INDIVIDUAL DOSES, WHICH IS FORMED FROM THE RADIOACTIVE CLOUD AT THE STRAIGHT ROUTE OF EXPOSURE

Lazutskiy A.[1)], Pisarev A.[2)], Kovzhoga S.[3)], Tuzikov S.[4)]

ABSTRACT
The study of direct exposure pathways, which include: external exposure to photons and β- particles radionuclides in the atmosphere and deposited on the soil: the internal exposure due to radionuclides In the body with inhaled air (inhalation route).

Key words:
photons, irradiation, radionuclides, individual doses, polluted, emissions, atmosphere

ABSTRACT
Исследование прямого прямого облучения, которые включают в себя: внешние пути воздействия фотонов и β- частиц радионуклидов в атмосфере и на отложившиеся в почве: внутреннее облучение обусловленое радионуклидами поступившими в организм с вдыхаемым воздухом (ингаляционный путь).

Key words:
фотоны, облучение, радионуклиды, индивидуальные дозы, загрязнение, выброс, атмосфера

The subject of this article is direct ways of irradiation, which include: external irradiation by photons and β ±-particle radionuclides, containing in the atmosphere, as well as deposited in the soil; the internal irradiation from radionuclides received the body from inhaled air (inhalation route). In these cases, are formed directly in the vicinity of the emission sources.

[1] Lazutskiy Anatoliy, PhD, ass. prof.;
[2] Pisarev Anatoliy, PhD, ass. prof.;
[3] Kovzhoga Sergey, PhD, ass. prof.;
4 Tuzikov Sergey, PhD, ass. prof.; all authors from department Principles of personal and social safety of National University “Yaroslav the Wise Low Academy of Ukraine”, st. Pushkinskaja, 77, Kharkiv, 61024, Ukraine, laf55@rambler.ru, Mobile Tel. +380 97-212-95-87.

By way of indirect exposure include internal irradiation from radionuclides in the body of the fallen as a result of their migration on food and biological chains. . This results in irradiation people living not only in the placement of the source of emissions, but also in other areas where may be polluted by emissions from food.

As a result, an emission of radioactive gases and aerosols in the atmosphere forming individual doses to humans occurs by direct and indirect routes of exposure.

Radionuclides dispersed in the atmosphere can be a source of photon radiation. This dose of the torch of radioactive gases and aerosols depends heavily on weather conditions (categories of weather), the effective height of chimneys or other source of emissions, the duration of ejection, physical and chemical forms of the radionuclides, the speed of gravitational sedimentation and precipitation scavenging, and, of course, the type and energy of radiation.

With prolonged release with changing wind rose, and other meteorological parameters of the radioactive cloud often interpreted like the source in the form of a semi-infinite space with a uniformly distributed over the volume of activity, Bq/m^3. Then the power of the equivalent dose $\dot{H}$, Sv/s, created in the surface (unprotected) layer of the human body on to the opening area, can be calculated by the formula

$$\dot{H} = A_V B_{\alpha\gamma} \quad (1)$$

where Vαγ - the dose coefficient of external irradiation by photons (in this case γ-quanta of radionuclides) from radioactive clouds, Sv·m^3/(s·Bq).

Its numerical value can be obtained on the basis of the law of radiation balance - the number of the emitted energy per unit volume of an infinite medium with a uniformly distributed volume activity equals the number of absorbed energy in this volume [1]. This is of course justified and $\beta^{\pm}$-particles to.

For 2π-geometry of irradiation with an accuracy of edge effect in the open areas, we have

$$B_{\alpha\gamma} = \frac{E\,1{,}062 \cdot 10^{-13} r}{2 w \rho}, \quad (2)$$

where $E = \sum_i n_i E_i$ - energy yield of photons, MeV/decay n_i - the absolute yield in the decay scheme, photon/decay; E_i - the energy of the *i*- photon, MeV/Photon); 1,602·10^{-13} - the energy equivalent, J/MeV; r=1,09 - transition ratio of the absorbed dose in air to the equivalent doze in biological tissue, Sv/Gy; ρ=1,293 - - air density with normal conditions, kg/m^3, 2 - coefficient accounting 2π-geometry of human exposure (inside an infinitely extended source, this coefficient is equal to 1); the coefficient *w* occurs in most of the dose coefficients,

$$w = 1 \text{ J/(Gy·kg)}, \quad (3)$$

i.e. the energy equivalent of gray, attributed to the mass in 1 kg of the radiated environment (in this case air).

Note that the power of the emission the Q, Bq/s, related to the volume activity of the nuclide in the air, A_V, Bq/m^3 ratio

$$\dot{Q} = A_V / G, \quad (4)$$

where G meteorological factor of dilution with the continuous releases, c/m^3. Then instead of (1) can be written

$$\dot{H} = \dot{Q} G B_{\alpha\gamma}, \quad (5)$$

In two previous formulas assume that that when determining the meteorological dilution $G(x)$ for a given distance from release point x is taken into account so-called function exhaustion of cloud.

