all recovered patients about 2/3 were treated by radiation therapy as a main method of treatment. One way for increasing of radiation therapy efficiency is use the high ionization radiation in particular, fast neutrons. Extensive clinical treatment of malignant tumors using neutrons have been conducted in more than 20 centers of USA, Japan, Germany, France and others. Today in the world more than 30 thousands patients have been treated.

In Russia the most experience in External Beam Radiation Therapy (EBRT) was accumulated in Medical Radiological Research Center (MRRC) of Russian Academy of Medical Science. Since 1985 up to now over 500 patients with different forms of tumors were treated in MRRC [1]. Fast neutrons from B-3 beam of the fast reactor BR-10 were realized the external beam radiation therapy.

At present time in the world many scientists took interests in BNCT. The scientists of many scientific centers of USA, Europe and Japan have begun the first phase of clinical BNCT trial for patients with brain tumors. The first phase of BNCT clinical trial in MRRC was begun after experimental researches. BNCT as a boost therapy was used for patients with superficial metastasis of melanoma. The peritrumonal injection of sodium borocoptate (BSH) was implemented. For forming of neutron capture dose the patient was situated near special moderator which slow down fast neutrons from B-3 beam of BR-10 reactor. In future after constructing the special beam for BNCT will begin clinical trial for patients with brain tumors.

The present paper is given the preliminary studies of the other way of beam constructing for combined EBRT and BNCT (boost therapy). For this aim were used the special filter satisfies a "good" geometry conditions. At such conditions any interaction of neutron with filter removes it from the beam. The special property materials for filter constructing for BNCT were used. These materials have different properties for epithermal and fast neutron interactions.

2. MATERIALS AND METHODS

Studies of physical characteristics of filter beam B-3 BR-10 reactor for boost therapy were carried out in tissue phantom of cubic form with rib dimension 25 cm. Studies were made for a few filters which permit to change the relative share of epithermal neutron flux. Aluminum and nickel isotopes were used as a filter material.

Filters were placed in the neutron channel of 5cm diameter and the phantom was placed in central hole of the BR-10 reactor at ~3.5 m from the radiated surface of the reactor. Experimental studies of fast flux density were carried out with using the rhodium detector [2] on the reaction Rh(n,n').

The detector was placed on the outlet of channel. To detect the conducted gamma activity the scintillation spectrometer with stilben crystal (NaJ) was used. The deposit of epithermal flux to total flux was defined by calculation. To estimate the dose from fast neutrons and boron capture dose the calculation data and measured density fluxes were used. The calculations were performed by Monte Carlo method using MMKFK code.

3. RESULTS AND DISCUSSION

The relative deposit of boron capture dose distribution to total dose on phantom depth and energy dependence is given on Figure 1.

We can see different dependencies with energy at different depths (more than 1 cm). The preferable energy region for boost therapy is 10 eV – 100 keV. Fast neutron KERMA and KERMA from capture on B-10 for four fluxes were studied in the present work:

1). Open beam with the density on the outlet of channel ~ $2{,}53 \cdot 10^9$ n/см$^{2}\cdot$s with the deposit of epithermal neutrons ~ 30%.

2). The beam with 10 cm aluminum filter with flux density ~ $4{,}58 \cdot 10^{8}$ $n/см^{2}\cdot s$ with the deposit of epithermal neutrons ~45%.

3). The beam with 15 см aluminum filter, flux density ~$3{,}7 \cdot 10^{8}$ $n/см^{2}\cdot s$, 60% - deposit of epithermal neutrons.

4). The beam with 8cm nickel–60 filter, flux density ~$2{,}46 \cdot 10^{8}$ $н/см^{2}\cdot s$ with the deposit of epithermal neutrons ~ 75%.

