ABOUT THE POSSIBILITY OF USING THE FIELD OF THE PORTABLE NEUTRON GENERATOR FOR TREATMENT OF ONCOLOGICAL DISEASES

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The possibility of using a portable neutron generator (PNG) for the treatment of oncological diseases is being considered. It has been shown that when using PNG as a neutron source, it is possible to ensure sufficient therapeutic impact on sick cells, with minimal damage to healthy cells. It's about applying PNG in a brachytherapy tumor. It is important to note that the presence of a narrow ion- pipe- needle allows a neutron source to be placed close to the tumor, and thus to increase therapeutic influence. Numerical estimates of the density of neutrons and the consumed dose when using PNG for brachytherapy performed, it is shown that, for a short period of time (~ 1 minute), sufficient dose of radiation for therapy is absorbed. The calculations of the neutron field and absorbed dose are accomplished through a computer program developed by the authors based on the Monte Carlo method, designed to simulate the generation, movement, braking and absorption of neutrons.

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MAIN CHARACTERISTICS OF PNG

The development of reliable and inexpensive neutron sources is an urgent task, the solution of which is necessary, first of all, for the use of such sources in radiation medicine. Work in this field has been carried out in the world for a long time [1 - 7].

The portable neutron generator (PNG) was developed at the NSC KIPT within STSU R497 project, the yield of neutrons provided by PNG is ~ 10^9 neutrons/s. Detailed design of PNG and modeling of neutron formation, inhibition and absorption processes are presented in [8].

In this paper, we indicate only the main characteristics of PNG (Fig. 1). The main idea is that the deuterons dispersed in the electrostatic accelerators fall on the target from beryllium, as a result of which neutrons of energies of ~ 2…4 MeV are formed. It is important to point out that the deuteron beam hits the target through a narrow ion-conducting needle, which allows for some cases of cancer to provide a sufficient therapeutic dose of radiation by placing the source in close proximity to the tumor. We note that the requirement of a narrow ion conductor leads to limitations on the intensity of the deuteron beam and, consequently, the yield of neutrons. At the same time, the structure of the neutron field is such that the dose absorbed by the healthy tissue is small (Fig. 2). The absorbed dose of Fig. 2,b,c is calculated for cases of a point target and a target of finite size placed in a water phantom.

The ion conductor is cooled by water, so the temperature of the outer surface of the ion conductor (including the neighborhood of the beryllium target) can be controlled by changing the water temperature in the cooling circuit. Consequently, it is easy to create comfortable conditions for the patient.

Numerical realization of the simulation of the neutron field provides for the use of momentum and energy conservation laws for each event, i.e. we can say that the simulation is carried out "from the first principles".

Details of the modeling algorithms and the features of the numerical implementation of the algorithm are presented in [8].

POSSIBILITY OF PNG APPLICATION IN ONCOLOGY

Fig. 2 above shows the distribution of the absorbed dose of neutrons in the case of a point source of neutrons and a source of finite dimensions. It is important that the absorbed dose is concentrated in a small neighborhood (~ 2…3 cm.) from the neutron source of the PNG target. At the same time, the absorbed dose decreases rapidly with the distance from the center of the source, therefore, the natural distribution of the absorbed dose field is exactly what is necessary for effective therapy- it is mainly the diseased tissue of the organism that is irradiated. The very organism of the patient (and the tissue of the organism is, to a large extent, water) acts as a retarder-reflector of neutrons. In this case, there is a significant difference between the field of neutrons produced in the reactor (irradiation with a narrow neutron "ray" obtained with the help of collimators) and irradiation of PNG. In both cases, a sufficient absorbed dose can be obtained, but in the case of using the reactor it is impossible (or at least very difficult) to deliver the neutron source to the tumor in the body.

In practice, the source of neutrons is delivered directly to the tumor by injecting into the body of the patient an ion-conductor needle-brachytherapy takes place. Brachytherapy in the general case involves the delivery of a source of neutrons to the site of the tumor. The peculiarities of the human body (and the presence of a narrow ion-conductor-PNG needle) make it possible in a number of cases (for example, in the treatment of uterine cancer in women or prostate cancer in men) to deliver a neutron source to the tumor site without surgical intervention.

Alternative use of PNG for tumor irradiation is to place the source of neutrons outside the patient's body, but close to the body surface (as should be done in the treatment, for example, of melanoma).

Consider the problem of assessing the impact of neutrons on personnel. At the same time, we place the neutron generator in a bunker with thick concrete walls.