Formulas radiation from the source in the form of a semi-infinite space (1) and (5) but usually used for elevated emissions at a reasonable distance from the vent pipe (with a maximum surface area of concentration).

Depending on the units dose coefficient (2) can be represented as follows:

$B_{\alpha\gamma} = 6{,}75 \cdot 10^{-14} E$ Sv· m^3/(s· Bq); (6)

$B_{\alpha\gamma} = 2{,}13\ E$ μSv· m^3/(year· Bq); (7)

$B_{\alpha\gamma} = 0{,}25\ E$ rem· m^3/(s· Ci). (8)

Numerical values of dose coefficients Bαγ for inert radioactive gases and isotopes of iodine are given in [2]. If there is a mixture of radionuclides using the superposition principle with the percentage contribution of each radionuclide and the spectrum of photon radiation.

With time-varying volumetric activity of $A_V(t)$ or burst power $Q(t)$ the expected equivalent dose in time T (N^c_T, Sv) is calculated by the formula

$$H_T^c = B_{\alpha\gamma}\int_0^T A_V(t)dt = B_{\alpha\gamma}\int_0^T Q(t)G(t)dt. \quad (9)$$

If the calculation of the measured or known distribution in time of dose rate $\dot{H}(t)$ then the total expected equivalent dose of H^c can be determined from the ratio

$$H^c = \int_0^\infty \dot{H}(t)dt.$$

Note those formulas (1) and (2) with a simple modification can also be used to calculate the dose for humans or other organisms which are above the water surface or submerged in it. In this case, ρ = 1000 kg/m^3, and the coefficient in the denominator decreases from two of the detector (a person) to one of his immersion to a depth of more than three mean free paths.

In short term emissions, when weather and other conditions remain the same, using various models of final cloud. In practice, most often a whiff of radioactive emissions simulated by a linear or cylindrical source. Formulas and functions of photon radiation output of extended sources of various geometrical forms with given self-absorption in the source and absorption in the protective layer is given in [2, 3, 4, 6].

Figure shows a simplified diagram of a jet of radioactive gas in the form of a non-absorbing line source, located at a height d above the flat surface of the soil.

If $\dot{Q}$ release (Bq/s), u - wind speed (m/s), the linear source activity (Bq/m)

$$A_L = \dot{Q}/u. \quad (10)$$

Then the equivalent dose rate (S_V/s) at point *1*

$$\dot{H}_1 = A_L r \Gamma_\delta F(\theta_1, \mu d)/d \quad (11)$$

at point *2*

$$\dot{H}_2 = A_L r \Gamma_\delta [F(\theta_2, \mu d) + F(\theta_3, \mu d)]/d \quad (12)$$

at point *2*, if $\Theta_2 = \Theta_3$

$\dot{H}_2 = 2A_L r\Gamma_\delta F(\theta_2,\mu d)/d$ (13)
at point *2*, if $\theta_2 = \theta_3 = \pi/2$
$\dot{H}_2 = 2A_L r\Gamma_\delta F(\pi/2,\mu d)]/d$ (14)
at point *3*
$\dot{H}_3 = A_L r\Gamma_\delta[F(\theta_4,\mu d) - F(\theta_5,\mu d)]/d$ (15)

In these formulas

$$F(\theta,\mu d) = \int_0^\theta \exp(-\mu d \sec\theta')\,d\theta' \quad (16)$$

is a function of photon attenuation in the air, the values of which are given in [2]; μ - linear attenuation coefficient of photons in the air; Γ_δ – kerma constant g·m^2/(s· Bq); r = 1,09.

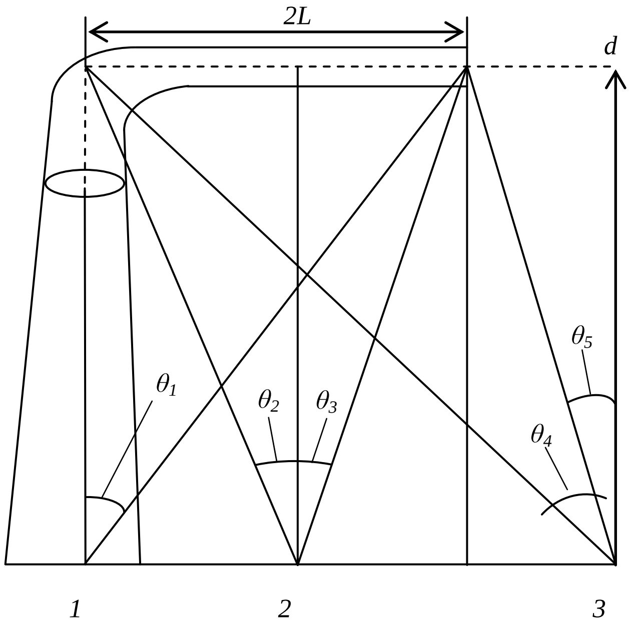

Figure 1 Schematic representation of the radioactive gas jet in the form of a line source

It is often more convenient to represent the response of the source in terms of volume activity of A_V (Bq/m^3). Then in formulas (10) – (15) is used the ratio
$A_V = A_L/\pi R^2$, (17)
where *R* is the radius of the cylindrical source, m.

