ЗАХИСТ ОВТ ВІД ЗАСОБІВ ВИЯВЛЕННЯ ТА УРАЖЕННЯ

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ACTIONS OF NBC RECONNAISSANCE UNITS DURING SEARCH FOR SMALL SITES OF RADIOACTIVE CONTAMINATION

The optimal ways of searching for small sites of radioactive contamination, so-called "dead" zones, which are formed in case of destruction of dangerous objects that use, process, store and transport radioactive agents during conducting reconnaissance by the NBC units, are analyzed. The following research methods have been applied: bibliographic, analytical, systematic and informational approach. The following ways of searching (reconnaissance) of contaminated sites of the area are considered: the zigzag locate technique, the boustrophedon technique, the classical and rectangular spiral technique and the star survey technique. The length of the route was determined and the optimal parameters for their carrying out under certain conditions were established. The zigzag method (29-52%) is found to be the most effective, while the star survey technique is fast but ineffective. The probability of finding contaminated sites based on the height of the location of the detection unit and the energy of γ-quanta of radioisotopes, which are formed during the destruction of a nuclear reactor, disruption of nuclear and thermonuclear ammunition, is calculated. Increasing the probability of finding depends on the distance between the routes, their length, as well as the specifications of the radiation reconnaissance devices. Removal of the detection unit outside the reconnaissance vehicle increases the search efficiency, which depends on the specifications of the detection units of radiation reconnaissance devices. It is shown that the use of aerial reconnaissance equipment significantly increases the survey area and the efficiency of detecting a radiation situation by productivity, since the detection unit is located at a significantly higher altitude than 3 m. Requirements for technical specifications of unmanned aerial vehicles of radiation reconnaissance are formulated. It is determined that in order to fully accomplish the task of radiation reconnaissance, it is necessary to use the means of aerial and ground radiation reconnaissance in a complex way, complementing one tool with another.

Keywords: *NBC reconnaissance, radioactive contamination, methods of NC reconnaissance*

Problem statement

Rapid development of renewable energy sources in the international energy community has not stopped the interest in nuclear power, despite some stagnation, caused by accidents at Chernobyl and Fukushima nuclear power plants. This is evidenced by the active construction of new and modernisation of existing reactors in many countries [1, 2].

The war in the east of the country continues, and still the real possibility of escalation, the spread of aggression into the peaceful territories, the expansion of the geography of terrorist attacks and sabotage remain the same. Ukraine has a great number of dangerous objects vulnerable to the attacks, attacks on which may cause huge disasters for the state as a whole and be a potential threat (emergency situations of technogenic and military nature) for the civilian population. Hypothetical destruction of such objects for various reasons can create conditions that can be comparable with the conditions of use of weapons of mass destruction and will require rapid and effective liquidation of their consequences by military forces of the country: the units of the State Emergency Service of Ukraine, Ministry of Defense, Ministry of Internal Affairs and other ministries and agencies. These units are usually combined into consolidated groups whose task is to eliminate aftermath of technological accidents and catastrophes [3].

In the conditions of unpredictable actions of the enemy in this area the timeliness and accuracy of detection of radiation, chemical, biological (NBC) contamination and assessment of the situation is especially important, which is one of the main tasks of NBC defence as one of combat support units [4,5].

The purpose of this task is to provide governing bodies, units with information on the NBC situation on the ground, in the air, the sea area in order to consider it in planning and giving tasks to NBC protection units. The objective of this task is achieved by conducting NBC reconnaissance, in particular, radiation reconnaissance, determining the doses of radiation in the area, fencing of contaminated sites, determinating directions (routes, roads), bypass. A quality criterion of detection of the actual radiation situation is the timeliness of obtaining intelligence [5, 6] and their completeness. Indicator of the completeness of conducting reconnaissance characterizes quality of conduct of radiation reconnaissance with onboard (portable) devices during focal contamination by radioactive agents in the form of "spots" [7, 8]. Accordingly, resolving issues related to accuracy, timeliness and completeness of conducting radiation reconnaissance are very important.

Analysis of recent research and publications

The problem of development of technical means of NBC reconnaissance in post-Soviet counrties remains extremely acute because since most of NBC reconnaissance vehicles, mostly served beyond the established terms of operation, are obsolete.

