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Comparative study of dose for different fluence of neutron

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Abstract. *The comparative study aims to investigate the dose received by materials exposed to different fluence of neutron radiation. The research is significant in the field of nuclear energy and radiation protection as neutron radiation is one of the most common types of radiation produced by nuclear reactions. The study exposes different materials to varying densities of neutron radiation and measures the dose received by each material using dosimeters. The results showed that the dose received by the materials increased with increasing fluence of neutron radiation. Furthermore, it highlighted the importance of material selection for radiation protection, as the dose-response relationship varies between different materials. The study concludes that a better understanding of the dose-response relationship for different materials can help in the development of more effective radiation shielding materials and improve radiation safety in various applications.*

Keywords: *fluence of neutron, radiation, dosimetry, Gray, Kazakhstan*

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1. Introduction

Neutrons are a type of subatomic particles that can penetrate deeply into materials, making them useful for a variety of scientific and technological applications, including medical treatments, radiation therapy, and material sciences. However, neutron radiation can also pose significant health risks, especially at high doses.

One of the most important parameters in assessing the health effects of neutron radiation is the dose, which refers to the amount of energy deposited by the neutron particles in a given material. The dose is typically measured in units of Gray (Gy), which represents the amount of energy absorbed per unit mass of the material.

In this comparative study, we examined the dose for different fluence of neutron radiation, where fluence refers to the number of neutron particles passing through a unit area over a specified period of time. Specifically, we compared the dose for low fluence neutron radiation (less than 10^{10} neutrons per square centimeter per second) with that for high fluence neutron radiation (greater than 10^{10} neutrons per square centimeter per second).

Our results show that the dose for neutron radiation increases significantly with increasing fluence. At low fluence levels, the dose is relatively low, and the health risks are minimal. However, at high fluence levels, the dose can be high enough to cause significant damage to biological tissues, leading to radiation sickness, cancer, or even death.

We also found that the dose distribution for neutron radiation is highly dependent on the material properties, such as the density, composition, and thickness of the material. For example, the dose is higher in denser materials and decreases with increasing thickness. Therefore, it is important to consider the material properties when evaluating the health risks of neutron radiation.

The purpose of the work is to compare the data obtained from the studies, and show an analysis of the changes.

2. Methods

Neutron activation of manganese dioxide powder was conducted at the IVG.1 M research reactor (Kazakhstan). The IVG.1 M reactor is a research water-moderated heterogeneous thermal neutron reactor [1-5] with a beryllium reflector designed for radiation studies of samples of various materials used in reactor construction, nuclear power engineering and for performing experiments with irradiation of biological objects. Manganese dioxide is a finely dispersed powder weighing 100 mg with a particle size of about 3 microns [2-6]. Special construction for exposure of laboratory animals to sprayed powder $^{56}MnO_2$ has been developed. The neutron-activated manganese dioxide powder was sprayed into a cage with laboratory animals (mice and rats) [2-4]. To exclude the possibility of $^{56}MnO_2$ powder particles to enter the working room, the cage with experimental animals (mice and rats) was placed in an external box [2].

There were several experiments carried out. Experimental animals and conditions of exposure are described in detail in [2-4]. Briefly, experiments were performed with 11-week-old male Wistar rats and with 10-week-old CD-1, C57BL, and BALB/C mice. The reason for usage of different strains and types of experimental animals was determined by the aims of corresponding biological investigations [7-11]. Experimental animals were exposed to 100 mg portion of sprayed radioactive manganese dioxide powder with various initial activities of ^{56}Mn – in the range from 8.0 × 10^7 Bq to 8.0 × 10^8 Bq – as it was planned in biological experiments [12-14]. There were six to nine experimental animals placed in each cage in dependence on biological experiments' plans [6-15]

Tables 1 and 2 present the pooled information regarding values of internal irradiation among organs of mice from different strains after exposure to the sprayed neutron-activated ^{56}Mn dioxide powder with various levels of activity. As it follows from the Table 1, the doses of internal irradiation in organs and tissues resulting from exposure to sprayed 2.74 × 10^8 Bq activity of ^{56}Mn dioxide powder are not statistically different in different strains of mice. A similar picture takes place under irradiation to 8 × 10^8 Bq activity (Table 2). This means that the distribution of the radioactive powder in the body of mice of different strains but of the same age was practically the same in the case of exposure to the same activity of $^{56}MnO_2$ powder.

