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FIREFIGHTER INTERVENTION IN RADIOLOGICAL EMERGENCIES

Abstract: Radiological emergencies (RE) are those emergencies which involve radioactive material that is not nuclear but emits ionizing radiation. Although such sources are usually kept and transported closed, their shielding or packing can be damaged in case of accident or fire. If the source becomes unshielded environmental exposure can increase or even radioactive contamination can occur. Depending on type and dose ionizing radiations can cause morbidity or even mortality, meanwhile they only can be detected with special instruments but not our senses. That is why first responders are the most endangered in a RE and their radiation protection is imperative. Thus, even at the initial stage of the intervention, the incident commander (IC) has to tackle with several urgent tasks and a huge responsibility. Alarm level classification and on-spot reconnaissance take on a crucial role here. The paper provides help to clarify hazards and make decisions on taking the risks.

Key words: radiological emergency, ionizing, radiation, protection, decision-making

ВАТРОГАСНА ИНТЕРВЕНЦИЈА ПРИ РАДИОЛОШКИМ ОПАСНОСТИМА

Резиме: Инцидент се сматра радиолошким догађајем када није нуклеарни догађај, али материјал емитује јонизовано зрачење. Такви извори се обично чувају и транспортују затворено, међутим несреће или пожари се ипак могу десити, приликом паковања се могу десити оштећења, при тим оштечењима паковање ће бити отвореног типа, чиме се значајно повечава изложеност животне средине или чак и могућност просипања материје. Изложеност јонизујућем зрачењу може имати штетне последице по здравље, што зависи од врсте и дозе. У екстремним случајевима може да проузокује и смрт. Људским чулима га не можемо детектовати, једино инструментима. Зато су ватрогасци који први дејствују у највећој мери изложени опасности и морају имати заштиту од радијације. Вођа ватрогасаца од самог почетка интервенције има огромну одговорност и бројне задатке. Кључну улогу има одређивање нивоа опасности и осматрање места пожара. Овај рад помаже да се разјасне ризици и лакше доносе одлуке о преузимању тих ризика.

Кључне речи: радиолошка опасност, јонизација, радијација, заштита, одлучивање

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1. INTRODUCTION

In fact, effective firefighter intervention includes parallel performance of professional actions with the point of wealth- and live-saving, extinguishing the fire and eliminating the potential danger [1]. These operations are based on well-practiced protocols which are regulated by laws and organization codes. Nevertheless, the variability of scenes and types of dangers can modify or even block these [11].

The main aim of the paper is to examine the hazards of the intervention in the presence of radioactive source [9].

Hungarian law[3] make difference between the expressions 'nuclear' and 'radioactive' material hence REs can be separated from nuclear accidents. REs are those emergencies which IR presents without any nuclear materials that are able to have a self-sustaining chain reaction. Particularly such as, fire or accident related to industrial or medical radioactive sources in institution or during transportation, malicious threats/acts and emergencies related to uncontrolled (abandoned, lost, stolen or found) sources [6].

Since depending on their type and dose IRs can cause morbidity or even mortality, radiation protection of the responders is extremely important during the live- and wealth-saving. In terms of this the operations may be limited spatially, temporally, in manpower or in other way.

2. DRAFTING THE PROBLEM

REs hardly ever happen but then their consequences can be serious. This could be because of late identifying of the radiation, missing personal protective equipment or underestimation of the hazard.

We consider unshielded sources because although such isotopes are usually kept and transported closed their shielding or packing can be damaged in case of accident or fire. So they become unshielded or even can spilled and the IC must suppose the worst while he verifies the opposite.

Optimally, the IC has appropriate information to make decisions on occupational safety [10]. The examined situation is highly dangerous since there is no exact information on the hazard only its type is identified but detailed reconnaissance can be carried out just on the spot. In Hungary, the rights and liabilities of the IC are determined by law. In the case of RE, evacuation, closures, informing the population and involving the co-organizations have special importance.

In Hungary, Disaster Management has a special unit namely a Mobile Laboratory (ML) which can be alarmed for radiological, biological and chemical emergencies. It is a CBRN (Chemical, Biological, Radiological and Nuclear) unit equipped with special staff and instruments for such special emergencies [8]. In a RE they explore the radiation situation, depending on the measured data they determine the safety perimeter (100 μGy/h) and the security perimeter (20 μGy/h), they calculate the staying time, search the source and gather data regarding its opening or spilling [6, 8]. As it can be seen, if the ML cannot support the

[3] Act CXVI of 1996 on atomic energy

IC at the initial stage of the intervention with these essential information it is really hard to make decisions for him. He must have a comprehensive view over the general firefighter routines and adopt further variables to his decision-making procedure [7] [12].

3. SCIENTIFIC BACKGROUND [5]

Most of the ionizing radiation affecting us is from natural sources (we are all radioactive) and a significant fraction of the artificial part comes from medical applications (voluntary). So radioactivity is the natural part of our normal life and most of our fears are unfounded. However it is important to point out that dose is a crucial quantity and high dose exposures can cause acute radiation syndrome (ARS) or death. To handle this issue properly it is required to gain adequate knowledge.

Absorbed dose is a physical quantity which gives the absorbed energy per mass unit; its dimension is Gray (Gy). Effective dose is the biological dose with dimension Sievert (Sv) and comes from 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.

In practice it has a high importance of dose rate which is the absorbed dose per time. Measuring dose rate, maximum staying time can be calculated for firefighters.