Today in the world, a priority direction of improvement of special NBC reconnaissance vehicles is the creation of a multipurpose modular set of equipment for collecting, processing and transfering data on changes in NBC situation in real time [6, 9]. The creation of land mobile complexes of detection and assessment of the situation, which would be equipped with automated sensors, primary processing and transmission of information about its condition, navigational data, development of unmanned aerial vehicles, equipped with onboard systems to detect contaminated sites is in demand [7, 9].

Unfortunately, modern developments do not always take into account the specific requirements for military radiation survey instruments that are necessary for the effective fulfillment of assigned tasks. The focus is on the improvement of the technical characteristics: increasing of informativeness, reducing of measurement error, increasing of sensitivity and enhancing of energy range of power measurement. While on the radius of the controlled area at the point of location of the NBC reconnaissance vehicles they do not pay attention.

Aim of the article

The purpose of this article is to determine the optimal search paths of small sites of radioactive contamination, so-called "dead" zones, which are formed in case of the destruction of dangerous objects, that use, process, store and transport radioactive agents during the conduct of radiation reconnaissance by NBC reconnaissance units. The following research methods: bibliographic, analytical, system and information approach have been applied.

The main material

At failure (accident) at nuclear power plants a nuclear reactor becomes a constant source of intake of radioactive agents into the environment until its isolation "suppression". Radioactive agents that come on the surface create zones of radioactive contamination, whose characteristics are somewhat different from the zones of radioactive contamination, which are formed during a nuclear explosion. A low height of release of radioactive agents, the unstable state of the atmosphere in the surface layer, the presence of ascending and descending air currents, which cause frequent changes in the direction and force of the wind, contribute to uneven contamination with the formation of a significant number of foci (spots) of radioactive contamination with significant levels of radiation. Generated zones of radioactive contamination will not always be continuous, and the probability of finding cells ("spots") of radioactive contamination will increase with increasing distance from the destroyed (damaged) reactor [5, 9].

The analysis of the methods of conducting radiation reconnaissance and monitoring radioactive areas, which are used in the Armed Forces of Ukraine and other countries shows that the data on radiation contamination of the area may not always be complete because a route of conducting reconnaissance is selected taking into account an area, time of the year, weather conditions, road network, and so on. Inaccessible areas are surveyed usually by dismounted patrols, which, in turn, significantly increases the time to perform tasks and exposes personnel not reasonable irradiation [6]. In addition, during the conduct of radiation reconnaissance unsurveyed areas so-called dead zones will remain, because not all area is available for reconnaissance vehicles, imperfection of radiation reconnaissance instruments, time constraints are also present.

To locate these areas of contamination, different methods are used in radiation reconnaissance, including the boustrophedon technique, zigzag, spiral, star survey technique, and so on. Each of them has its advantages and disadvantages and allows to reveal the presence of a small (small in size) zone of radioactive contamination. Determination of the optimal way of conducting radiation reconnaissance requires to set criteria by which to assess effectiveness. This can be, in particular, the probability of detection, the time during which the search is to be performed and the area that is surveyed. All three of these quantities are related by (1) [8]:

$$t = \frac{-\ln(1-P_0)\cdot S_p}{u} \quad (1)$$

where: t – time of reconnaissance (search), P_0 – given probability of finding a contaminated site; Sp – area of search (area of reconnaissance) km^2, u – speed of search (reconnaissance), km^2/h.

The time of the search (reconnaissance) will depend on the length and configuration of the route, width of a zone covered with a detection unit of detection devices, speed of reconnaissance vehicles on a particular route.

Speed of conduct of radiation reconnaissance substantially depends on technical feasibilities of radiation reconnaissance devices. The standard area to be determined for a reconnaissance by the NBC reconnaissance section is up to 100 km^2.

Accordingly, the effectiveness will depend on the accuracy of the information, which will be affected by the route of a reconnaissance section on this site. It is obvious that the reduction of the distance between contour lines of passing by a section (lanes, spirals or zigzags), the probability of detecting radioactive contamination increases, but the length of the route of reconnaissance also increases that will influence the search time of contaminated sites.

Having calculated by appropriate formulas the length (L) of the routes, we determine the optimal parameters of the search method of the contaminated site with the highest probability and the least time for its detection. For comparison, we will consider the different methods of reconnaissance of an area 10×10 km, with the speed of a reconnaissance vehicle 40 km/h.