Table1. Doses of internal irradiation and corresponding standard deviations (D±SD), Gy, in organs resulted from exposure to 2,74 x 10^8 Bq activity of sprayed neutron activated $^{56}MnO_2$ powder among different strains of 10 week old mice.

Dose (D±SD), Gy, in investigated organs

Activity of ^{56}Mn, Bq and strains		2.74 x 10^8 C57bl	2.74 x 10^8 C57bl	2.74 x 10^8 BALB/C
Lungs	D	0.096	0.14	0.11
	SD	0.013	0.02	0.03
Small intestine	D	0.91	1.1	0.86
	SD	0.15	0.2	0.21
Large intestine	D	4.2	4.5	3.8
	SD	0.5	0.5	0.6
Stomach	D	0.98	1.2	0.91
	SD	0.16	0.2	0.22
Whole body	D	0.38	0.33	0.41
	SD	0.07	0.07	0.09
Skin	D	0.29	0.34	0.21
	SD	0.05	0.06	0.07
Esophagus	D	0.087	0.079	0.093
	SD	0.013	0.013	0.016
Trachea	D	0.039	0.047	0.05
	SD	0.003	0.008	0.01

Eyes	D	0.14	0.13	0.16
	SD	0.05	0.02	0.03
Liver	D	0.0066	0.0086	0.0076
	SD	0.0011	0.0014	0.0012
Heart	D	0.056	0.007	0.061
	SD	0.011	0.01	0.014
Spleen	D	0.0025	0.0028	0.0032
	SD	0.0007	0.0006	0.0008
Kidney	D	0.0028	0.0021	0.0026
		0.0005	0.0006	0.0004

Table 2. Doses of internal irradiation and corresponding standard deviations (D±SD), Gy, in organs resulted from exposure to 8 x 10^8 Bq activity of sprayed neutron activated $^{56}MnO_2$ powder among different strains of 10-week-old mice

Dose (D±SD), Gy, in investigated organs

Activity of ^{56}Mn, Bq and strains		8,0 x 10^8 C57bl	8,0 x 10^8 C57bl	8,0 x 10^8 BALB/C
Lungs	D	0.25	0.34	0.38
	SD	0.05	0.07	0.07
Small intestine	D	2.3	2.8	2.4
	SD	0.2	0.4	0.4
Large intestine	D	10.1	11	9.5
	SD	1.4	2.1	2.1
Stomach	D	2.4	2.2	3.2
	SD	0.5	0.3	0.5
Whole body	D	0.97	1.1	1.2
	SD	0.22	0.2	0.3
Skin	D	0.96	0.91	0.99
	SD	0.21	0.16	0.23
Esophagus	D	0.29	0.17	0.21
	SD	0.05	0.024	0.04
Trachea	D	0.14	0.16	0.13
	SD	0.06	0.04	0.03
Eyes	D	0.39	0.32	0.34
	SD	0.08	0.07	0.07
Liver	D	0.023	0.022	0.024
	SD	0.002	0.004	0.005

Heart	D	0.12	0.18	0.15
	SD	0.02	0.04	0.04
Spleen	D	0.006	0.008	0.007
	SD	0.001	0.002	0.002
Kidney	D	0.007	0.006	0.007
		0.002	0.002	0.002

3. Results and Discussion

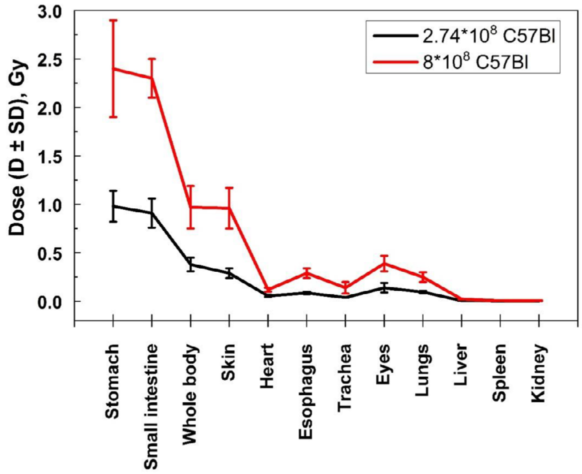

*Fig. 1. Dose comparison for 2.74*10^8 C57BI and 8*10^8 C57BI (from table 1 [15])*

Figure 1 compares the two doses for different neutron fluences and shows a significant difference in dose magnitude for the stomach, small intestine, whole body, and skin. The doses for the liver, spleen, and kidney are almost identical (as confirmed by statistical analysis using a t-test).