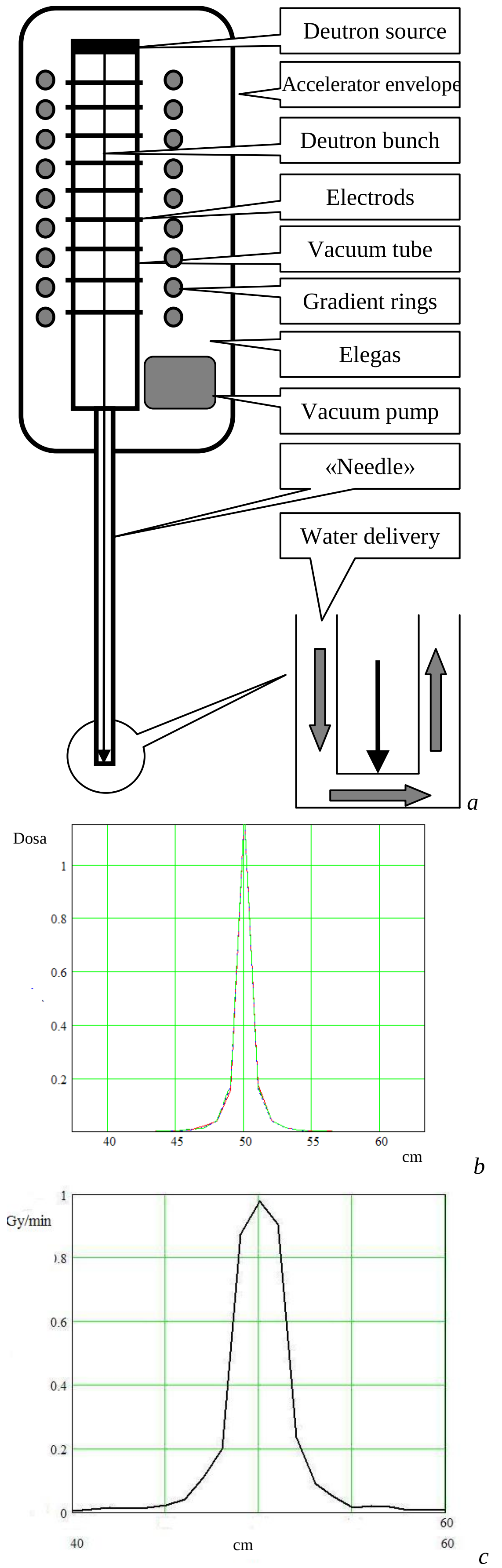

Fig. 1. a) General scheme of PNG; b) Absorbed dose (Gy / min) as a function of the distance from a point source of neutrons (cm); c) Dose distribution along the Y axis at a finite ion source, Neutron source, perpendicular to the Z-axis, of size ~ 1×1 cm

In fact, similar estimates can easily be made for any set of rooms, but it should be noted that thin walls or large openings in walls (doors, windows) may cause harmful radiation exposure to personnel. Therefore, the methodology for assessing the danger (or lack of danger) of the work of PNG for personnel should be considered as a model for similar calculations in relation to the actual premises in which the facility will be located.

PNG is installed in a bunker with concrete walls of thickness D = 1 m. The neutron yield is $W_{neutron} \sim 10^9$ N/s. Neutrons and γ-radiation can penetrate through the concrete wall to the adjacent room L1×L2×L3 = 600×800×900 cm, dimensions of the bunker L1b×L2b×L3b = 300×300×400 cm. We assume (within the general principle of assessing the danger from above) that neutrons remain fast, with all the neutrons leaving the patient's body. The layout of the installation in the bunker and the adjacent room is shown in Fig. 2

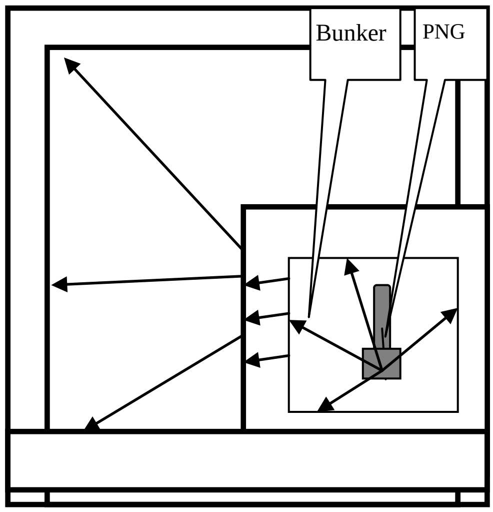

Fig. 2. Location of PNG installation in the bunker and adjacent room

Let us estimate the value of the flux density of gamma radiation at point A (see Fig. 2) – behind the wall separating the bunker from the adjacent room. Data on the irradiation weakening in concrete, as subsequently data on the weakening of the neutron flux in concrete, is taken from the handbook [9]:

$$\Phi_\gamma \sim \frac{10^9}{(4\cdot300\cdot300+2\cdot300\cdot400)} e^{-\frac{100}{33/2.4}} = 1.157\frac{MeV}{cm^2\cdot s} \quad (1)$$

it is easy to see that the radiation flux density is negligible (we achieved this by placing the stand in a hopper with sufficiently thick walls).