Reconnaissance by the boustrophedon technique (Fig. 1) suggests passing of straight lanes by a section (l) and turnings half-turns on the border of a certain search square. The length of the route can be determined by the formula:

$$L = 4 \cdot n + l(k+1) + \pi \cdot n \cdot (2k+1) \qquad (2)$$

(or simplified: $L = (l + n) \cdot k$),

where: L – distance that will be passed by a section (patrol), n – distance (width) between tacks, km; l –length of lane where search is conducted, km; k – number of tacks on the site, that is searched.

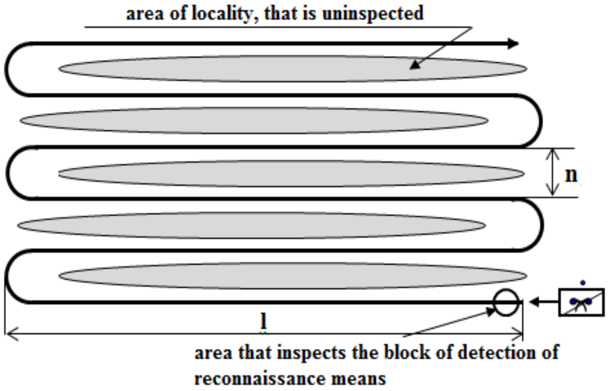

Fig. 1. **Boustrophedon technique (BD – is a block of detection)**

A reduction of the distance between the tacks increases the length of the route, and, respectively, time to conduct the reconnaissance, but increases the probability of finding a contaminated site. The most optimal distance on a site 10×10 km is the distance between the tacks 1÷1,5 km, the length of the route will be 80,5÷99 km.

Conduct of reconnaissance by the zigzag locate technique suggests the movement of the patrol along a line oriented a certain angle from the starting point of reconnaisance. After passing 500 m along the first zig, the patrol turns 90° and moves in the opposite direction along the next zigzag. The process is repeated until the whole territory is searched (Fig. 2). The length of the route will depend on the angle of movement of the NBC reconnaissance patrol, the number of zigzags and number of turns performed by the patrol:

$$L = n \cdot k \cdot \sqrt{B^2 + (B \cdot tg\alpha)^2}$$

$$n = \frac{D}{B \cdot tg\alpha} \qquad (3)$$

$$k = \frac{F}{B},$$

where: L – distance that will be passed by a section, B – width of the site, where reconnaissance is conducted; F – width of the site where the search is conducted; D – height of a single site where a search is conducted; k – number of sites where reconnaissance is conducted in a district; α – given angle of the zigzag in determining movement of a reconnaissance section; n – number of points of change to a traffic route on one site of reconnaissance.

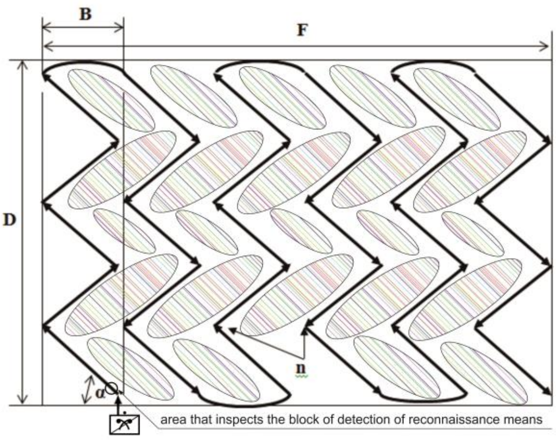

Fig. 2. **Zigzag locate technique**

A reduction of distance between the sites of search (reconnaissance) increases the length of the route. An increase of the angle at which a movement of a reconnaissance vehicle is conducted reduces the number of points of change to the direction of search and, respectevily, reduces the length of the route, but reduces the probability of detection. Optimal parameters of search on a site 10 x 10 km will be an angle of 45 ° and distance between the routes (sites) of search 1÷1,5 km; the length of the route is 94÷141 km.

The total length of the trajectory of movement of a section (L) when conducting reconnaissance by "spiral" method (Fig. 3) is at $n \in N$ [10]:

$$L = \pi \cdot r \cdot (n^2 + n + 1)$$

or if $n \notin N$ (4)

$$L = \pi \cdot r \cdot (n^2 + n + 1 + \{n\} - \{n\}^2),$$

where: r – distance between the trajectories; n – number of complete turns on the area of search; $\{n\}$ – fractional part of number of turns. Reducing of the distance between the spirals increases the length of the route. The length of the route when the distance between the trajectories 1÷1,5 km is 79÷97 km.