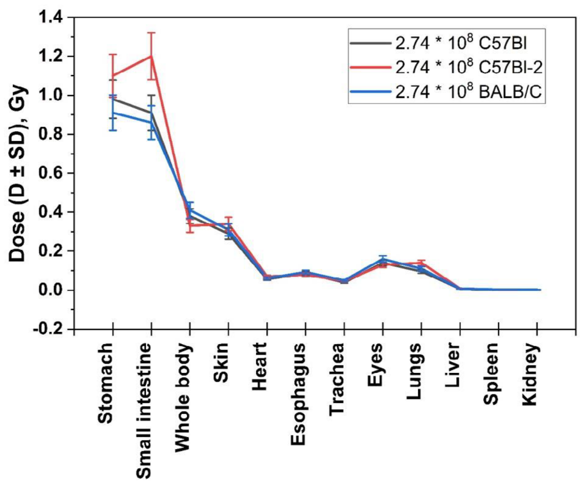

*Fig. 2. Dose comparison for 2.74*10^8 C57BI for different type of irradiated (from table 1 [15])*

Figure 2 compares three types of rats for fluence of neutrons 2.74*10^8. The doses for different fluencies of neutrons show significant differences in the amount of doses for the stomach, small intestine, whole body, and skin. However, the doses for the liver, spleen, and kidney are almost the same, as confirmed by statistical analysis using a t-test.

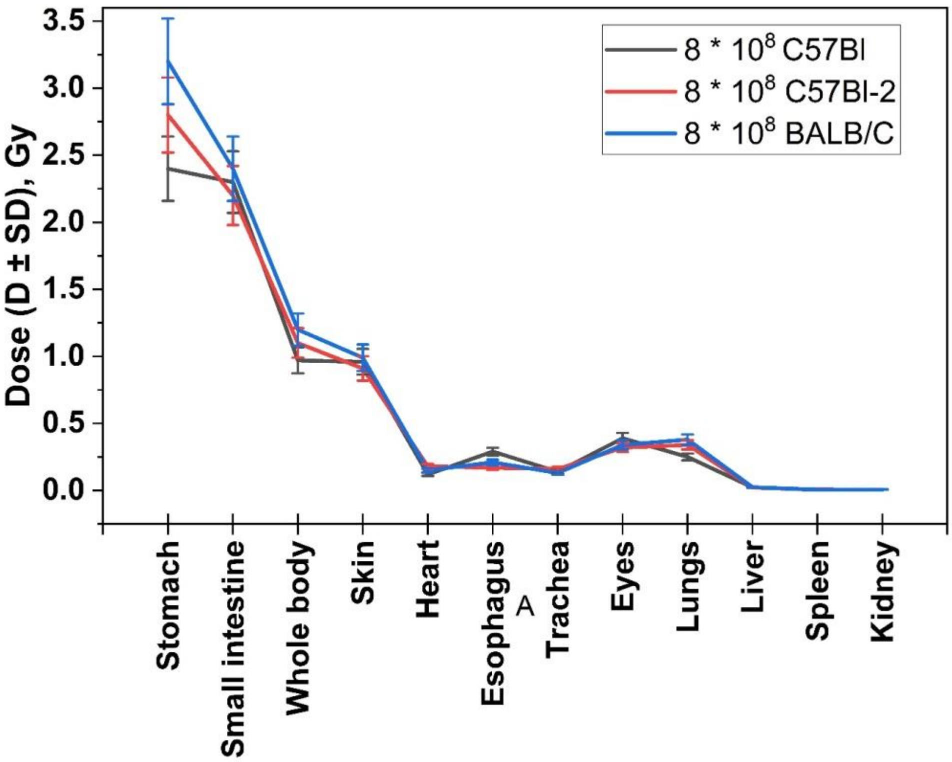

*Fig. 3. Dose comparison for 8*10^8 C57BI for different type of irradiated rats (from table 1 [15])*

Figure 3 compares of three types of rats for fluence of neutrons 8*10^8. The doses for different fluencies of neutrons show significant differences in the amount of doses for the stomach, small intestine, whole body, and skin. However, for the liver, spleen, and kidney, the doses are almost the same (statistically confirmed by t-test) [16].

Unpaired t test results (stomach, small intestine, skin)

P value and statistical significance:

The two-tailed P value equals 0.1629

By conventional criteria, this difference is considered to be not statistically significant.

