NATURAL NEUTRON EQUIVALENT DOSE IN MIDDLE EUROPE REGION.

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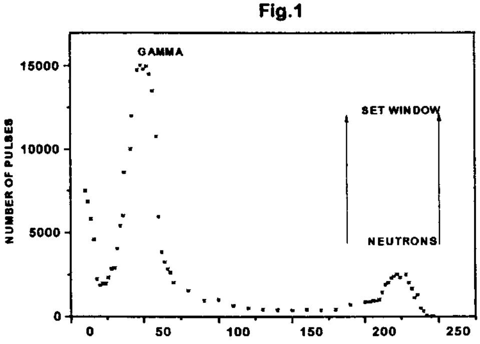
INTRODUCTION. Determination of the neutron fluence rate dependence on the elevation at small distances above the earth's surface is important both for estimation of the neutron radiation contribution to the whole population dose and from point of view of the influence of neutron radiation on detector back-ground as well. We carried out such the measurements at localities with various elevation from 113 m to 2632 m, placed between geodetic latitudes 48° -52° N and longitudes 16° - 20° E (Czech and Slovak Republic).

The spectrum of the ambient neutrons were determined using a calibrated Bonner spectrometer placed on the site with the highest elevation (Lopmnitsky Peak in The High Tatras, 2632 m). A ^{3}He-proportional counter with a sensitive volume of $1*10^4$ cm^3 was the second used detector [1]. The amplitude spectrum of the ambient neutrons registered by ^{3}He-detector is shown on Fig.1.The significant peak generated by thermal part of ambient neutrons (reaction He[n,p]T) was observed. We set the window of a single channel analyzer on this peak The back-ground counting rate (in the set window from interior surface alpha activity was $N=(0.061\pm0.0002)\ s^{-1}$ The effective detection area (or sensitivity) C of the counter, determined according

Fig.1



$$N[s^{-1}] = C[m^2].\Phi\ [m^{-2}\ s^{-1}] \qquad /1/$$

depends on the shape of the neutron spectra. For thermal neutrons it amounted to $C_{th} = (0.015\pm0.0013)\ m^2$. This value exceeds by approximately 600 times the sensitivity of a LiJ(Eu) crystal with dimensions of 4 * 8 mm.

The thermal part of natural neutrons spectrum Φ_{th} was detected directly by the proportional counter. In order to detect possible changes in the intermediate Φ_{in} and fast Φ_f components ambient neutrons at different sites we also used the ^{3}He-counter which was wrapped in layers of polyethylene (PE) moderators, 23 mm or 64 mm thick, lined (on the outside) by a thermal neutron absorber of Cd 0.8mm thick, for to shift the maximum of a response function into the intermediate or the fast region neutron energy.

Measurements on the other sites were carried out with only a ^{3}He-counter. We supposed that the shape of neutron spectrum, is elevation independent at law altitudes. This assumption is based on theoretical models of Lal [2], O'BRIEN [3] and MASARIK and REEDY [4] calculation.. Physical foundations for it is the existence of an equilibrium distribution of low energy nucleons ($E < 500$ MeV) through out the low altitudes region in the atmosphere.

RESULTS AND EVOLUTION OF MEASUREMENTS

The results of measurements are presented on Fig.2 (thermal part of natural neutrons) and Fig.3. (when were registered mainly intermediate or fast neutrons).The measured counting rates were corrected for the intrinsic background of the counter and they exhibit an exponential dependence on the elevation of the site **z**. Consequently the neutron fluence rate and dose equivalent rate can be approximated by the exponential function in the form $\sim \exp(\alpha*z)$. From our experimental data $\alpha = (0.85\pm 0.05)\ 10^{-3}\ m^{-1}$.

For the neutron spectrum evaluation the SAND II. code has been applied. For the response functions of Bonner-Spheres the published data calculated by Hertel were used [5]. The neutron fluence rate were calculated from neutron spectra.