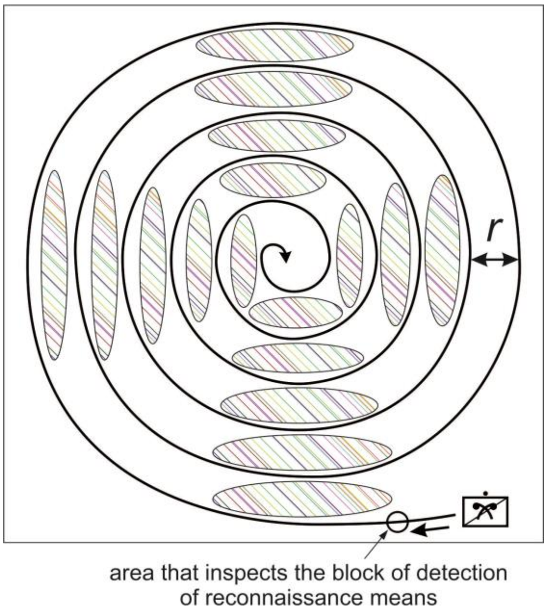

Fig. 3. **Spiral method (classic)**

In some cases, to reduce "dead" zones, it is more practical to carry out the search (reconnaissance) in a particular area using the "rectangular spiral" (Fig. 4), in this case, the length of the route (search) can be calculated using the appropriate formula in the spiral:

$$L = [a + \{a + d \cdot (n-1)\}] \cdot n \qquad (5)$$

when twisting the spiral:

$$L = [a + \{a - d \cdot (n-1)\}] \cdot n, \qquad (6)$$

where: a – length of the first site of the search, km; d – a distance between sites of the search, km; n – number of sites, of a different length.

The length of the route at distance between the areas of search 1÷1,5 km is 84÷110 km.

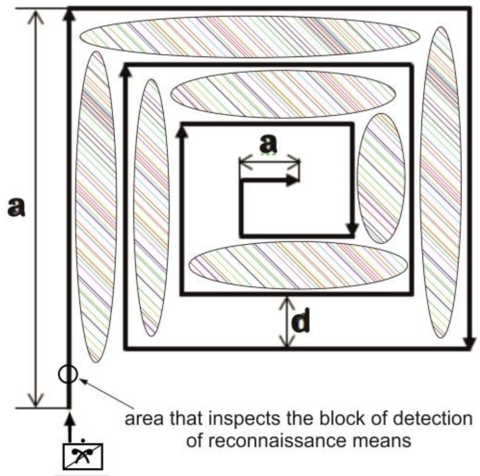

Fig. 4. **Method "rectangular spiral"**

The star survey technique (Fig. 5) is quite rough but a quick method of searching a contaminated site. An NBC reconnaissance unit moves under the angle of 135º in the direction of possible contamination, defining the level of radioactive contamination at certain intervals (e.g. 200 m). Passing a certain distance, the unit turns approximately 135º and moves towards the contaminated site until the whole area is searched. Similarly, a section moves until all the "legs" of the star are connected. The probability of detecting radioactive contamination is the least among the methods.

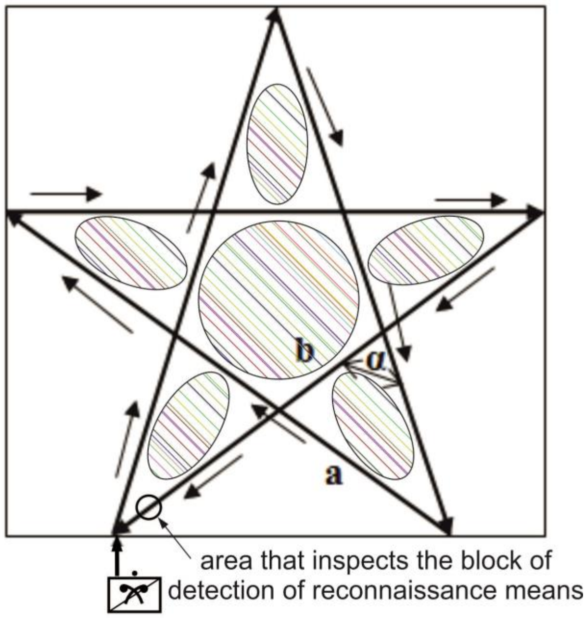

Fig. 5. **Star survey technique**

The length of the route will consist of the perimeter of the star and the perimeter of a pentagon that is inscribed in a star because during the search (reconnaissance) by this method, a reconnaissance vehicle passes the angles of the pentagon twice:

$$L = 10a + 5b = 5(2a + b) = 10(a + a \cdot \cos\alpha)$$

$$b = 2a \cdot \cos\alpha\,, \qquad (7)$$

where: *a, b* – sides of the triangle (the star rays), *α* –an angle in determining movement of a reconnaissance section. An increase of the "star" side leads to an increase in the length of the route, but the probability here will not be significant (on a site 10×10 km with a length of one ray of the star 4.4 km total distance will be 57,6 km).

Defining the search area, it is necessary to be aware that the energy of γ-rays of radioactive isotopes formed during the destruction of a nuclear reactor, detonation of nuclear and thermonuclear ammunition is almost the same (table 1) [8 ,9]. At a low altitude above the ground a dose of γ-radiation is mainly determined by the sources located at a distance of not more than 100÷150 m from the measurement point (table 1).

Table 1

Radiuses of sites of contamination area depending on energy of γ-rays and measuring height

Energy, MeV	The fullness of the power at the measuring point	The distance from the surface of the earth H, m			
		1	3	10	50
0,41	50%	6	7	8	12
	75%	40	50	86	60
	90%	122	131	170	250
1,25	50%	6	12	38	98
	75%	42	55	92	173
	90%	130	142	180	280
2,8	50%	7	15	45	112
	75%	50	66	115	205
	90%	140	153	200	300

Mainly isotopes $^{137}_{55}Cs$ with the energy of γ-rays 0,661 MeV will infect the area in destruction of a nuclear reactor for a long period. Accordingly, a detection unit can determine the presence of radioactive agents in the range of approximately 130 m. Considering that, the area (*S*) of the surveyed area is calculated on the formula:

$$S = L \cdot C\,, \qquad (8)$$

where: *S* – area surveyed, km^2; *L* – length of the route, km; *C* – width of search lane, km. The width of the search lane depends on location and height of placing of a detection unit.

We find the probability of finding a contaminated site by formula 1:

$$P = 1 - e^{-\frac{t \cdot u}{S}}\,,$$

where: *P* – probability of detecting a contaminated site; *t* – time required for search, h; *u* –speed of search (reconnaissance) of the area, km^2/ h; *S* – area in which search (reconnaissance) is performed, km^2. The results of the search calculations in different ways on a site 10×10 km, provided that the distances between the routes of the reconnaissance vehicle moving at a speed of 40 km/h are 1 km, are given in table. 2.

As it can be seen from table 2, with a probability of detection of the contaminated site search methods do not differ much from each other. The best method to search (detect) contaminated sites with radioactive agents is the zigzag locate technique.

Search efficiency will depend substantially on the technical capabilities of dosimetric devices (location, height of placing and arrangement of the detector, its design features, the material from which it is made, sensitivity, error of measurement, energy of γ-rays (table 1)).

It is known that the detection unit of the detection device is in the middle of the reconnaissance vehicle at a height of ≈1 m from the surface of the earth. Object's body, which attenuates γ-radiation, affects the sensitivity of detection of ionizing radiation. The imposition of the detection unit from outside of a reconnaissance vehicle and placing it at a height of 1.5÷2 m above the object using a special device (for example telescopic rod) will reduce the influence of the body on the sensitivity.

Table 2

Search results in different ways by reconnaissance vehicle BRDM-2 nbc at height of 1 m above ground

Indicators	Search methods (reconnaissance)				
	Boustrophedon	Zigzag	Spiral	Rectangular piral	*star*
The length of the route, *L*, km	99	141	97	110	53
The surveyed area, *S*, km^2	24,2	34,4	23,7	26,8	13
Time, *t*, hours	2,5	3,5	2,4	2,75	1,3
Search speed *u*, km^2/ hour	9,7	9,8	9,9	9,7	10
The probability of detection of contamination, *P*	0,21	0,29	0,21	0,23	0,12

Placing it above the object at a height of 3 m above the ground is the most optimal because it affects only the action of the object as a screen. The coefficient value of shielding to consider will be much smaller than the attenuation coefficient. This will reduce the measurement error of the exposure dose of γ-radiation (table. 3).

