About possibility to calculate radioactive pollutants taking into account climatic and meteorological peculiarities.

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Abstract: - It is developed the model of three-zones radioactive pollutions, which are exhausted while an explosion at Atomic Power Plant. It is formulated how radioactive pollutions behave in each zone. The problem of the radioactive pollutants distribution from the explosion epicenter for the far zone is solved. The algorithm for analytical solution is given. It is stated that there is the space limit for pollutions distribution from the epicenter. Quantitative discussions are provided. Effect of the climatic and meteo peculiarities are considered.

Key-Words: - radioactive pollutions, far limit, radial symmetry, the coefficient of diffusion, climatic peculiarities

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1 Introduction

In case of force-majeure at Atomic Power Plant (APP), there are essential exhaust of radioactive pollutions in environment. These pollutions can be represented as particles, which later settle onto the Earth's surface. The area of radioactive precipitation might be very wide and expand on large distance from APP through international borders. In forming radioactive pollutions, it is necessary to take into account the climatic and geographic factors, which make a contribution into this propagation. The matter of this paper is to clear how a) radioactive pollutions from APP propagate after explosion at APP, and b) different atmospheric peculiarities affect the distribution of radioactive pollutions in space.

Especially for this type of problem, we developed a model for radioactive pollutants propagation. In this model it is suggested that an explosion has occurred at APP, and radioactive pollutants were thrown out up to certain height and then move radially from epicenter which is located at the explosion point (maybe the APP tube). Then we take some simplifications like:

- The pollutants move from the epicenter strictly radially without any turbulence and rotations in propagation plane;
- All the pollutants move radially within tine plane so that no mixing with pollutants moving at parallel plane;
- The pollutants are thrown homogeneously to all the directions from the explosion epicenter independently on the azimuthal angle, so we can propose that there is the radial symmetry of the problem.

In our model, it is proposed that after explosion with radioactive pollutions at APP three zones of fallout are valid:

1) Near zone, where intensive mixing substances take place together with the great speed of substances motion from the APP center. This zone is located near the epicenter of explosion;
2) Medium zone, where propagation wave has a great speed, which is much more in comparison with the pollutants mixing;
3) Far zone, where radial propagation of pollutants sharply reduces and can be neglected with the pollutants diffusion, so in solving the problem we should take into account just mixing factor.

These three zones gently cross over to each other but are managed by different models and laws. In this paper the authors have developed model for describing, how radioactive pollutions are distributed from the epicenter in the far zone.

2 Problem Formulation

To the authors' stand point, maximal harmful effects should be expected in far zone since the effect of radioactivity will be long-term and could be minimize anyhow. So, it is preferable to modelling how radioactive pollutions are distributed in space after passing large distance from the explosion epicenter.

For the third case in above classification, when we try to describe how pollutants can affect the periphery, for solving the problem of pollutions distributed radially from the APP center we use the radial equation of diffusion

$$\frac{\partial n}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(\lambda(n) r \frac{\partial n}{\partial r}\right) \qquad (1)$$

In the representation (1), it is proposed that the coefficient of diffusion λ is non-linear and depends upon the concentration of pollutants. The function $n = n\ (r,\ t)$ to be found is the pollutants radial distribution from the explosion center. The dependence $\lambda(n)$ is empirical and should be determined from the field measurements but in this paper, we accept some law more probably valid from practice, namely

$$\lambda(n) = \sigma_1 n + \sigma_2 \qquad (2)$$

where σ_1 and σ_2 are constant values and should be found from experiments. Additionally, the coefficient λ should take into account the climatic and geographic peculiarities of the territory under consideration to ensure relevant description of radioactive pollutants.

It is well known, that account of climatic, meteo- and geographic peculiarities are highly important for forecasting, how radioactive pollutants are formed and propagate in atmosphere; as it was recently described by one of authors in [1]. The coefficient of diffusion introduced accordingly to the formula (2) gives an opportunity to correctly evaluate the effect of these peculiarities on the final spatial radioactive pollutants distribution.

For modelling the distribution of pollutants, we have to take the next conditions: one condition by time

$$n\ (t=0) = n_0 \qquad (3)$$

and two conditions by coordinate

$$n(r = r_f) = n_0(t) \ \text{ and } \ \frac{\partial n}{\partial r}\left(r = r_f\right) = n_C(t) \quad (4)$$

Physically, the conditions (3) and (4) have the next matter. Solution of the problem is made only after pollutants reach the point r_f from the explosion center, moreover we can not minimize r_f to zero because in the given statement the problem is correct just for the far zone described in above classification. So, we accept that we are looking for the distribution of pollutants after they come to point r_f. The concentration of pollutions and their changes by time at the radius r_f from the epicenter are the time-dependent as it follows from the conditions (4).

