Increase in Efficiency of Use of Pedestrian Radiation Portal Monitors

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Abstract. Most international airports in the world use radiation portal monitors (RPM) for primary radiation control organization. During the exploitation pedestrian radiation portal monitors operators (in the Russian Federation it is a special subdivision of customs officials) have certain problems related to the search of an ionizing radiation source causing the alarm signal of a radiation monitor. Radiation portal monitors at standard (factory) settings have to find out the illegal moving of the radioisotopes moved by physical persons passing through a controlled zone and having a steady radiation by the gamma or neutron channel. The problem is that recently the number of the ownerships who underwent treatment or medical diagnostics with the use of radio pharmaceuticals considerably increased, i.e., ownerships represent such an ionizing radiation source. The operator of the radiation portal monitor has to define very quickly whether the ownership is a violator (takes unsolved radioisotopes illegally) or is just a patient of the clinic who underwent treatment/diagnostics with the use of radio pharmaceuticals. The research showing the radioisotopes which are most often used in the medical purposes are given in article, it is offered to use the new software developed by the authors allowing the operator of the radiation portal monitor to define the location of the ownership which has such ionizing radiation source by the activity of radiation similar to the radiation from radio pharmaceuticals.

1. Introduction

In 2014-2016 the officials of customs authorities (OCA) responsible for radiation control at aviation international check points (airports), revealed about 1700 cases of detection of the facts of conveyance of the natural persons who underwent treatment by radio pharmaceutical medicines and having the increased level of ionizing radiation. Definition of the natural person who underwent preliminary treatment (treatment) by radio pharmaceutical medicines causes certain difficulties. The main arising problem is an emergence of a large number of false alarm signals which arise at pass of the ownerships who don't have the raised background of the ionizing radiation (IR) through working space of the RPM. Such feature of work of the RPM is explained by increase in the common background radiation indoors where it is established. Radiation in turn is caused by the ownership, undergone treatment or diagnostics by radio pharmaceuticals.

In that case the RPM will give an alarm at each pass through working space (even if the ownership is not the ionizing radiation source (IRS)). On a result OCA have not solvable task: it is necessary to...
reveal the ownership having the increased level of IRS, but the ownership still did not pass through controlled space of the RPM, and the RPM was already given by several spurious signals of alarm on ownerships at whom IRS is absent. In practice such situation in the conditions of the actual check point can take away the considerable time from OCA. The situation is considerably aggravated if on the check point it is used a little nearby the standing pedestrian modifications of the RPM since the ownership who underwent diagnostics (treatment) by radio pharmaceuticals will affect on all available the RPM.

2. The main radioisotopes used in the medical purposes

Many experts in the Russian Federation and abroad note annual body height of intensity of use for diagnostics or treatment of radioactive medical supplies [1-5]. According to Federal State Statistics Service during 2013 in various medical institutions of the Russian Federation about 7.2 million medical procedures with use of various radionuclides were performed. This number was increased to 8.3 million in 2014. From total of procedures about 98% it is possible to carry to diagnostic procedures and 2% to therapeutic procedures. It should be noted that today in the Russian market of medical services it is possible to find more than 50 different types of the radio pharmaceuticals used in more than 100 various types of medical procedures. It is possible to carry 16 main which meet in the majority of the radio pharmaceuticals produced as in the territory of the Russian Federation, and imported from foreign countries to the most often used radioisotopes. From 16 main radioisotopes 9 are used only concerning ambulatories. The ownerships who underwent such medical diagnostics or treatment have an increased level of the ionizing radiation which can cause an alarm in any the RPM. The main radioisotopes causing an alarm in pedestrian modifications of the RPM are given in table 1.

| Radioisotope | Period half-decay | Radioisotope | Period half-decay |
|--------------|------------------|--------------|------------------|
| C-14         | 5730 years       | In-111       | 67.3 hours       |
| Co-57        | 271 days         | Rb-82m       | 6.47 hours       |
| Cr-51        | 27.7 days        | Sm-153       | 46.7 hours       |
| F-18         | 109 minutes      | Sr-89        | 50.6 days        |
| Ga-67        | 78.3 hours       | Tc-99m       | 6.01 hours       |
| I-123        | 13.2 hours       | Ti-201       | 73.1 hours       |
| I-125        | 60.1 days        | Xe-133       | 5.25 days        |
| I-131        | 8.04 days        | Y-90         | 64.1 hours       |

