RAD Conference Proceedings, vol. 2, pp. 75–79, 2017
www.rad-proceedings.org

OCCUPATIONAL SAFETY OF FIREFIGHTERS IN RADIOLOGICAL EMERGENCIES — ISSUES IN HUNGARY

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Abstract. *Radiological emergencies (RE) are those emergencies which involve radioactive material that is not nuclear but emits ionizing radiation (IR). Although such sources are usually kept and transported shielded and closed, their shielding or packing can be damaged in case of an accident or fire. If the source becomes unshielded or opened, the environmental exposure can increase or even radioactive contamination can occur. Depending on the type and dose, IRs can cause morbidity or even mortality; meanwhile, they can only be detected with special instruments but not our senses. That is why first responders are the most endangered in RE and their radiation protection is the imperative. Thus, even at the initial stage of the intervention, the incident commander (IC) has to tackle several urgent tasks and a huge responsibility on the occupational safety of the interveners. Therefore, beside the technical support, training and education are also essential in the appropriate handling of risks. The paper introduces some issues of this special field and presents a start-up Hungarian research.*

Key words: *Decision-making, education, firefighter, intervention, ionizing, occupational radiation safety, personal dosimeter, radiation protection, radiological emergency*

DOI: 10.21175/RadProc.2017.16

1. Introduction

In Hungary, in the last few years REs have been put less emphasis on than other (classic chemical) industrial emergencies. Nowadays, with the ongoing extension project of the nuclear power plant of Paks, radiation protection and preparation for prevention of nuclear accidents are getting into the focus. Meanwhile, it is necessary to examine the daily practicable knowledge and preparedness on radiation protection of the firefighters to be appropriate and effective. For this reason, a wide and deep cooperative research on Hungarian firefighters' radiation protection has been started last year. Authors have just started to collect and systemize information on national and international radiation protection practice to study the possibilities of development of the technical and educational preparedness.

The aim of the paper is to introduce some issues of occupational safety of Hungarian firefighters in radiological emergencies.

Those emergencies in which some radioactive material but not nuclear material, hence it is not able to have a self-sustaining chain reaction, presents are called REs. Emergency, particularly fire or accident, which is related to the usage or transportation of industrial or medical radioactive sources. Additionally, malicious threats/acts and emergencies related to uncontrolled (abandoned, lost, stolen or found) sources are also REs [1].

Depending on their type and dose, IRs can cause morbidity or even mortality [2]; therefore, radiation protection of the responders is extremely important during the intervention. An effective firefighter intervention includes a parallel performance of professional actions with the point of wealth- and life-saving, extinguishing the fire and eliminating the potential danger. These operations are based on well-practiced protocols which are regulated by laws and organization codes [3]-[5]. Nevertheless, the variability of scenes and types of dangers can modify or even block these. In a RE, in terms of occupational safety, the operations may be limited spatially, temporally, in manpower or in other way because of the special situation.

Thus, even at the initial stage of the intervention, the IC has to tackle with several urgent tasks and a huge responsibility on the occupational radiation protection of the interveners. In Hungary, the rights and liabilities of the ICs are determined by the law [3]-[5], and optimally he has appropriate information to make decisions. The IC is an experienced officer firefighter who is actually the party at fault on his own.

In terms of the firefighting and saving IC takes action for the professional application of the available tools and resources; determines the type and class of the protective equipment for even a person or for the

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crew; makes tactical decisions on the tasks and their order; specifies the extinguisher material, the method and the most safety or less unhealthy working conditions. For the sake of fulfilling his responsibilities IC has many rights and possibilities; e.g. limiting someone's fundamental rights, cordoning areas, effecting entrances, requesting for the help of co-organizations or citizens, etc.

The examined situation can be highly dangerous since there is no exact preliminary information on the hazard, only its type is identified, but the detailed reconnaissance can be carried out just on the spot. Moreover, in Hungary, personal dosimeters (PD) are not involved in the basic personal protective equipment of the firefighters, which makes the determination of the exposure more difficult.