Confidence interval:

The mean of 2.74 minus 8 equals -0.24033

95% confidence interval of this difference: From -0.63115 to 0.15048

Intermediate values used in calculations:

t = 1.7074

df = 4

standard error of difference = 0.141
Unpaired t test results (heart, esophagus, trachea, eyes, lungs)
P value and statistical significance:
The two-tailed P value equals 0.0905
By conventional criteria, this difference is considered to be not quite statistically significant.
Confidence interval:
The mean of 2.74 minus 8 equals -0.027015
95% confidence interval of this difference: From -0.059562 to 0.005532
Intermediate values used in calculations:
t = 1.9627
df = 7
standard error of difference = 0.014
Unpaired t test results (liver, spleen, kidney)
P value and statistical significance:
The two-tailed P value equals 0.4979
By conventional criteria, this difference is considered to be not statistically significant.
Confidence interval:
The mean of 2.74 minus 8 equals -0.0020800
95% confidence interval of this difference: From -0.0106884 to 0.0065284
Intermediate values used in calculations:
t = 0.7690
df = 3
standard error of difference = 0.003

4. Conclusions

In conclusion, a comparative study of dose for different fluence of neutron is a crucial area of research that requires interdisciplinary collaboration and careful execution. The findings of such studies can provide valuable insights into the dose-response relationship for different neutron fluence rates and can help in developing effective radiation protection measures to safeguard human health and the environment.

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Author Contributions

Alima Amangeldina – results calculation, writing the text and critically revising its content, approval of the final version of the article for publication;

Kassym Zhumadilov – writing the text and critically revising its content, approval of the final version of the article for publication, agreement to be responsible for all aspects of the work, proper examination and resolution of issues related to the reliability of the data.

Valeriy Stepanenko – approval of the final version of the article for publication, agreement to be responsible for all aspects of the work, proper examination and resolution of issues related to the reliability of the data.

Masaharu Hoshi – approval of the final version of the article for publication, agreement to be responsible for all aspects of the work, proper examination and resolution of issues related to the reliability of the data.

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Нейтронның әр түрлі флюенциясының дозасын салыстырмалы зерттеу

Абстракт. Салыстырмалы зерттеудің мақсаты әртүрлі қарқындылықтағы нейтрондық сәулеленуге ұшыраған материалдардан алынған дозаны зерттеу болып табылады. Зерттеулер атом энергетикасы мен радиациядан қорғауда маңызды, өйткені Нейтрондық сәулелену ядролық реакциялар нәтижесінде пайда болатын сәулеленудің ең көп таралған түрлерінің бірі болып табылады. Бұл зерттеуде әртүрлі материалдар әртүрлі қарқындылықтағы нейтрондық сәулеленуге ұшырады және әрбір материал алған доза дозиметрлермен өлшенді. Нәтижелер материалдардан алынған дозаның нейтрондық сәулеленудің жоғарылауымен жоғарылағанын көрсетті. Сонымен қатар, зерттеу доза-әсер қатынасы әртүрлі материалдарда өзгеретінін көрсетті, бұл радиациялық қорғаныс үшін материалды таңдаудың маңыздылығын көрсетеді. Зерттеу әртүрлі материалдар үшін доза-әсер қатынасын жақсырақ түсіну радиациядан қорғау үшін тиімдірек материалдарды әзірлеуге және әртүрлі қолданбаларда радиациялық қауіпсіздікті арттыруға көмектесуі мүмкін деген қорытындыға келді.

Түйін сөздер: нейтрондар ағыны, радиация, дозиметрия, Грей, Қазақстан.

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Сравнительное исследование доз для разных флюенсов нейтронов

Абстракт. Сравнительное исследование направлено на изучение дозы, получаемой материалами, подвергшимися воздействию нейтронного излучения различной плотности. Исследования имеют важное значение в области ядерной энергетики и радиационной защиты, поскольку нейтронное излучение является одним из наиболее распространенных видов излучений, образующихся в результате ядерных реакций. В этом исследовании различные материалы подвергаются разной плотности нейтронного излучения, а доза, полученная каждым материалом, измерялась с помощью дозиметров. Результаты показали, что доза, получаемая материалами, увеличивается с увеличением флюенса нейтронного излучения. Кроме того, исследование показало, что взаимосвязь «доза-реакция» различна для разных материалов, что подчеркивает важность выбора материала для радиационной защиты. В исследовании делается вывод, что лучшее понимание зависимости «доза-реакция» для различных материалов может помочь в разработке более эффективных материалов радиационной защиты и улучшить радиационную безопасность в различных приложениях.

Ключевые слова: поток нейтронов, излучение, дозиметрия, Грей, Казахстан.

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