To detect radioactive spots on large areas you can use aerial equipment, which have the appropriate equipment for conducting radiation reconnaissance. However, their use is not always advisable (expensive) and can be dangerous for the crew.

Table 3

Search results in different ways, when a detection unit is placed outside of reconnaissance vehicle at height of 3 m above the ground

Indicators	Search methods (reconnaissance)				
	Boustrophedon	Zigzag	Spiral	Rectangular piral	*star*
The length of the route, *L* , km	99	141	97	110	53
The surveyed area, *S*, km^2	25,7	36,7	25	28,6	14
Time, *t*, hours	2,5	3,5	2,4	2,75	1,3
Search speed *u*, km^2/ hour	10,3	10,5	10,4	10,4	10,8
The probability of detection of infection, *P*	0,23	0,31	0,22	0,25	0,13

The most appropriate option to obtain information about the exposure dose rate is the use of unmanned aerial vehicles (UAVs). Today experience of the use of UAVs for the purpose of conducting radiation reconnaissance is being developed in the world and in Ukraine [11-13].

In our view the UAVs, as a means of radiation reconnaissance, can be equipped of devices for measuring the exposure dose rate, determining coordinates of a measurement visualization with the relevant specifications, the ability to launch them manually (tab. 4).

Table 4

Approximate specifications of UAVs of radiation reconnaissance

Descriptions	Value
Measurement of γ-radiation at hight of	- aircraft type: 0÷500 m - helicopter type: 20÷500 m
Control	distance up to 20 km
Conduct of video surveillance	from the height of 20÷500 m at a distance of 20 km
Maximum takeoff weight	up to 5 kg
Weight of special equipment for measuring gamma radiation and sampling	to 1 -2 kg
Takeoff system	starting with his hands
Landing system	landing on a dirt surface
Control of UAVs rr	manual and automatic, according to the appropriate program

For efficient determination of radioactive contamination in different conditions, it is advisable to have UAVs (radiation reconnaissance) in two models of helicopter and airplane types.

A detection unit should provide power measuring range of amnt equivalent dose of x-ray and gamma radiation 0.01 μsv/h – 10 SV/h; the energy range of 0.05 ÷ 3 MeV; the basic error of measurement no more than ± 15 %; energy dependence of the sensitivity in the range of 15 to 60 Kev ± 35 %; energy dependence of the sensitivity in the range from 60 Kev to 3 MeV ± 20 %; sensitivity $^{137}_{55}Cs$ 70 imp/s at 1мкЗв/h; operating temperature range from -30 to 50 ° C; the speed of conducting radiation reconnaissance of the routes up to 90 km/h, the speed of conducting radiation reconnaissance of the areas up to 180 km^2/h.

The use of UAVs with given specifications of the search tasks of contaminated sites will be carried out more quickly and reduce the time on identification of the radiation environment in 2-2,5 times (tab. 5).

Table 5

Search results in different ways, when a detection unit is placed on UAVs and conduct of search of the site of radioactive contamination at height of 50 m

Indicators	Search methods (reconnaissance)				
	Boustrophedon	Zigzag	Spiral	Rectangular piral	*star*
The length of the route, *L* , km	99	141	97	110	53
The surveyed area, *S*, km^2	51,3	73	50,3	57	27,5
Time, *t*, hours	1,1	1,6	1,1	1,2	0,63
Search speed *u*, km^2/ hour	46,6	45,6	45,7	47,5	43,7
The probability of detection of contamination, *P*	0,4	0,52	0,39	0,43	0,24

Conclusions

1. Among the considered methods of search (reconnaissance) contaminated with radioactive materials sites the most effective method is the method of "zigzag" (29-52%). All other methods ("boustrophedon", "spiral") is generally not different from each other. According to calculations the method of " star survey technique " is ineffective (the probability of detection гз to 20%, depending on the height of placing of a detection unit). Increasing of probability of finding depends on the distance between the routes and their length, as well as the technical capabilities of radiation reconnaissance instruments.

2. The imposition of the detection unit outside of reconnaissance vehicle increases search efficiency, which depends on the technical capabilities of the detection units of the radiation reconnaissance instruments.

3. Use of aerial reconnaissance means greatly increases the efficiency of detecting of radiation environment through the placement of the detection unit at a much higher altitude of 3 m. The area of reconnaissance and speed of UAVs are increasing, but contaminated sites will not marked by warning signs.