Fig.2

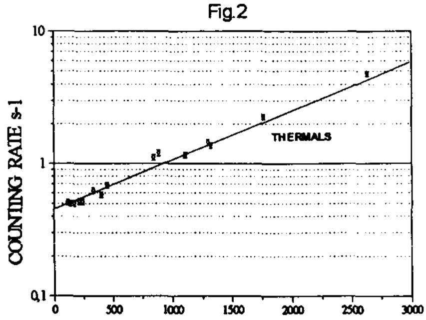
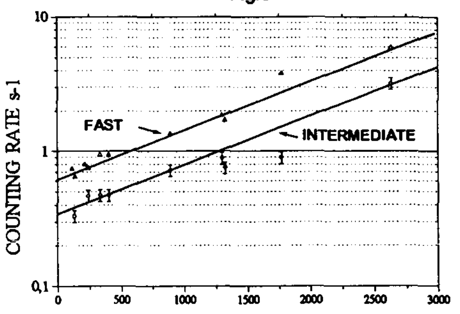


Fig.3



The dose equivalent rate were calculated from the neutron spectra. All data given in the publication have calculated before the ICRP 60 Recommendation has been published. In this way we got the value 40 nSv/h for elevation 2632 m . Partial and total fluence rate ϕ on this site determinated by Bonner spectrometer are on theTab.1 The extrapolation of the height dependence counting rate to zero altitude gives the values: $\Phi_{th}(0)=(30\pm6)m^{-2}*s^{-1}$; $\Phi_t(0) = (100\pm20)\ m^{-2}*s^{-1}$ .and $H(0) = (4.1 \pm 1.2)$ nSv/h.

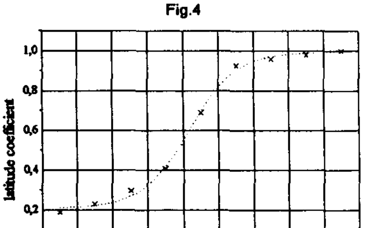
Energy group	$\phi[m^{-2}*s^{-1}]$
Φ_{th} (E_n < 0.5 eV)	280
Φ_{in} (0.5 eV ≥ E_n > 0.1 MeV)	330
Φ_f(E_n ≥ 0.1 MeV)	340
Φ_t	950

DISCUSSION

Our measurement were carried out at varies localities with different relative concentrations of clay, sand and stone in the composition of ground. The statistical errors of our measurement were less then 5 %. As can be seen in Fig.2-3, the results confirm that the elevation dependence of neutron fluence rate and also dose equivalent can be with reasonable accuracy approximated with the functions ~ $\exp(\alpha*z)$, where $\alpha = 0.85\ km^{-1}$. Deformation of the neutron spectrum occurs with the increase of ground moisture content. Such deformation of the neutron spectrum lowers the annual dose equivalent. Because our measurements were done in the summer season during a long-lasting period without precipitation, the value of H(z) obtained should be considered as a maximum one.

In order to find the dependence of the mean value of the annual dose equivalent <H(z)> on relevant elevation, both <H(0)> and parameter α have to be decreased, because precipitation increases with increasing elevation.This fact is reflected in analytical expressions have been developed for the general relationship between annual dose and elevation for the neutron component of cosmic ray, which are given by BOUVILLE and LOWDER [6] and recommended by Forty-first session of UNSCEAR (1992) for estimate the distribution of collective effective dose with elevation. There are two expressions [6]: one for elevation z< 2 km, in the form $H(z)=H(0)*\exp(1.04*z)$, and second in the form $H(z)=H(0)*[1.98*\exp(0.7*z)]$ for elevation z > 2 km, where H(0)=20 µSv/a = 2.4 nSv/h. These equations may by applied to estimate doses from natural neutrons at habitable elevations around the world. Because there is strong dependence of neutron fluence rate on latitude, our experimental data valid for latitude ~50° N distinguish (Fig..4) from latitude-averaged value[6]. Comparing our value $\alpha = 0.85\ km^{-1}$ with value 0.7 km^{-1} [6] we made conclusion, that seasonal variations should be lead to decreasing α maximum 20%. Unfortunately, the accuracy of experimental data is not satisfactory for making the unambiguously conclusion.