When using these formulas and more accurate calculation:

1) introduce an amendment *k* to the radiation shielding walls of buildings to the time of human presence in them [2];

2) take into account the multiple scattering of photons in the air by multiplying by the factor of accumulation of *B* (*E, μd, Z*) in the air [2];

3) take into account the differential spectrum of γ-radiation radiation for individual radionuclides and presence of daughter's nuclides. [5].

According to the formula (10) and the amendments referred to above, the link between the power of emission the $\dot{Q}$ and the power of equivalent dose *H* (Sv/s) corresponding to, for example, the case of (14), when θ = π/2, can be represented as

$$\dot{H}_2 = 2Q\sum_{i=1}^{m} r\Gamma_{\delta i} F(\theta,\mu,d) k_э B_D(\mu_i d, E_i Z)/ud. \quad (18)$$

Often the shape of the jet can be represented in the form of a cylindrical non-absorptive source of radius R. In this case, the total activity A in the jet of length $2LA = 2LA_L = \pi R^2 2LA_V$, where A_V - volume activity, Bq/m^3. Then in formulas(11) - (16) of the linear active AL should be replaced by volume activity $A_V = A_L/\pi R^2$, but formula (10) rewrite in the form

$$A_V = \frac{\dot{Q}}{\pi R^2 u} \qquad (19)$$

For practical purposes, you can use the extrapolation formula [3]

$D(x) = K(x)D_\infty(x) + [1 - K(x)]\, D_L(x)$

where $D_\infty(x)$ - dose calculated by the formula (6) or (7) for the cloud in the form of semi-infinite space; K (x) is a multiplier takes into account the altitude the jet above the ground. For short-term emissions

$$K(x) = \exp\left[-\frac{h^2}{2\sigma_z(x)^2}\right];$$

for continuous emissions

$$K(x) = \sum_j \omega_j \exp\left[-\frac{h^2}{2\sigma_{z,j}(x)^2}\right],$$

where ω_j repeatability $j^{\text{-th}}$ category of stable weather. If necessary, a more accurate calculation of the dose rate of photon radiation from the radioactive cloud complex form it is necessary to simulate it as a series of small volume sources and produce numerical integration for all sources, using the equation

$$\dot{H} = \frac{a}{4\pi} \iiint_V \frac{A_V B_D}{r^2} [\exp(-\mu r)]\, dV,$$

where a - dose coefficient, which depends on the choice of units; B_D - dose factor accumulation in the air; r - the distance from the detector to elemental volume dV.

SUMMARY

When assessing doses of external radiation due to β-particles or electrons of conversion of radionuclides it is necessary to mean small uncertainties and possible errors that are primarily associated with their relatively small penetration in the material. So, if the cloud of radioactive gases is higher than 20 m above the ground, then the contribution to the dose of β-particles can be ignored. Shoes, clothing or personal protective equipment also to screen the stream of β-particles, if their the effective thickness of greater than 2 g/cm^2.

However, it is precisely because of low penetration and, consequently, a large energy loss dE/dx per unit length of the absorbing material - of biological tissue - β-particles can be dangerous damaging factor unshielded skin, if a power source is great. Most often this can be in an emergency.

REFERENCES

[1] Защита от ионизирующих излучений. Т. 1. Физические основы защиты от излучений: Учебник для вузов / Н.Г.Гусев, В.А.Климанов, В.П.Машкович,

А.П.Суворов; под ред. Н.Г.Гусева – 3-е изд., перераб. и доп. М.: Энергоатомиздат, 1990.
[2] ГусевН.Г., БеляевВ.А. Радиоактивные выбросы в биосфере: Справочник. – 2-е изд., перераб. и доп. – М.: Энергоатомиздат, 1991. – 256 с.
[3] Защита от ионизирующих излучений. в 2-х т. Т. 1. Защита от излучений ядерно-технических установок: Учебник для вузов / Н.Г.Гусев, Н.Е.Ковалев, В.П.Машкович, А.П.Суворов; под ред. Н.Г.Гусева – 3-е изд., перераб. и доп. М.: Энергоатомиздат, 1990.
[4] Норми радіаційної безпеки України (НРБУ-97), Київ 1997.
[5] ГусевН.Г., Дмитриев П.П. Радиоактивные цепочки: Справочник. – 2-е изд. – М.: Энергоатомиздат, 1991.
[6] Ковжога С., Писарєв А., Тузіков С., Лазутський А., Малько О. Природа фізико-хімічних процесів глибинного радіоактивного забруднення довкілля. // Культура безпеки, екології та здоров'я. Всеукраїнський науково-популярний журнал, січень 2010. № 1.

Článok recenzovali dvaja nezávislí recenzenti