The equation (1) can be changed to

$$\frac{\partial n}{\partial t} = \frac{1}{r}\lambda(n)\frac{\partial n}{\partial r} + \frac{\partial \lambda}{\partial r}\frac{\partial n}{\partial r} + \lambda(n)\frac{\partial^2 n}{\partial r^2} \quad (5)$$

If make formal substitution of required function as

$$\theta(r,t) = \sigma_1 n(r,t) + \sigma_2\,, \qquad (6)$$

then we obtain the next equation

$$\frac{\partial \theta}{\partial t} = \frac{\theta}{r}\frac{\partial \theta}{\partial r} + \left(\frac{\partial \theta}{\partial r}\right)^2 + \theta\frac{\partial^2 \theta}{\partial r^2} \qquad (7)$$

In the substitution (6), the constants σ_1 and σ_2 are the same as in (2). The equation (7) in non-linear one and the author has already developed the algorithm for solving such a type of equations in his paper [2].

3 Stationary case for pollutions distribution after explosion

This case describes the distribution of pollutants after long time passing from the explosion when process became balanced and time-independent. Mathematically, this case is obtained if in the equation (7) one takes $\partial\theta/\partial t$=0. Under such a condition, we have

$$\frac{\theta}{r}\frac{\partial \theta}{\partial r} + \left(\frac{\partial \theta}{\partial r}\right)^2 + \theta\frac{\partial^2 \theta}{\partial r^2} = 0, \qquad (8)$$

and after formal transformations finally one gets

$$\frac{1}{r}\frac{d}{dr}\left(\theta r \frac{d\theta}{dr}\right) = 0 \qquad (9)$$

with obvious $\theta r \frac{d\theta}{dr}$ = C₁, after that we can find the solution of equation (9) in a view

$$\theta(r) = \sqrt{2C_1 ln r + C_2} \qquad (10)$$

In the equation (10), the values C_1 and C_2 are constant which to be found from the conditions (4) but for asymptotic case $t\rightarrow\infty$, which physically corresponds to the stationary case. For this, we have to come back to the required function *n (r)*.

Using the conditions (4) provides two algebraic equations for finding C_1 and C_2, namely

$$\sqrt{2C_1 \ln r_f + C_2} = \sigma_1 n_{0\infty} + \sigma_2 \qquad (11)$$

and

$$\frac{C_1}{\sigma_1 r_f} \cdot \frac{1}{\sqrt{2C_1 \ln r_f + C_2}} = n_{C\infty} \qquad (12)$$

The values $n_{0\infty}$ and $n_{C\infty}$ are defined as the asymptotic case for the functions $n_0(t)$ and $n_C(t)$ at $t\rightarrow\infty$, respectively.

By solving the last two equations we can finally write

$$C_1 = -\sigma_1 r_f n_{C\infty}(\sigma_1 n_{0\infty} + \sigma_2) \quad (13)$$

and respectively,

$$C_2 = (\sigma_1 n_{0\infty} + \sigma_2)^2 + 2\ln r_f \ \cdot |C_1| \qquad (14)$$

If put values C_1 and C_2 in the solution (10) and keep in mind the substitution (6), one finally gets for the distribution of radioactive pollutants after explosion at periphery the next formal law

$$n(r) \sim \sqrt{a - b\, lnr} \qquad (15)$$

Herein, a and b are some constants which are expressed through C_1 and C_2. The formula (15) is in accordance with the result obtained by authors in their early publication [3].