In 2015-2016 one of the most often defined radioisotopes the ownerships who underwent medical diagnostics with use of radio pharmaceuticals had a radioisotope - technetium (99mTc).
99mTc is used in medicine as a g-radiation source, the main radio pharmaceuticals carries the name “Rezoskan”.

The executed researches showed that clinics recommend to the patients after use of radio pharmaceuticals to be 5-6 days under observation of the doctor in out-patient conditions. The citizens, who underwent treatment/diagnostics by radio pharmaceuticals for the purpose of economy of tools for payment of the stay in clinic, are written out from it for 4-5 days before the recommended term that causes increase in a hum noise from the ownership and can exceed normative limits in tens of times [6,7]. Crossing by such person of controlled space of the RPM will cause very serious cases of alarm signals (excess over normative values can reach several hundred times).

For 2016 in the Far Eastern Federal District 279 cases of a call of alarms of the RPM from the raised hum noise proceeding from ownerships were revealed, it was also established that 269 of them were patients of foreign clinics and underwent treatment/diagnostics by radio pharmaceuticals.
In the figure 1 graphic representations of distribution of a dosage (size of II) from each revealed a radionuclide by OCA and a median number of a dosage as function of a radioisotope are given.

Figure 1. Graphical representation of distribution of a dosage (size of II) from medical radionuclides.

As a result of implementation of the analysis the 11 most often found radioisotopes concerning which further researches were carried out were defined.

All radioisotopes were distributed on groups which have the low power radiations, the average and the high power radiation. The total characteristic on power radiation for each studied radioisotope is shown in the figure 2. All radioisotopes in the figure 2 are distributed on probability of their detection at standard settings of the RPM (settings correspond to passport characteristics).

Figure 2. Power distribution of intensity of IR from medical radioisotopes.

Analyzing the figure 2 it is possible to note that the majority of medical radioisotopes have size of IR lower than 250 keV and, thus, under this energy levels have to be ready by the RPM. As radioisotopes of Cr-51, Ga-67 and I-131 have size of IR higher than 250 keV, they were carried to an average energy level (it should be noted that the high level of IR occurs at a radioisotope of I-131 that was carried to a high level of radiation).

Other feature noticed in the figure 2 is the revealed radiation lower than 25 keV on which the RPM was given an alarm signal.
For simplification of development of the procedure of reaction of OCA on ownerships who underwent treatment by radio pharmaceuticals, two most often found intervals of IR were defined: 1) 5-250 keV; 2) 25-250 keV.

3. **The algorithm of detection of the ownership having the increased level of IRS with use of the RPM**

Researches on development of the algorithm of actions of OCA at identification of the increased level of IR from ownerships were carried out in the conditions of actual check points. For control of ownerships at radiation control two modifications of the RPM consisting of one or two racks are used [8-11].

The experimental generalized scheme of the check point on which it is used one-rack-mount and two rack-mount systems of the RPM was made for descriptive reasons. The generalized experimental scheme is provided on the figure 3. On technology of radiation control ownerships have to pass through controlled space of the RPM only on one, but the trajectory of their movement is defined self-contained.

![Figure 3. The generalized experimental scheme: a – the use of one-rack-mount modification of the RPM; b – the use of two rack-mount modifications of the RPM.](image)

Model operation of various cases was carried out on the basis of several postulates: 1) the ownership underwent diagnostics/treatment only with use of one radionuclide; 2) the passenger underwent diagnostics/treatment only of one body (heart, a thyroid gland, etc.), i.e. only one source having dot character of radiation was assumed; 3) IRS belong on a degree of activity only to one of the groups shown in the figure 2; 4) RPM have standard modes of control of sensitivity (settings on the sensitivities of detectors recommended by manufacturer); 5) ownerships move only on one of trajectories shown in the figure 3; 6) OCA which are carrying out functions on radiation control follows - the established procedure.