2. Materials and Methods

The most commonly used isotopes in research or industrial and medical field are the followings: sodium-24 (β), cobalt-60 (γ), selenium-75 (β), iodine-131 (β), caesium-137 (γ), iridium-192 (β-γ), plutonium(beryllium)-239 (γ-n°), americium-241 (α-γ), americium(beryllium)-241 (γ-n°) [6]. Although such isotopes are usually kept and transported closed, their shielding or packing can be damaged in case of an accident or fire. So in an institution or transportation incident, the radioactive material may become unshielded or even spilled.

As it is signed in brackets, in an emergency related to these sources, first responders can meet alpha, beta, gamma and/or neutron radiation. It is known that these are IRs with different features and their harmfulness for the human body can be described with different parameters. Regarding the sources, the essential information is which isotope is of which element, what kind of radiation is emitted and how much is its activity in Bq (decay/sec). Regarding the effect of radiation, the absorbed dose and effective dose are useful terms. Former is a physical quantity, which gives the absorbed energy per mass unit; its dimension is Gray (Gy). The effective dose is the biological dose with dimension Sievert (Sv) and comes from the absorbed dose considering the different sensitivity of the tissues and the different biological effectiveness of the types of radiations. In Hungary, the ionizing exposure level from the natural background is 2.4 mSv per year and with man-made sources total background is about 3 mSv/y [6], [7]. In practice it has a high importance of dose rate which is the absorbed dose per time (Gy/h). Measuring the dose rate, the maximum in-staying time can be calculated for firefighters inside a danger zone.

Anyhow, a fire incident does not differ significantly in regard to whether a radioactive source is present or not; at least in that sense, it does not have any influence on the spreading and other features of the burning. The main difference will appear in the methodology in order to prevent the unnecessary and extreme exposure of the responders.

The point of the radiation protection is always to avoid the deterministic effects and to decrease the possibility of stochastic effects. Latter are long term ones and they are mainly genetic and carcinogenic effects; at lower dose exposures that are not exceed the deterministic threshold limit (100 mSv) and the probability of their occurrence is increasing with the dose but not their severity. Deterministic effects are actually equal to the symptoms of acute radiation syndrome (ARS). ARS does not appear below a threshold limit and above that the severity of the symptoms is increasing with the dose [2], [6], [7]. Although radioactivity is the natural part of our normal life and most of our fears are unfounded, it is important to point out that the dose is a critical quantity and high dose exposures can cause ARS or even death. As it is known, typically below a 200-500 mSv whole-body absorbed dose, there are no notable symptoms whereas, at around 1000-2000 mSv, common mild symptoms occur with some latent period. The so-called half-lethal dose ($LD_{50/60}$) is 3000 mSv and the lethal dose is about 6000 mSv (without medical care) [2]. So in a RE, the monitoring of personal dose is crucial, and the application of radiation protection regulations, namely justification, optimization and limitation, is highly needed [1], [6], [7], [8].

First is the justification, which means that the advantages must outweigh the disadvantages during the intervention. Disadvantages can be definitely reduced with keeping the radiation dose limits. In Hungary, these are 50 mSv for general interventions, 100 mSv for some special cases and 250 mSv for life-saving, respectively [8]-[9]. If the dose is unknown because of either no PDs or no measured data from the area, then it is the task of the IC to weigh risks and benefits. It must be taken into consideration among others whether life-saving is needed, the escalation of the emergency is expected or what financial loss and environmental damage can be caused by the cancellation or delay of the intervention [10]-[11].

For the risk assessment, gathering information is fundamental so the reconnaissance should cover the followings: what kind of isotope it is and how high its activity is, whether the package is damaged, and what the possibility of opening or spilling is. Without measured data, dose-estimation can be carried out with the calculation if the type, activity and location of the radionuclide are known. For instance, in the case of a transportation accident, the type and activity are marked on the label. However, it is not obvious that on a vehicle, which is on fire, the label will be readable or technician and documentation for identifying the source are available. In this case, if the decision of the IC is that some operation is necessary despite the unidentified radiation, then principle ALARA (As Low as Reasonably Achievable) should be kept by all means [1], [8].

