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Determination of the Absorption Coefficient and Cloudiness Multiplicity Attenuation During the Gamma-Radiation Passage

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Abstract. The paper presents background value equivalent dose of gamma-radiation investigation in different weather: clear cloudy and overcast. The change of the dose rate of gamma radiation, depending on the weather and the ability cloudiness to shield gamma rays is shown. A new method for eliminating the consequences of accidents at nuclear power plants or plants using radioactive elements is proposed. A calculation method of cloudiness coefficient absorption and cloudiness gamma-radiation multiplicity attenuation is developed. The gamma-radiation multiplicity attenuation and the absorption coefficient of gamma radiation were calculated.

1. Introduction

In today's world there are many unresolved problems [1-3], one of which is to find engineering solutions for protection against to exposure to ionizing radiation, for example, in the case of a nuclear explosion or leakage on the radiation-hazardous facility. It is known that an important spread factor of radiation is the atmosphere, in particular, cloudiness [4-6].

Basic methods of radiation exposure protection can be divided into three types (Fig.1).

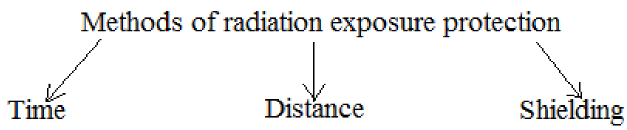

Figure 1. Basic methods of protection against exposure to ionizing radiation

Protection time is to residence time reducing the in areas with high background radiation. The distance protecting is increasing distance from the radiation contamination source to the spacing at which radiation level will reach background values. The ionizing radiation intensity dependence with distance from the source is represented by the formula:

$$Radiation\ intensity \propto \frac{1}{(Distance^2)} \quad (1)$$

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In some situations, just need to carry out any activities in the zone with high background radiation. An example would be the elimination of the nuclear power plants accident consequences or industrial jobs, where radiation sources take place. In this case is the use of shielding, such as sarcophagus, radiation-resistant enclosures, personal protective equipment.

According to the International Commission on Radiological Protection, in most countries, the ionizing radiation sources of natural origin provide about 50% of the average human dose irradiation [7](Table 1).

Table 1. Contribution of different sources to the total human exposure

Radiation sources	Contribution to the annual exposure of human,%
Natural background	23
Irradiation of human by decay products of radon and thoron indoors	42
Nuclear testing products fallout	0,77
Nuclear power	0,03
Motor vehicles using	0,1
Consumption of radio luminescent products	0,1
Usage of ionizing radiation in medicine	34

At the same time according to the research about 30% of the natural background make it cosmic particles [7].

Cosmic radiation bumps into Earth's upper atmosphere, which provides effective protection for all living creatures without missing much of the radioactive particles. Cosmic rays consist of «galactic» particles which occur outside the solar system and the "sun" particles emitted by the sun. The solar radiation is energetic charged particles, electrons, protons and nuclei injected Sun into interplanetary space Galactic radiation consist of the various chemical elements nucleus having a kinetic energy of more than a few tens of MeV/nucleon, and the electrons and positrons with E> 10 MeV.

The cosmic rays comprised of high-energy atomic particles, the percentage contribution of which is as follows [8]:

- 87% protons.
- 11% α-particles,
- ≈1% heavy atoms,
- ≈1% electrons.

In the atmosphere "solar" particles produce cascades of nuclear interactions, which give a lot of secondary particles that play an important role in the production of space radionuclides (Fig. 2).