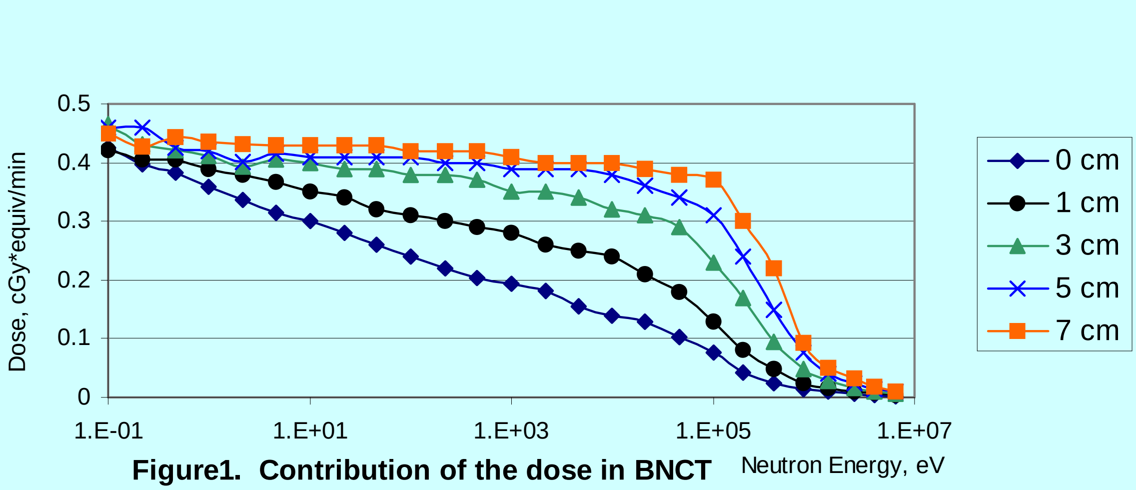

Figure1. Contribution of the dose in BNCT

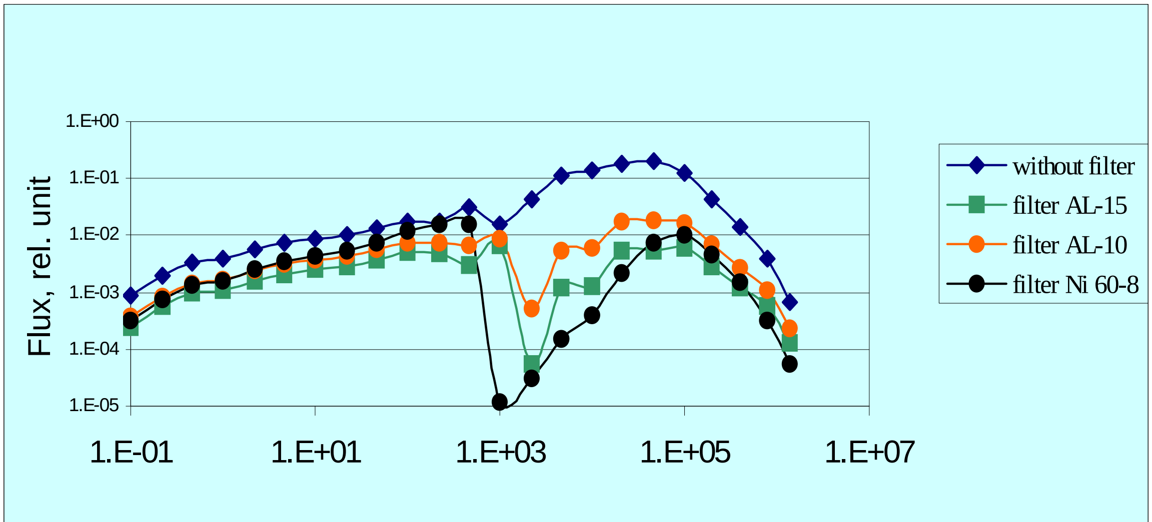

Figure 2. Neutron spectrums of beam B-3

The neutron fluxes of studied beams are given on Figure 2. The most deformation of fast neutron flux is observed for beam with Ni-60 filter, the deformation of epithermal flux is not very large. The characteristics of studied beams are given in Table 1: KERMA from neutron capture by B-10 and fast neutron KERMA have dimension cGy /min. For calculations the concentration of B-10 was 30 μg/g.