Let us perform a similar estimate for the neutron field (estimate for the neutron albedo, η = 0.8).

$$\Phi_N^0 = \frac{3\cdot6\cdot10^8}{(1-\eta)(4\cdot300\cdot300+2\cdot300\cdot400)} e^{-\frac{100}{26/2.4}},$$

$$\Phi_N \sim \frac{6\cdot10^9}{(1-\eta)(4\cdot300\cdot300+2\cdot300\cdot400)} e^{-\frac{100}{26/2.4}} +$$

$$+\frac{6\cdot\Phi_N^0\cdot300\cdot400}{(1-\eta)2(600\cdot800+600\cdot900+800\cdot900)} = 20\frac{N}{cm^2\cdot s}. \quad (2)$$

The density of the neutron flux is close to the permissible flux density of fast neutrons for personnel in Category A according to НРБ-99, which is acceptable.

CONCLUSIONS

The portable neutron generator developed at the NSC KIPT can be used to treat certain oncological diseases, without surgical intervention. Within a few minutes of the generator's work, a sufficient dose of neutron irradiation is absorbed by diseased tissues, at the same time, due to the obtained structure of the neutron field, the damage to healthy cells is minimal.

Estimates of the effect of radiation on the environment, in particular, evaluation of the characteristics of the neutron field in the bunker, where the neutron generator is located, and the adjacent room are performed. It is shown that there is no danger to the personnel in this case. A similar calculation should be made each time the installation location is selected.

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О ВОЗМОЖНОСТИ ИСПОЛЬЗОВАНИЯ ПОЛЯ ПОРТАТИВНОГО НЕЙТРОННОГО ГЕНЕРАТОРА ДЛЯ ЛЕЧЕНИЯ ОНКОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ

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Рассматривается возможность применения портативного нейтронного генератора (ПНГ) для лечения онкологических заболеваний. Показано, что при применении ПНГ в качестве источника нейтронов можно обеспечить достаточное терапевтическое воздействие на больные клетки, с минимальным повреждением здоровых клеток. Речь идет о применении ПНГ при брахитерапии опухоли. Важно отметить, что наличие узкого ионопровода «иглы» позволяет разместить источник нейтронов близко к опухоли, а следовательно, усилить терапевтическое воздействие. Выполнены численные оценки плотности потока нейтронов и поглощенной дозы при использовании ПНГ для брахитерапии, показано, что в течение небольшого промежутка времени (~1 минуты) поглощается достаточная для терапии доза излучения. Расчеты потока нейтронов и поглощенной дозы выполнены с помощью разработанной авторами компьютерной программы, основанной на применении метода Монте-Карло и предназначенной для моделирования процессов образования, движения, торможения и поглощения нейтронов.

ЩОДО МОЖЛИВОСТІ ЗАСТОСУВАННЯ ПОЛЯ ПОРТАТИВНОГО НЕЙТРОННОГО ГЕНЕРАТОРА ДЛЯ ЛІКУВАННІ ОНКОЛОГІЧНИХ ЗАХВОРЮВАНЬ

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Розглядається можливість застосування портативного нейтронного генератора (ПНГ) для лікування онкологічних хвороб. Показано, що за умови застосування ПНГ в якості джерела нейтронів можна забезпечити достатній терапевтичний вплив на хворі клітини, з мінімальним ураженням здорових клітин. Мова йде про застосування ПНГ при брахітерапії пухлини. Важливо зауважити, що наявність вузького іонопровода «голки» дає можливість розташувати джерело нейтронів у безпосередній близькості до пухлини, а отже – підсилити терапевтичну дію. Виконані чисельні оцінки щільності потоку нейтронів і поглиненої дози під час застосування ПНГ у брахітерапії, показано, що протягом невеликого проміжку часу (~1 хвилини) поглинається достатня для терапії доза опромінювання. Обчислення потоку нейтронів і поглиненої дози виконано за допомогою розробленої авторами комп'ютерної програми, заснованої на методі Монте-Карло і призначеної для моделювання процесів створення, руху, гальмування та поглинання нейтронів.