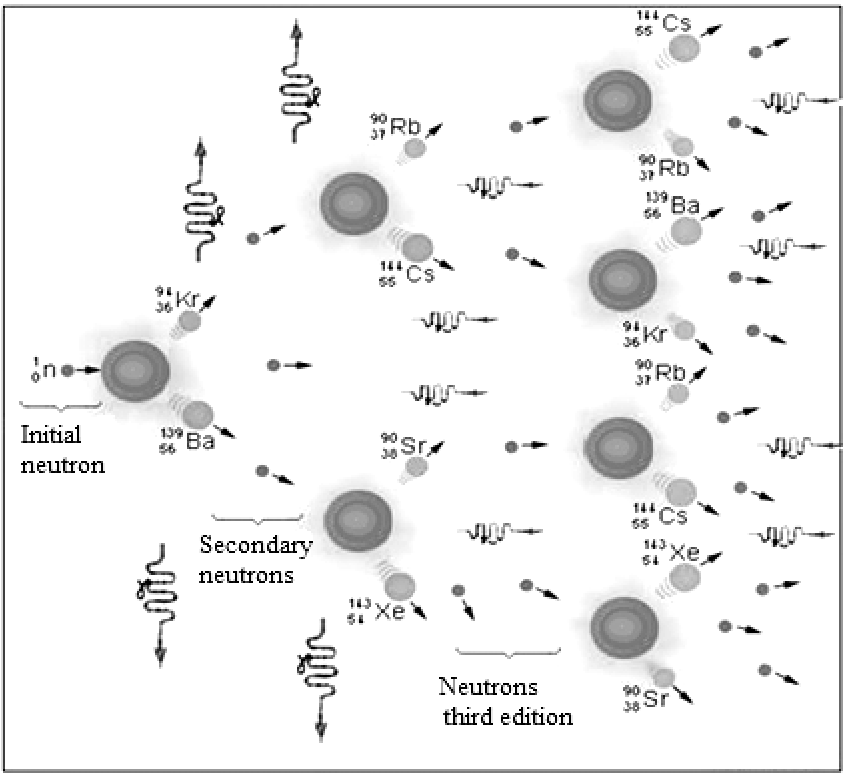

Figure 2. Basic Cascades interaction of nuclear particles

Radioactive transformation is a chaotic process and often leaves the transforming nucleus in an excited state in which the protons and neutrons in the shells of the nucleus are not in the most tightly bound state possible. This excitation energy will be emitted as electromagnetic radiation as the protons and neutrons in the nucleus rearrange themselves to the desired lowest energy state. The shell model of the nucleus suggests discrete energy states for neutrons and protons; it is this difference between energy states that is emitted as a gamma photon when rearrangement takes place. Thus, the emitted gamma ray is characteristic of that particular nucleus [7].

At the passage of radiation through the atmosphere, there are altitude, barometric and geomagnetic effects:

1. The altitude effect - dependence of the radiation intensity I and the height of the observation point above sea level H. The higher point of observation, the greater will be the contribution of cosmic radiation. The observations were made at a height of 200-300 meters above sea level.

In absolute terms the absorbed dose increasing with the height above sea level:

Table 2. The correlation of the absorbed dose rate and height above sea level

H(km)	0	4	8	20
D (μGy/h)	0,032	0,14	0,84	8,72

2. The barometric effect - dependence of the cosmic radiation intensity I from the atmospheric pressure p at the observation point.

Change *p* means that a substance amount varies over the observation point. This leads to a change in cosmic radiation intensity *I*. The barometric effect is expressed barometric coefficient quantitatively:

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$$b = \frac{1}{I} * \frac{\Delta I}{\Delta p} \quad (2)$$

The coefficient b is uniquely associated with an average of cosmic radiation absorption coefficient in the air $b = -\mu$. The b and μ values are different for the various components of cosmic radiation. The value $b \geq 1{,}5\%$ by 10 mm Hg. Maximum variation with a period of several days more than 10% for the charged particles and up to 15% of neutrons.

3. The geomagnetic effects (latitude and longitude) - dependence of the intensity and cosmic radiation energy spectrum from the geomagnetic coordinates of the observation point. The coordinates of the observation point *55 °44'00"* N *84 °54'00*" E:

At this development society stage is quite technically feasible is the creation or deletion of cloud clusters. Therefore the aim of this research is: ability determining of cloudiness to shield of gamma-radiation and can therefore be used for gamma-radiation protection.

Tasks

- To determine the gamma radiation dose rate in clear weather
- To determine the gamma radiation dose rate in cloudy weather
- To determine the dose rate in overcast weather
- To calculate the cloud absorption coefficient and the multiplicity attenuation when gamma radiation passes.

2. Results and Discussion

The gamma radiation dose rate is investigated during the research. It has the highest penetration ability. And it is a byproduct of the radioactive particles decay majority, including galactic particles. So gamma radiation dose rate can be used to evaluate the cosmic radiation influence on the radiation situation.

Detector dosimeter is used to convert the phenomena caused by ionizing radiation into an electrical or other easily accessible to measurements signal. The detector of the dosimeter is the ionization counter, by type of Geiger counter with a sensitivity of 20,000 pulses/μSv. The gamma radiation dosimeter has two measurement channels: to measure ambient dose equivalent rate of gamma radiation and to measure the dose with independent reset these values. The measurement carried out continuously with the constant refinement of the result, at what the statistical error displayed on the screen. So we can get a result with the necessary statistical accuracy. The measurements were carried out with not more than 5% statistical error.

Carrying dosimetric characteristics investigation performed during the spring and autumn. The measurements were made every day at 14 o'clock in the afternoon, as it is the time of greatest solar activity [9-11].

The dosimetric characteristics were obtained at atmospheric pressure 730-760 mm Hg. The indications are taken at the same distance of 1 meter from the ground is strictly horizontal relative. Measurements at a height of 1 meter correspond to the peculiar standards related to the gamma and beta radiation ratio and the location of the most sensitive body parts standing person.

The experimental data were processed by the ORIGIN program. And approximation of the resulting curve is conducted. The results are shown in Fig. 3 and Fig. 4.