This can be realized in practice in three main ways: reducing the time spent in exposure, increasing the distance from the source and applying shielding if it is feasible [8]. Besides this, it is suggested to register the in-staying time of the responders since this can be helpful in the afterward dose-estimation if then later measured data are available [9]. It is a cardinal requirement that IC has a sufficiently wide, deep and practical knowledge in the field of radiation protection.

Evidently, optimally it would also be a main precondition to have appropriate information on radiation levels at the scene of the incident. In Hungary, basic firefighter units are not equipped with any instruments or devices that are able to even detect radiation. Hungarian Disaster Management has special rapid units (be alarmed and react in 120 sec), namely Mobile Laboratory (ML) which can be alarmed for radiological, biological and chemical emergencies. It is a CBRN (Chemical, Biological, Radiological and Nuclear) unit supplied with special staff and instruments for such special emergencies. These are in service in each county of Hungary and, in some counties, there are additionally more special units, namely Radiological Units – RU [5], [9]. In a RE, they instrumentally explore the radiation situation and, depending on the measured data, they determine the safety perimeter (100 μGy/h) and the security perimeter (20 μGy/h), they calculate the in-staying time, search the source and gather data regarding its opening or spilling [1], [5], [9]. As it can be seen, if the ML/RU cannot support the IC at the initial stage of the intervention with these essential information, it is really hard to make decisions for him. He must suppose the worst case while he verifies the opposite. He must have a comprehensive view over the general firefighter routines and adopt further variables to his decision-making procedure [10]-[11].

Obviously, in a RE, PD would have a key role in occupational radiation protection. However, in Hungary, it is not the part of the firefighters' basic personal protective equipment but the ML/RU has a set for the crew. It means 3 pieces of SOR/T (Mirion Technologies, USA) PD (see in Fig.1.) for three persons in a daily duty of ML/RU.

This is a tactical electronic operative personal dosimeter, which is basically developed for the military. It provides a stable, accurate dose measurement for soldiers, first responders, and anyone needing lightweight, easily configurable radiation monitoring. Its design is ideal for battlefield operations since it is light and small, water-, dust and shockproof. Additionally, it can be read and configured through clothing layers; moreover, it has a backlit LCD display and alarm option. There is a scintillation gamma and neutron detector in it, so it is able to measure the dose or dose rate from these radiations [12].

Figure 1. SOR/T personal dosimeter [12]

Notwithstanding, in a RE the mentioned amount is apparently not sufficient for the whole time of operations for all of the rescue team, only for reconnaissance.

3. Results

An ADR (Accord européen relatif au transport international des marchandises Dangereuses par Route) vehicle which has a ^{137}Cs closed and shielded source as shipment is considered. A road accident happens in which the vehicle, the driver and the package are all damaged. The vehicle is on fire, the driver is unconscious and the radioactive material may be released. A bystander calls 112, but there is no information on any labels about dangerous goods. So first responders only have information about the fire, a vehicle and a trapped, injured person, but nothing about the hazardous conditions. In this case, it is the preparedness, awareness and precision (or maybe the experience) of the IC that will determine the reconnaissance as it should include the presence of any danger labels on the vehicle [10]-[11].

The next question is what the procedure is, whether the IC has information on the presence of radioactive material and whether life-saving is necessary, but there is definitely no measured data about radiation levels. According to an internal regulator, they must keep 300 metres of distance from the suspected source in this case, but it would obviously make the reconnaissance and the intervention impossible [1].