The key points for understanding the far zone model are the next:

1) The equations (8) – (15) are valid for balanced process of radioactive pollutants distribution in far zone after explosion at APP. As it was proposed by our classification in the beginning of this paper, this zone is characterized by poor convective radial speed of pollutants and exceeding mixing pollutants in propagation plane but not between the planes.
2) The law (15) gives an opportunity to formally calculate the far limit of radioactive pollutants expansion r_∞. As it is seen from the dependence (15), this limit can be calculated as $r_\infty = e^{a/b}$. As it is can be logically concluded, the ratio a/b is critical for describing the radioactive pollutants distribution in the far zone. The analysis shows that the formula (15) as well as the ratio a/b is very sensitive to the climatic and meteo peculiarities of the territory where the APP is located and radioactive pollutants are distributed.
3) If after explosion a few radioactive components/substances are polluted, then one needs to solve the same number of the equations as it has been made in this paper. The algorithm (2) – (15) should be realized for each component after that we can conclude that each radioactive component has own far limit $r_{\infty(i)}$, (i – the number of components threw up to atmosphere after explosion at APP) which is defined by the physical properties of the component. As the analyses shows, component with more mass (in atomic units) will expand less in comparison with lighter components. So, we finally have different $r_{\infty(i)}$, thereto the more is mass of substance, the less will be corresponding $r_{\infty(i)}$.

The approach given in this paper allows calculating the total level of radioactive pollutants moved from the explosion epicenter to periphery as well. Accordingly to the diffusion theory, the equation

$$-\lambda \frac{dn}{dr} = N \qquad (16)$$

describes the intensity of the radioactive pollutants flow through unit length of covering line from the explosion epicenter. So, for the closed line radioactive (equi-polluted line) pollutions N_{total} one has

$$-\oint_{(L)} \lambda \frac{dn}{dr}\, dl = N_{total}$$

In case of pollutants expansion in form of concentric circumferences which is corresponded to the radial symmetry of the problem solved, one has

$$-\oint_{(C=2\pi r_f)} \lambda \frac{dn\,(r = r_f)}{dr}\, dl = N_{total}$$

If the pollutants are distributed homogeneously by circumference and the physical properties of the process do not change at the circumference, then the last integral will be reduced to the final view

$$N_{total} = 2\pi\lambda R \left|\frac{dn\,(r=R)}{dr}\right| \qquad (17)$$

The last formula describes the total circular level of radioactive pollutants at the distance R from the explosion epicenter. Moreover, if one knows how the coefficient λ depends upon the climatic, meteorological and geographic peculiarities of given territory, it will be possible to find the dependence of the radioactivity level on indicated physical factors. The magnitude N_{total} can be measured by wireless monitoring system, which has been proposed in [4].

Of course, it should be taken into account that the result (17) is relevant just for the stationary case, when all the physical magnitudes included into the algorithm (2) – (17) are time-independent.

4 Conclusion

1. In the present paper it is developed the model of radioactive pollutants propagation in space after the explosion at APP. The model introduces three zones of propagation, each of these zones is characterizes by specific criteria.
2. The problem of the radioactive pollutants distribution in the far zone proves to be non-linear. This is explained by the fact, that the diffusion coefficient in the far zone depends upon the concentration of radioactive isotopes exhausted while the explosion. This type of concentration is expected to be closer to the reality. The algorithm for solving such a problem is found.
3. The algorithm for calculating the far limit in the radioactive pollutants propagation after explosion at APP is given. It is proposed that after the explosion radioactive isotopes are exhausted into atmosphere and move radially from the explosion epicenter. The calculations show that this spatial limit for radioactive pollutants depends upon the explosion conditions and physical characteristics of the pollutants.
4. It is obvious that this far limit is different for various radioactive isotopes, which are exhausted while explosion and move in atmosphere from the explosion epicenter. In this paper, the general formula for calculating the far limit for arbitrary radioactive isotope could be throwing up into atmosphere is given.
5. The analytical formula for calculating the total doze of the radioactive pollutions of territory is found. This formula allows to determine the pollutions degree in the simplest case when it is suggested that after the explosion radioactive pollutants are distributed from the epicenter in form of the concentric circumferences. However, the linear integral for calculating the radioactive pollutions propagation for any arbitrary case is also provided. Additionally, one can calculate the circular density of the radioactive pollutions degree. Indeed, if one uses the

$$\rho_{circular} = \frac{N_{total}}{C} = \frac{N_{total}}{2\pi R} = \lambda \left| \frac{dn\,(r=R)}{dr} \right| \quad (18)$$

The last formula is much more convenient for making an experiment because the value $\rho_{circular}$ describes the radioactivity degree on the unit length of the circumference with the radius R.

6. The analysis of the formula (17) shows that the level of radioactive pollutions is directly proportional to temperature. This leads to very important conclusion, the level of radioactive pollutions are much more intensive and wide in hot regions in comparison with cold ones. In other words, the explosion at APP in hot regions will result in much harmful damages than that in cold regions under otherwise equal conditions.

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