Use of Portal Monitors for Detection of Technogenic Radioactive Sources in Scrap Metal

D B Solovev\textsuperscript{1,2}, A E Merkusheva\textsuperscript{2}

\textsuperscript{1}Training center, Vladivostok Branch of Russian Customs Academy, 16, Strelkovaya St., Vladivostok 690034, Russia
\textsuperscript{2}Department of Innovatics, Far Eastern Federal University, 8, Sukhanov St., Vladivostok 690950, Russia

E-mail: solovev.db@dvfu.ru

Abstract. The article considers the features of organization of scrap-metal primary radiation control on the specialized enterprises engaging in its deep processing and storage at using by primary technical equipment - radiation portal monitors. The issue of this direction relevance, validity of radiation control implementation with the use of radiation portal monitors, physical and organizational bases of radiation control are considered in detail. The emphasis is put on the considerable increase in the number of technogenic radioactive sources detected in scrap-metal that results in the entering into exploitation of radioactive metallic structures as different building wares. One of reasons of such increase of the number of technogenic radioactive sources getting for processing with scrap-metal is the absence of any recommendations on the radiation portal monitors exploitation. The practical division of the article offers to recommendation on tuning of the modes of work of radiation portal monitors depending on influence the weather factor thus allowing to considerably increase the percent of technogenic radioactive sources detection.

1. Introduction

Processed scrap-metal is growingly used in the modern production of steel and products of construction assignment (pipes for the gasket of main pipelines, metallic constructions for finishing of facades of and etc.). In 2016 universal use of scrap metal made 540 million tons \cite{1,2}. Last years on dumps and on productive areas metallurgical complexes cases of finding out technogenic radioactive sources getting in a scrap-metal as a result of accidents or careless appeal became more frequent. So about 350 000 cases of maintenance in scrap-metal of technogenic radioactive materials of different origin were registered in the world in 2015\cite{3,4}. Some of them were not found out in time and acted on a meltback or trimming and thus got in a metallic stream. In the Russian Federation cases of detection of the technogenic local and distributed radioactive sources in the metal constructions intended for use as construction materials at construction of large federal objects are regularly fixed \cite{3,5,6}.

It is possible to consider several last examples of identification of such cases on buildings of federal importance: in 2010 the train with freight in the form of metal pipes arrived from St. Petersburg to Vladivostok, with a diameter of 400 mm, intended for laying of the pipeline of a campus under construction of Far Eastern Federal University on Russky Island, ionizing radiation represented...
distributed nature about excess of a background radiation more than 20 times [7,8]; in 2012 metallic buttons of elevators made the French company Otis were found out having an enhanceable level of the ionizing radiation caused by a presence in the alloy of radioactive cobalt-60 (Co-60) [7]; in 2014 on the building of five-stars hotel in the city of Vladivostok the metal designs intended for external facing of the building, having the increased level of the ionizing radiation, containing radioactive Co-60 in alloy were revealed and set of other cases [7].

The origin of the radioactive sources getting to the processed scrap metal stream very often remains to unknowns. In the last several years the significant increase in number of uncontrolled radioactive sources was noted [1-4,8].

Dangerous radioactive materials can be in a scrap-metal in three forms: as component part of metal, as the surface pollution of metal or as the pressurized radioactivity source. The greatest health hazard of workers and the public, and also the greatest economic consequences for metallurgical industry result from casual melting of the pressurized radioactivity sources. This category of sources creates the greatest danger as the pressurized sources may contain components with rather high level of radioactivity, also the radionuclides capable to disappear from a melt.

2. International rules of radiation control at processing of scrap-metal

More than 12 years the International Atomic Energy Agency (IAEA) developed recommendations for realization of radiation control during the work with scrap metal [9]. In 2004 the fundamental international document was developed: IAEA-TECDOC-1388 “Strengthening control over radioactive sources in authorized use and regaining control over orphan sources: National strategies” [10] according to which, all developed countries (having capacities for production of the ionizing radiation sources (IRS)), have to develop characteristic state systems of the account, monitoring and physical protection of nuclear materials and radioactive substances.

In the Russian Federation a number of the documents relevant to recommendations of IAEA-TECDOC was developed, such documents have character the leading documents [11-17]. According to these documents in the organizations and at the enterprises occupied with preparation, processing, including meltback and realization of scrap metal routine radiation control has to be exercised.

3. Basic problems, educed during exploitation of the technical equipments applied for primary radiation control of scrap-metal

Productive radiation control of scrap-metal is conducted in two stages: entrance radiation control, which is exposed to all incoming scrap and control of the party of scrap-metal prepared for realization by results of which on it the sanitary and epidemiologic conclusion is made out is exposed. In the latter case the control is carried out by the laboratories of radiation control accredited in accordance with the established procedure. The main way of exercise of entrance radiation control at the enterprises occupied with preparation, processing, including meltback and realization of scrap metal routine radiation control has to be exercised.