The conducted researches in the conditions of concrete check points allowed to reveal zones in which ownerships settle down before pass through controlled space of the RPM. It should be noted that for one-rack-mount and two rack-mount modifications of the RPM the zone of preliminary detection of IRS has approximately identical values and equals 10-30 meters. The distance of detection is defined by activity of IRS, the IRS has larger activity, the more distance at which such source will cause an alarm on racks of the RPM.

It was established by practical consideration that for activity 5-250 keV the distance at which the source is concerning a rack equals 10-20 meters, for activity 25-250 keV - approximate distance of 15-20 meters, and for sources with activity more than 250 keV such distance will already equal 20-30 meters (in certain cases the distance can reach 50-70 meters). In the figure 4 the revealed zones of a presumable arrangement of the ownership who underwent treatment by radio pharmaceuticals are shown.

In the figure 4 the restriction zone is showed by dashed lines in which detectors gamma and neutron channel can record IR, coming from local, point sources of the studied activity. As shown in...
the figure 4 a, at one-rack-mount such zone is considerably reduced by the RPM that is bound to design features of execution of the RPM (in one-rack-mount modification only about one detector gamma and neutron filing is used). In the figure 4 b, the increased detecting zone for two rack-mount modifications of the RPM is shown (increase in a zone of detecting of IRS is explained by existence of two detectors gamma and neutron filing). It was experimentally also revealed that two rack-mount systems have firmware limiters (in the figure 4 two dashed lines characterizing operation of limiters are shown), limiters are executed in the form of the steel plates isolating gamma sources in particular sectors. Such arrangement of steel plates considerably simplifies the procedure of searching of the ownership undergoing treatment by radio pharmaceuticals and being in a zone before controlled space of the RPM.

Figure 4. The generalized experimental scheme: a – the use of one-rack-mount modification of the RPM; b – the use of two rack-mount modifications of the RPM.

During multiple tests the main probability zones in which there can be ownerships who underwent treatment by radio pharmaceuticals were revealed by practical consideration:
- The zone A is characteristic of sources with activity not higher than 5 keV;
- The zone B is characteristic of sources with activity within 5-250 keV;
- The zone C is characteristic of sources with activity within 25-250 keV;
- The zone D is characteristic of sources with activity more than 250 keV.

Using statistical information on the medicines which are most often used for diagnostics/treatment by radio pharmaceuticals, activities for each of them that allowed to develop the new algorithm of the software allowing OCA in the shortest possible time to locate finding of the ownership, being IRS were revealed [5, 12].

The offered algorithm will allow OCA to survey only those areas (Zone A-D) in which presumably there are III that considerably will allow to reduce time of searching of a source and to reduce negative reaction of the ownerships to DLTO who are carrying out it to inspection without systemic search in all halls of arrival/departure of ownerships.

4. Conclusion
1. Using statistical information on the medicines which are most often used for diagnostics/treatment by radio pharmaceuticals, activities were revealed (ability to radiate ionizing radiation) for each of medicines that allowed to develop the new algorithm of the specialized software allowing OCA in the shortest possible time to locate finding of the ownership which are an ionizing radiation source.
2. Within the executed researches the main radionuclides used for diagnostics/treatment as in foreign and Russian medical institutions were revealed. Co-57; Cr-51; Ga-67; I-123; I-131; In-111; Sm-153; Tc-99m and Tl-201 are belong to the main radionuclides. It was established that medical radioisotopes have to be easily found with use of the RPM after the term of the medical procedure in a time term of 3-115 days, depending on a radioisotope half-life [13-15]. If during radiation control at the ownership who showed the certificate of passing of the procedure of diagnostics/treatment the
radionuclide disharmonious to the established list of radio pharmaceuticals will be revealed, then for OCA responsible for radiation control, algorithms of actions are developed for establishment of the reason of discrepancy (legal or illegal movement of IRS through customs border).

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