Table I. KERMA distribution in phantom for different beams on depth

	Open beam		Filter Al, 10cm		Filter Al, 15cm		Filter Ni-60, 8cm	
T, cm	BNCT	BNCT+ KERMA	BNCT	BNCT+ KERMA	BNCT	BNCT+ KERMA	BNCT	BNCT+ KERMA
0	5.1	200	1.41	32.3	1.12	20.6	0.99	12.7
1.0	19.5	191.5	4.82	33.1	5.15	23.2	3.72	15.7
1.5	26.2	180.2	6.3	31.6	6.21	20.9	4.22	15.3
2.0	29.8	167.8	6.91	23.4	6.5	21.7	4.74	14.8
2.5	30	150.5	6.68	27.3	6.62	19.8	4.67	13.8
3.0	32.9	136.6	6.85	25.1	5.73	17.7	4.61	12.8
3.5	32.2	122.5	6.71	23.8	5.78	15.8	4.26	11.6
4.0	30	109.1	6.12	20.9	5.4	14,9	3.91	10.4
4.5	29	93.5	5.47	18.1	4.88	13.5	3.49	9.43
5.0	28.6	86	4.9	16.2	4.51	12	3.04	8.34
5.5	26.2	86.9	4.52	14.1	4,09	10.4	3.62	7.31
6.0	24.9	68.6	4.18	12.5	3.53	9.13	2.27	6.26
6.5	22	57.6	3.6	11.8	3.16	8.17	1.98	7.05
7.0	19	50	6.72	10.1	2,92	7.23	1.71	4.66

The results in Table I show that increasing of the relative neutron deposit in the beam lead to increasing of the relative deposit of neutron capture dose in the total dose and increasing of half-dose depth. So, for open beam half-dose depth is ~ 4,2 см with ~25% deposit of boron capture dose, and for Ni-60 filter half-dose depth ~ 6,5см, deposit of boron dose in total ~ 40%. The surface deposit of boron dose for all studied beams is negligible. The results of studies for four beams distributions on depth of boron capture and total doses are given on Figure 3. The most dose from fast neutrons is ~200 cGy/min for open beam. The increasing of relative deposit of epithermal flux in the beam leads to decreasing of fast neutron flux and decreasing of dose from fast neutrons. The present results can be used in future for constructing of therapy neutron beam.

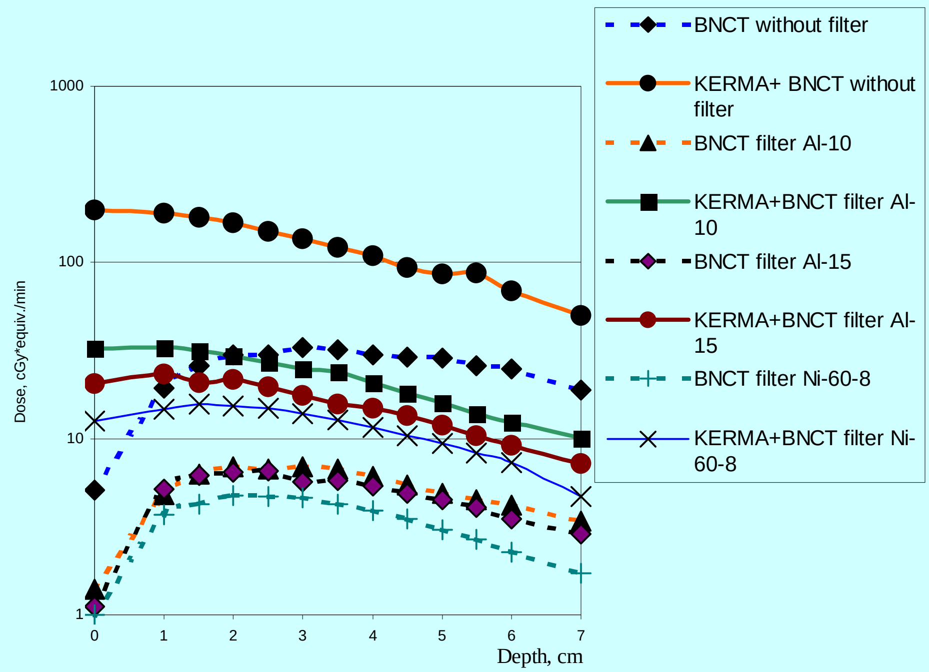

Figure 3. Dose dependens on the depth distribution.

4. CONCLUSIONS

Increasing of the relative neutron deposit in the beam leads to increasing of the relative deposit of neutron capture dose in the total dose and half-dose depth.

Open beam half-dose depth is 4,2см; deposit of boron capture dose is 25%. Ni-60 filter half-dose depth is 6,5см; deposit of boron dose in total is 40%. The surface deposit of boron dose for all studied beams is negligible.

The present results can be used in future for constructing of therapy neutron beam.

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