According to interregional territorial administrations on supervision of nuclear and radiation safety for 2016 only under supervision in all territory of the Russian Federation there were more than 800 organizations and the enterprises occupied with preparation, processing, and scrap metal realization. Primary radiation monitoring at such enterprises is provided by exploitation about 1500 various express modifications of the stationary RPM. In most cases at the enterprises are used moto-car or railway RPM [18,19].

During exploitation moto-cara and railway RPM, the main problems were revealed which essence consists in need quickly to find in weight uncertain on structure, physical characteristics and geometry of material rather weak sources of all types of the unknown chemical and nuclide composition ionizing radiations.
Researches was executed at Far Eastern Federal University have shown that the main cause of contact IRS to be melted together with a “clean” scrap is not the response of RPM to move the post through a controlled space in adverse weather conditions - strong atmospheric precipitation (heavy rain or snow).

It is obvious that the RPM was developed to work in the background and to trap the indications exceeding the certain thresholds established earlier by the operator of the RPM depending on the concrete place of exploitation. During heavy atmospheric phenomena (a heavy rain, snow) the background level of natural radiation can increase considerably. At the same time the operators exploiting the RPM have no instructions for change of parameters (work constants) of the RPM (in respect of kickdown of their sensitivity). All this leads to growth of number of false alarms from the RPM and to increase in probability not of detection of IRS (especially screened IRS).

4. Description of educational-research ground
The educational-research ground consists of combination of two consistently located modifications of RPM (railway and motor-car modification). Investigated RPM are located so that allow through the controlled space to skip both automobile and freight motor transport. The scheme and the photo of a relative positioning of the RPM are provided on figure 1.

![Figure 1. The scheme of the educational and research ground: a – the relative positioning of racks motor-car and railway RPM (top view); b – photo of the educational and research ground (view from the party of arrival of motor transport).](image)

The direct proximity of the arrangement of motor-car and railway modifications of the RPM allows to create the studied space which is designated in figure 1 (a) by the shaded grey area. According to the classical theory of detecting, IRS which is in this zone has to cause an alarm signal at least in one of two RPM [19-21].

5. Research of influence of atmospheric phenomena on exploitation of the stationary systems of radiation control (radiation portal monitors)
Parameters of the minimum ionizing radiation which, at factory settings of thresholds of detection, motor-car and railway modifications of the RPM have to find without fail are specified in technical documentation [19] (to give an alarm signal). In table 1 examples of thresholds of detection of technogenic radioactive sources in scrap metal for moto-car and railway modifications of the RPM are
given. Factory recommendations about the adjusted operation thresholds are provided in table 2, thresholds are fair for any modifications of the RPM.

The operation thresholds presented in table 2 are set as the size of excess over background level. At the same time the coefficient L gets out of a number of values 4, 6, 8, 10 and influences characteristics of system: the lower it value, the is more sensitivity, but at the same time the number of false operations increases. Sensitivity and the number of false operations are normalized at \( L=4 \). For convenience of an assessment of level of excess at operation of system three thresholds, separately for neutron and gamma ports are set. At production systems are installed values of thresholds according to table 2.

### Table 1. Thresholds of detection of technogenic radioactive sources in scrap metal for various modifications of the RPM.

| The name of the sharing and radioactive materials | Modifications of RPM |
|-----------------------------------------------|----------------------|
| Cs-137 | Motor-car RPM | Railway RPM |
| 300 kBq | 900 kBq |
| Co-60 | 150 kBq | 450 kBq |

### Table 2. Installed values of thresholds.

| Thresholds, (x10) | Gamma channel | Neutron channel |
|------------------|---------------|-----------------|
| 40 60 80 | 80 90 100 |

During realization of the experimental measuring thresholds on motor-car and railway modifications of the RPM were exposed according to table 2. All information on background values on the gamma and neutron channel proceeding from both RPM was analysed with use of the server of acquisition (the automated workplace of the operator).

Each point shown on the subsequent schedules has a statistical weight more than 10 times of repetition (i.e. information was entered in the database of background indications if the system showed similar result not less 10th time in a row). After realization of the experimental part which was conducted for calendar year (January-December, 2016) information was processed with use of the specialized software intended for processing of statistical sequences of data.