In the example, a Yellow-III shipment is damaged. Inside the package, which is a cube with 1-metre edges, there is a ^{137}Cs isotope with 175.4 GBq activity in a cube with edges of 10 cm, with a 4 cm thick lead shielding around inside and polystyrene foam filling outside. Outside of the shielding, the activity is only 2.63 GBq. Hence, the dose rate is 1038 μGy/h on the surface (519 μGy/h at vertex), 100 μGy/h at 1 metre from the surface, so TI=10 (Transport Index, given for transporting of dangerous goods, defined as the maximum radiation level in mSv/h at 1 m from the surface of the package, multiplied by 100), and 20 μGy/h at 2.8 m from the surface. Therefore, if the source remains closed, the dose rate at 1 m from the package is 100 μGy/h and interveners have about 500 hours to work without exceeding the 50 mSv dose. If it is necessary to get closer, they still have at least 48 hours to perform the tasks of invention. In contrast, if the shielding is damaged and the source is opened and unshielded, then the dose rate at 1 m from the source is 14 mGy/h, which allows only 3.5 hours for the invention. In addition, if the source must be neared within 10 cm for some technical reason for the sake of saving, that means operations must be carried out in an area with exposure level of 1.4 Gy/h and the firefighters would have only 2 minutes left for work at that place. Certainly, as in the case of life-saving the maximum dose is five times higher (250 mSv) according to the guidelines, the in-staying times above are five times bigger as well. Meanwhile, if the possibility of spilling of the radioactive material or contamination of responders emerges, it can be very dangerous because of the drastic decreasing of the distance between the radioactive material and the body. Depending on the ratio of the spilled material, the effective dose can be lethal during even a very short period – e.g. if 10 percent of the material has spread uniformly then, calculating with the distance of the source 1 cm from the body considering the thickness of the protective clothing, the firefighter is exposed to the lethal effective dose of 7 Sv in half an hour.

It can be seen that the radiological exploration and the instrumental measurement of the scene of a RE have capital importance in planning and realizing the intervention. Without these, it is contraindicated to even start life-saving. As it can be established, based on the above mentioned, the intervention in the presence of a radioactive source even raises occupational-ethical and moral questions. According to Hungarian laws, interveners can work in a RE only voluntarily and only if their dose is registered [8]. Meanwhile, members of the professional disaster management service must serve the safety of the wealth and life of the civil population even taking risks on their own life and physical safety [3]. At the same time, it is worth to highlight the expression 'taking risks'. It must be seen clearly that in some cases entering a spot of RE cannot be considered as simply risk-taking. For example, to enter a gas tank in a house that is on fire can be called risk-taking since depending on the conditions and the intervention, if a firefighter is quick, smart and lucky enough, he may get safely away without exploding. In contrast, in a RE when a source is unshielded and spilled, exposure levels can be so high that surely leads to serious ARS, so it is not risk-taking rather a potential suicide [13].

4. Conclusions

REs hardly ever happen, but their consequences can be serious. This could be because of late identifying of the radiation presence, missing personal protective equipment or underestimation of the hazard. However, the overestimation can be just as dangerous. So, to handle this issue properly, it is required to gain adequate knowledge.

Working out of the problem sketched above is impossible here because of the large number of variables but, by giving some part-answers and guidelines, interventions can be safer. Knowing the special danger, working out potential procedures and education of the interveners can be achieved with a complex and detailed methodological guidance, which must be implanted to education at the Disaster Management.

Another good question is the cooperation with co-organizations since REs cannot be solved without this. In the case of RE, evacuation, closures, informing the population and involving the co-organizations have also special importance – these are the tasks of the Civil Defence department within the Disaster Management (DM) organization.

Nevertheless, firefighters are still the very first responders so they must be prepared for reconnaissance and quick-reaction. The IC should not be passive even until ML arrives, especially when life-saving is needed, but intervention may be more than risk-taking in the absence of PDs.

The main consequence is that it is well-founded to supply the staff with PDs, even though REs rarely happen.

Moreover, the exact classification of the incident is crucial which helps to alarm the appropriate power and to be cautious at the initial stage of the intervention.

Finally, it is a precondition to work out and manage a multilevel, practice-oriented education system within the organization of DM for the ICs and the intervener firefighters.

Acknowledgement: *The work was created in commission of the National University of Public Service under the priority project KÖFOP-2.1.2-VEKOP-15-2016-00001 titled "Public Service Development Establishing Good Governance" in Győző Concha Doctoral Program.*

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