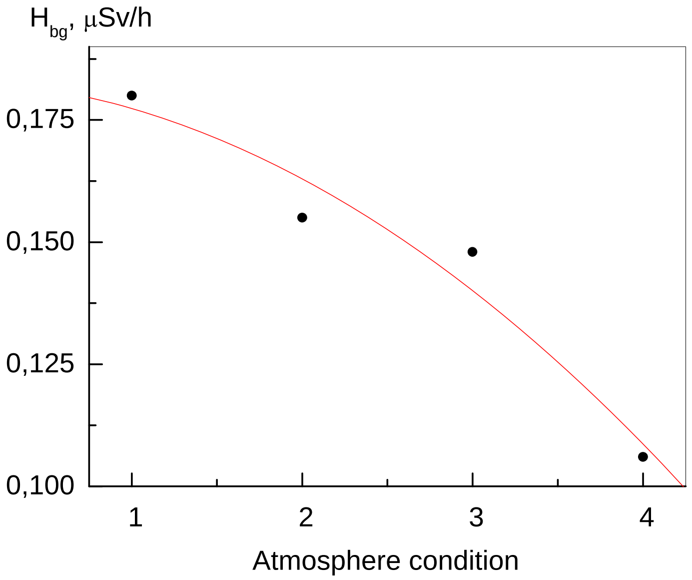

Figure 3. Background radiation value dependence from the weather type, spring: 1 - clear weather, 2 - cloudy weather, 3 - overcast weather; H_{bg} – background dose rate of gamma-radiation.

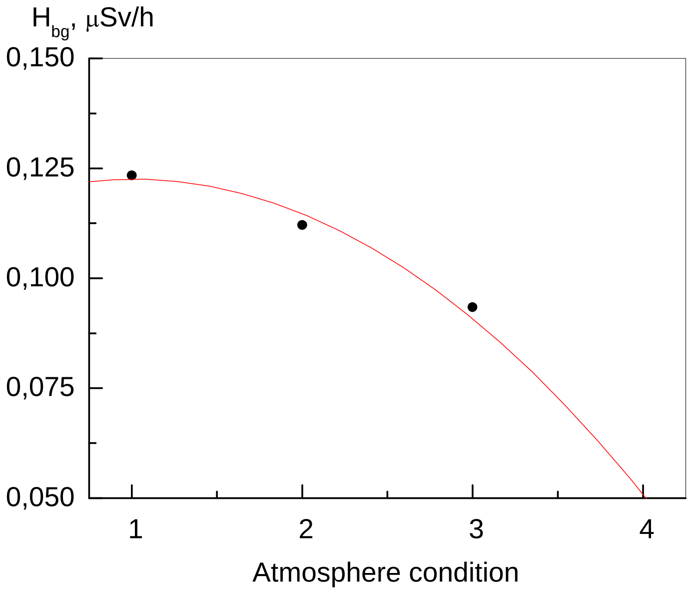

Figure 4. Background radiation value dependence from the weather type, autumn: 1 - clear weather, 2 - cloudy weather, 3 - overcast weather; H_{bg} – background dose rate of gamma-radiation.

In order to determine cloudiness absorption coefficient formula for attenuation intensity of narrow gamma radiation monoenergetic beam with a layer thickness in the matter is used.

$$I = I_0 * (\exp(-\mu * \chi)) \quad (3)$$

where:

- I - the intensity,
- I_0 - initial intensity of the gamma radiation,
- μ - linear (mass) absorption coefficient,
- χ- thickness.

And for a parallel gamma radiation stream:

$$I = I_0 * (\exp(1 - \mu * \chi)) \tag{4}$$

The gamma radiation dose is proportional to the intensity and dose rate of gamma-radiation, then the following expressions are valid:

$$H = H_0 * (\exp(1 - \mu * \chi)) \tag{5}$$

where:

- H - the dose rate of gamma-radiation after passing the thickness of cloud clusters,
- H_0 - initial dose rate of gamma-radiation before passing the thickness of cloud clusters,

Whence by means of mathematical transformations, we obtain an expression for the absorption coefficient:

$$\mu = \frac{1 - ln\frac{H}{H_0}}{\chi} \tag{6}$$

Substituting the values of the dose rate of gamma radiation and the average height of the middle layer cloud clusters (2000 - 3000 meters), we obtain the value of the cloud absorption coefficient:

$$\mu_{cloudiness}=6.3*10^{-4}m^{-1}$$

For comparison, the absorption coefficient for air and lead:

$$\mu_{air}=4*10^{-4}m^{-1}, \mu_{lead}=1,18m^{-1}$$

Thus, the absorption coefficient of lead, of course, more, but the cloudiness about 3000 meters can attenuate gamma radiation in two or more times. Thus, it is possible to use cloudiness to restrain the radioactive contamination spread and this will solve the global issues of environmental safety [12]. The use of special decontamination additives for spraying will allow to precipitate the radioactive substances and to delay the radiation spread effectively.

Similarly, the gamma radiation multiplicity attenuation was calculated - as one of the main shielding characteristics from gamma - radiation, showing how many times the need to reduce the exposure dose rate to get set (limits) the gamma radiation dose rate H_{lim}:

$$K = \frac{H}{H_{lim}}$$

$$K_{cloudy} = 0,90$$
$$K_{overcast} = 0,80$$

Conclusions.

The following conclusions can be made on the basis of the study:

1. A result of research revealed that average equivalent dose rate of gamma radiation higher in clear weather than in cloudy weather. Thus cloud clusters may be used to eliminate the consequences of accidents at nuclear power plants or plants using radioactive elements.
2. There is no doubt, we have to be shielding and absorption of gamma radiation in the thickness of the cloud clusters.
3. The absorption coefficient of gamma radiation and gamma radiation multiplicity attenuation for cloudy and cloudy weather are calculated.

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