At the first stage of the pilot studies experiments were made in the conditions of lack of an atmospheric precipitation. As the studied IRS were used: Cs-137 (activity of 1,5 MBq), Co-60 (activity of 1,0 MBq). Each source moved along controlled space with an identical speed on a direct trajectory. A number of experiments was conducted, the speed of movement of an ionizing radiation source changed from 5 km/h to 25 km/h. Such speed corresponds to the passport recommendations provided in the section of the recommendation about exploitation of the RPM. Sources moved on a trajectory along a controlled zone with a step of an interval of 50 cm, to fig. 2 and, movement trajectories are given in the horizontal plane.

For detection of an ionizing radiation source important parameter is the vertical location of a source since the probability of detection will increase or decrease depending on the provision of a source of rather efficient center of the detectors which are in the RPM [19]. In fig. 2, movement trajectories are given in the vertical plane. Due to the technological features of carrying out experiments, researches were conducted only concerning four distances from earth level (0,5 meters; 1 meter; 1,5 meters and 2 meters).

In the process of experimental researches the different brands of vehicles were used, IRS wer without a screening bioshield, a source took place into a car by his fastening to the basket of vehicle. A car drove through the investigated space so that IRS moved directionally 1-5 (see a fig. 2). Speed of moving of vehicle was determined 5-25 km/h. On the first stage of experimental researches (absence of atmospheric phenomena) any moving of source, on the described trajectories, caused stable evocation of alarming, both at motor-car and at railway modification of RPM.
Figure 2. Trajectories of movement of IRS in working space of the RPM: a - the movement of a source in the horizontal plane; b - the movement of a source in the vertical plane

On the second stage of experimental researches (heavy atmospheric phenomena) of condition of moving of source of ionizing radiation through the investigated space saved in an absolute identity with the terms of realization of the first stage.

At plentiful precipitations, both in the form of a rain, and in the form of snow (at thresholds of detection of IRS corresponding to factory recommendations, see table 2), the movement of an ionizing radiation source on a trajectory No. 3 (see fig. 2 and) did not cause an alarm at motor-car the RPM in 90% of cases, and in railway modification in 70% cases. In turn, movement of an ionizing radiation source on trajectories No. 1 and No. 5 caused a steady alarm by investigated RPM in independence of a form of precipitations.

The result received when moving sources on trajectories No. 2 and No. 4 is ambiguous; it is possible to note that with increase in speed of movement of a source through controlled space the probability of emergence of an alarm in both modifications considerably decreases. The factor of height on which the ionizing radiation source moved is important. Such result is proved by rather long distance of removal of the moved ionizing radiation source from the closest rack of the RPM (the distance in the described case made about 2 meters). Results of data interpretation are given in figure 3 (a - the trajectory of driving No. 4; b - the trajectory of driving No. 2).

Figure 3. Results of experimental research of moving of source of ionizing radiation on trajectories, remote from the monitor of the RPM on distance of 2 meters from the leader or the conducted rack: a - the trajectory of driving No. 4; b - the trajectory of driving No. 2.
The conducted experiment allowed to execute the analysis of intercommunication of probability of finding out IRS from speed of moving of the controlled object. For a change and quantitative expression of intercommunication between the phenomena distinguish the types of conformities to law and corresponding to them types of connection. There are two types of connections: dynamic and statistical, and the corresponding to them intercommunications (complete and incomplete) related to functional and stochastic to the types of connections.

Special case of stochastic communication is correlative communication at which not one corresponds to each value of an argument, and several values of function, at the same time between an argument and function it is impossible to establish resistant dependence.

Correlative dependence is shown only in average sizes and expresses a tendency to increase or decrease of value of one variable at increase or decrease another.

Correlative communication is the communication characterizing interdependence of two random values of X and Y. At the same time change of a productive sign (Y) is caused by influence of factor – (X) not wholly, and only partially since influence of other factors is possible.

6. Conclusion
The executed researches clearly demonstrate influence of a plentiful atmospheric precipitation on work of motor-car and railway modification of the RPM. It should be noted the fact that the exploitation of the RPM with the thresholds recommended for installation by firm-producer, does not correspond to the technology of radiation monitoring of technogenic radioactive sources in scrap metal accepted in separately the taken enterprises for scrap metal processing. Such exploitation of the RPM considerably increases probability of transportation of technogenic radioactive sources in scrap metal through controlled space of the RPM without alarm.

As the recommendation increasing probability of detection of movement of technogenic radioactive sources it is possible to express opinion that at a plentiful atmospheric precipitation the operators operating the RPM without fail have to lower thresholds of detection of radioactive sources.

The executed experimental researches showed that if to put the thresholds of discovery equal twenty (there is a channel on all), motor-car and railway modifications of RPM gives out the stable alarming at moving of technogenic radioactive sources on any of the trajectories presented on figure 2.

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