4. For completion of the task of radiation reconnaissance it is essential to use air and ground radiation reconnaissance in complex, complementing one means with another.

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Дії підрозділів РХБ розвідки під час пошуку невеликих осередків радіоактивного зараження

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Проведено аналіз оптимальних шляхів пошуку невеликих ділянок радіоактивного зараження, так званих «мертвих» зон, які утворюються у випадку руйнування небезпечних об’єктів, що використовують, переробляють, зберігають і транспортують радіоактивні речовини під час ведення радіаційної розвідки підрозділами РХБ розвідки. Застосовано наступні методи наукового дослідження: бібліографічний, аналітичний, системного та інформаційного підходу. Розглянуто наступні способи пошуку (розвідки) заражених радіоактивними речовинами ділянок місцевості: «зигзаг», «паралельне галсирування», класична та прямокутна «спіраль» і «зірка». Визначено протяжність маршруту та встановлено оптимальні параметри їх проведення за визначених умов. Встановлено, що найефективнішим є спосіб «зигзаг» (29-52%), тоді як за розрахунками спосіб «зірка» є швидким, але малоефективним. Розраховано імовірність знаходження заражених ділянок місцевості залежно від висоти розміщення блока детектування та енергії γ-квантів радіоізотопів, які утворюються при руйнуванні ядерного реактора, підриві ядерного та термоядерного боєприпасів. Підвищення імовірності знаходження залежить від відстані між маршрутами, їх протяжності, а також технічних можливостей приладів радіаційної розвідки. Винесення блока детектування за межі розвідувальної машини збільшує ефективність пошуку, яка залежить від технічних можливостей блоків детектування приладів радіаційної розвідки. Показано, що використання засобів повітряної розвідки значно збільшує площу обстеження та підвищує оперативність

виявлення радіаційної обстановки за продуктивністю, оскільки блок детектування розміщується на суттєво більшій висоті, ніж 3 м. Однак заражені ділянки позначені на місцевості знаками огородження не будуть. Сформульовано вимоги до технічних характеристик безпілотних літальних апаратів радіаційної розвідки. Визначено, що для повного виконання завдання радіаційної розвідки необхідно використовувати засоби повітряної і наземної радіаційної розвідки комплексно, доповнюючи один засіб іншим.

***Ключові слова**: РХБ розвідка, радіоактивне зараження, способи РХ розвідки*

Действия подразделений РХБ разведки во время поиска небольших очагов радиоактивного заражения

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Проведен анализ оптимальных путей поиска небольших участков радиоактивного заражения, так называемых «мертвых» зон, образующихся в случае разрушения опасных объектов, которые используют, перерабатывают, хранят и транспортируют радиоактивные вещества при ведении радиационной разведки подразделениями РХБ разведки. Применены следующие методы научного исследования: библиографический, аналитический, системного и информационного подхода. Рассмотрены следующие способы поиска (разведки) зараженных радиоактивными веществами участков местности: «зигзаг», «параллельное галсирование», классическая и прямоугольная «спираль» и «звезда». Определены протяженность маршрута и установлены оптимальные параметры их проведения при определенных условиях. Установлено, что наиболее эффективным является способ «зигзаг» (29-52%), тогда как по расчетам способ «звезда» является быстрым, но малоэффективным. Рассчитана вероятность нахождения зараженных участков местности в зависимости от высоты размещения блока детектирования и энергии γ-квантов радиоизотопов, которые образуются при разрушении ядерного реактора, подрыве ядерного и термоядерного боеприпаса. Повышение вероятности нахождения зависит от расстояния между маршрутами, их протяженности, а также технических возможностей приборов радиационной разведки. Вынесение блока детектирования за пределы разведывательной машины увеличивает эффективность поиска, которая зависит от технических возможностей блоков детектирования приборов радиационной разведки. Показано, что использование средств воздушной разведки значительно увеличивает площадь обследования и повышает оперативность выявления радиационной обстановки по производительности, так как блок детектирования размещается на существенно большей высоте 3 м. Однако зараженные участки не будут обозначены на местности знаками ограждения. Сформулированы требования к техническим характеристикам беспилотных летательных аппаратов радиационной разведки. Определено, что для полного выполнения задания радиационной разведки необходимо использовать средства воздушной и наземной радиационной разведки комплексно, дополняя одно средство другим.

***Ключевые слова**: РХБ разведка, радиоактивное заражение, способы РХ разведки*