Neutron Characterization of BNCT Water Phantom Based on Kartini Research Reactor Using PHITS

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ABSTRACT

Boron Neutron Capture Therapy (BNCT) is a therapy that utilizes the interaction of thermal neutrons with a boron-10 core that produces alpha particles and lithium nuclei. The result of this boron reaction has high linear energy transfer (LET). BNCT has an advantage over other radiation therapy in that it has a high selectivity level. This research was run using PHITS simulation to find out the value of neutron flux spread over a water phantom. The conclusion of the research is the distribution of neutron flux in the water phantom without boron is higher than the distribution of neutron flux in the water phantom containing boron.

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1. INTRODUCTION

Cancer is one of the leading causes of death worldwide. Cancer is the second leading cause of death globally. Lung, prostate, colorectal, gastric and liver cancers are the most common type of cancer in men, while breast, colorectal, lung, cervix and stomach cancers are most common among women [1][5]. Cancer is a group of diseases characterized by uncontrolled growth and the spread of abnormal cells. Cancer is a general term for one large group of diseases that can affect any part of the body [2].

Cancer is caused by two factors: internal and external factors. Internal factors are caused by mutations genetic, hormones, and immune conditions. External factors are caused by tobacco, infectious organisms, radiation & UV rays and unhealthy diets[3]. In Indonesia, the World Health Organization (WHO) predicted that by 2030 the number of cancer patients will be very high; and even now the quality and quantity of the treatment is not sufficient[4].

According to sources, between 30% and 50% of cancer deaths can be prevented by modifying or avoiding major risk factors, including smoking and alcohol consumption[6]. Along with many deaths being caused by cancer in the world, the treatments being used are developing.

Some types of cancer treatment that already exist are Chemotherapy, Radiotherapy, Surgery, and Brachytherapy [4][15][16][17]. Chemotherapy uses drugs to weaken cancer cells but also has the side effect of damaging the immune system. Radiotherapy uses high-dose of radiation sourced from radioactive energy in addition, the radiotherapy beam is less effective because it has a low linear energy transfer (LET). Surgery is usually used for initial treatment when the condition of the tumor is still in its early stages [7]. Such cancer treatment can cause side effects that occur when treatment affects tissues or healthy organs[1][18][19][20]. To overcome these weaknesses BNCT has been developed with selective characteristic to cancer cells.

BNCT is a method of radiation therapy that is based on the ability of nonradioactive Boron-10 to capture neutrons with low energy

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(thermal neutrons)[8]. This interaction produces ^{11}B by emitting α and lithium nuclei. The result of this boron reaction has high LET (Sauerwein et al, 2012). The recommended epithermal neutron flux for therapy is $10^9 \text{ n/cm}^2\text{s}$, which has the most profound effectiveness in tumors [9]. BNCT has been clinically used to treat various cancers around the world [10][14].

Thermal and epithermal neutrons play an important role in the efficiency of BNCT treatment. Thermal neutrons can easily reach cancer located near the surface tissue (skin) with energy less than 0.5 eV, whereas for epithermal neutrons it is targeted to treat tumors with a deeper range with energy from 0.5 eV to 10 keV[11][12]. Neutron flux is a measure of the intensity of neutron radiation.

The aims of this research are to find out the value of thermal and epithermal neutron flux scattered in a water phantom by using the simulation program PHITS (Particle Heavy Ions Transport Simulation).

2. MATERIALS AND METHODS

2.1 Research Instruments

The research was conducted in Engineering Room of PSTA-BATAN YOGYAKARTA for 30 days. On February 6, 2017 to March 6, 2017. The research was conducted by running PHITS program, Input PHITS program (surface card, cell card, and data card) and was started by making the geometry of the water phantom with the dimensions of 20 cm x 20 cm x 20 cm and the geometry of the Kartini Research Reactor using the reactor neutron source according to the proprietary design of Rosilatul Zailani. Then the neutron flux was calculated by running the PHITS program with the neutron source from the Kartini Research Reactor (KRR). Characteristically the type of pool with power working at 250 KW is used. The average thermal flux generated is about $1.2 \times 10^{13} \text{ n/cm}^2 \text{ s}$ and the average fast Flux is $2.5 \times 10^{12} \text{ n/cm}^2\text{s}$ [13]. The Water phantom used contained D_2O (Deuterium Oxide), was 30 cm x 30 cm x 30 cm, and was wrapped in acrylic glass 1 cm thick. This research used two variants, that is,

water phantoms without boron and water phantoms containing boron.

Fig 1. Geometry of water phantom without boron

In figure 1 the geometry of simulation where part 1 is a water phantom with the density 0.017, part 2 is acrylic glass with 1.18 density, while part 3 is air with density 0.0012.

2.2 Shoot the Neutron Spectrum

The neutron spectrum is shot into the phantom water from the left and interacts with the boron inside the water phantom. Then we can get the value of flux which is observed according to depth. The depth of the water phantom is divided in 6 part. Next, the spread of absorbent neutron flux was calculated using the PHITS program.

Figure 2. Shooting neutron spectrum at water phantom containing boron

Figure 3. Shooting neutron spectrum at water phantom without boron

2.3. Calculation of Dose

To calculate neutron flux in water phantom one of the tally functions in the PHITS software was used, [T-deposit].

3. RESULTS AND DISCUSSION

3.1 Water Phantom Containing Boron

Figure 4. Neutron distribution on part 1

Figure 5. Neutron distribution on part 2

Figure 6. Neutron distribution on part 3

Figure 7. Neutron distribution on part 4

Figure 8. Neutron distribution on part 5

Figure 9. Neutron distribution on part 6

Table 1. Neutron flux Water Phantom

Region	1/cm ² /source
1	9.4300E+09
2	1.5530E+09
3	1.9234E+08
4	4.0219E+07
5	5.0744E+06
6	0.0000E+00

Based on the Figure, the distribution of neutron flux on water phantom containing boron is not so low in the first region but in the last region there is no neutron flux distribution. It is caused by interaction between the neutrons and boron.

3.2 Water Phantom Without Boron

Figure 10. Neutron distribution on part 1

Figure 11. Neutron distribution on part 2

Figure 12. Neutron distribution on part 3

Figure 13. Neutron distribution on part 4

Figure 14. Neutron distribution on part 5

Figure 15. Neutron distribution on part 6**Table 2.** Neutron flux Water Phantom

Region	1/cm ² /source
1	2.6339E+10
2	1.9273E+10
3	1.2506E+10
4	7.6660E+09
5	4.4091E+09
6	2.2129E+09

In the neutron distribution on water phantom without boron, it is stable and high in the first and the last region because there is no interaction between neutrons and boron.

4. CONCLUSION AND REMARKS

The conclusion of the research is the distribution of neutron flux in the water phantom without boron is higher than the distribution of neutron flux in the water phantom containing boron.

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