Fig.4



LCS was used also for estimation of latitude dependence of neutron fluence rate that is expressed through coefficient k_φ. Its values for sea level altitude are presented in Fig.4. Our measurements were carried out at near geomagnetic latitudes ~50°, that are characterized with k_φ =0.84 (values are normalized to unit for high latitudes) and we estimate latitude-averaged value assign weights to Earth'area for different latitudes with step of 10°. We get the same value 2.4 nSv/h, that was used by BOUVILLE and LOWDER [6].

We can normalized the values in the front of the exponential factor (in accordance with the value for geomagnetic latitude φ=90°) as latitude-independent parts, that is multiply by factor k_φ . Then dependence of total, thermal neutron fluence rate and dose equivalent rate on elevation z and latitude φ can be parametrized

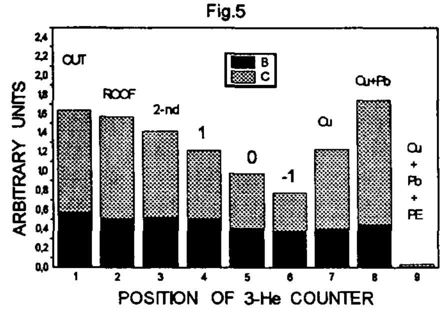
$$\phi_t (z,\varphi) = 119*k_\varphi*\exp(\alpha*z) \qquad /2/$$

$$\phi_{th} (z,\varphi) = 35* k_\varphi*\exp(\alpha*z) \qquad /3/$$

$$H (z,\varphi) = 4.8*k_\varphi*\exp(\alpha*z) \qquad /4/$$

Knowledge of elevation and latitude dependence thermal component of natural neutron fluence is important for determination of high-sensitive neutron detector backgrounds, because it is determined mainly by this energy group. Effective area of neutron detector C_{th} can be easily calculated or experimental determination using /1/, where ϕ_{th} is calculated from /3/ for a given locality. In the case of experimental determination, detector have to be located in the open space, far enough from massive constructions, buildings.etc. As an illustration Fig.5 shows the influence of the construction materials on the natural fluence rate (B - ϕ_{th} , C - $\phi_f + \phi_{in}$) on the locality outside the building of the Department of Nuclear Physics (position 1), on the roof (2) and the different floors (3,4). Into the basement there is a low background massive shielding , position (5) - the counter placed into the shielding, when it was made of copper only, next position - the shielding was made of copper and lead and last - the shielding was made of copper, lead and polyethylene (PE) with boron.

Fig.5



CONCLUSION

Results of our measurements show, that change in dose equivalent rate [nSv/h] from natural neutrons for the Middle Europe region can be described with reasonable accuracy exponential dependence $H(z)=4.1*\exp(0.85*z)$ valid for elevation z = 0 - 2.6 km, having an error about 30 %, where the errors of calibration (20 %), the statistical errors (5 %) and the error (20 %) caused the variation of moisture in ground in during year are included. The calculated by us the values k_φ quote to the good agreement with the latitude-averaged annual value <H(0) > , but they need experimental tests for localities with different latitudes.

REFERENCES

1. FLOREK, M.,.HOLY, K., JANIK, R., MELICHAR, Z., ^{3}He-proportional Chamber for Delayed Neutron Registration, .Nuclear Energy, **30**,171 (1984)

2. LAI D.,PETERS B.,Cosmoc ray produced radioactivity on the Earth, in Encyclopedia of Physics, vol. **46/2** edited by K.Sitte, pp.551-612, Springer,New York, (1967).

3. O'BRIEN K., SANDMEIER H.A.,HANSEN G.E., CAMBELL J.E., Cosmic ray induced neutron background sources and fluxes for geomagnetic of air over water, ground, iron, and aluminum, J.Geophys. Res. **83** (A1), pp.114-120 (1978)

4. MASARIK J.,REEDY R.C.,Terestrial cosmogenic nuclide production systematics calculated from numerical simulations. Earth and Planetary Science Letters,1995 (accepted).

5. HERTEL H.E. DAVIDSON I.V. The response of Bonner Spheres to neutrons from thermal energy to 17.3 MeV.Nucl.Instrum.Method, A 2388,509(1985).

6. BOUVILLE ,A.,LOWDER W.H.,Human population exposure to cosmic radiation. Radiat.Prot.Dosim. **24**,293-299(1988).