Regarding sources it is essential information that which isotope of which element is, what kind of radiation is emitted and how much is its activity[4]. The emitted radiation type can be alpha, beta, gamma or neutron radiation.

Alpha radiation consists of alpha particles which are helium nuclei. It has high penetrating power (PP) and specific ionizing power (SIP). It can be absorbed by a piece of paper or some centimetres of air. Nevertheless, its quality factor is 20, that is it is twenty times more hazardous biologically than beta or gamma radiation. Especially getting inside the human body with ingesting or inhaling, so called incorporation, must be avoided.

Beta radiation consists of electrons or positrons. It has a medium penetrating power (PP) and specific ionizing power (SIP). It can be absorbed by a piece of metal disk or about 2 metres of air.

Gamma radiation is electromagnetic radiation made by high energy photons. It is electrically neutral so it has high penetrating power (PP) and specific ionizing power (SIP). It can be absorbed by high atomic numbered elements like lead and concrete.

Neutron radiation consists of neutrons. It is electrically neutral and its special danger that it can induce nuclear reactions. It can be absorbed by light elements like water.

The most commonly used isotopes in research or industrial and medical field are the following: sodium-24 (β), cobalt-60 (γ), selenium-75 (β), iodine-131 (β), caesium-137 (γ), iridium-192 (β-γ), plutonium(beryllium)-239 (γ-n^0), americium-241 (α-γ), americium(beryllium)-241 (γ-n^0).

[4] activity: radioactive decays per seconds; dimension: Becquerel, Bq.

IR can cause stochastic and deterministic health effects to the human body. Formers are long term, genetic and carcinogenic effects with increased possibility at lower dose exposures. Deterministic effects 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. Typically below 200-500 mSv whole-body absorbed dose there are no notable symptoms, at around 1000-2000 mSv common mild symptoms occur with some latent period. Syndrome is headache, fever, nausea, vomiting, diarrhea, fatigue, weakness, leukopenia. With raising the dose latent period gets shorter, severity increases, and hemorrhage, CNS[5] signs, epilation and infections may appear. The so called half-lethal dose ($LD_{50/60}$) which causes the mortality of half of the patients within 60 days is 3000 mSv and the lethal dose is about 6000 mSv. Nevertheless, both values can be doubled with medical care so there was a patient who survived 12000 mSv of exposure thanks for the medical care [2].

4. RADIATION PROTECTION OF THE FIREFIGHTERS

A fire incident does not differ significantly in that regard whether a radioactive source is present or not. At least in that sense, that it does not have any influence on the spreading and other features of the burning [13]. The only difference will appear in the methodology in order to prevent the unnecessary and extreme exposure of the responders [14]. The point is to avoid the deterministic effects [6].

In RE application of the radiation protection regulations is needed as well. These are the justification, optimization and limitation. 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 and 250 mSv for live-saving, respectively. If the dose is unknown because of either no personal dosimeters 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 live-saving is needed, escalation of the emergency is expected or what financial loss and environmental damage can be caused with cancellation or delay of the intervention [3, 8].

For the risk assessment gathering information is fundamental so the reconnaissance should cover the followings: what kind of isotope and how much its activity, whether the package is damaged, and what is the possibility of opening or spilling. Without measured data dose-estimation can be carried out with calculation if the type, activity and location of the radionuclide[6] are known. For instance, in the case of transportation accident, 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 [4]. In this case if the decision of the IC is that some operation is necessary despite the unidentified radiation, then principle ALARA[7] should be kept by all means [3].

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[5] CNS: central nervous system

[6] Radionuclide: an atom that has excess nuclear energy, making it unstable and inducing alpha, beta or gamma emission

[7] ALARA: As Low As Reasonably Achievable, like radiation levels should be kept

This can be realized in practice in three main ways: reducing the time spent in exposure, increasing distance from the source and applying shielding if it is feasible [3]. Besides this, it is suggested to register the staying time of the responders since this can be helpful in the afterward dose-estimation if then later measured data are available.

5. AN EXAMPLE

Consider an ADR vehicle which has a ^{137}Cs closed source as shipment. A road accident happens in which also 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 on fire of 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.

Next question what is the procedure if IC has information on the presence of radioactive material and live-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 obviously would make the reconnaissance and the intervetion impossible [6].

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 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[8]=10, 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 now the dose rate at 1 m from the source is 14 mGy/h which allows only 3.5 hours for invention. And if the source must be neared within 10 cm for some reason, that means a level of 1.4 Gy/h and only 2 minutes for saving. Certainly, as in the case of live-saving the maximum dose is five times higher (250 mSv) according to the guidelines, the staying times above are five times bigger as well.

Meanwhile, if the possibility of spilling of 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 1 cm distance because of the protective clothing, the firefighter is exposed to the effective dose 7 Sv in half an hour.

[8] TI: 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

It can be seen that the radiological exploration and the instrumental measurement of the scene have crucial role in planning and realizing the intervention. Without these it is contraindicated to start even live-saving.

6. OTHER ISSUES OF THE INTERVENTION

As it can be established, based on the above mentioned, intervention in 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 [3]. Meanwhile members of the professional disaster control service must serve the safety of the wealth and life of the civil population even taking risks on their own life and physical safety [1]. Nevertheless, 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 fireman is quick, smart and lucky enough he may get safely away without exploding. In contrast, in a RE when a source unshielded and spilled, exposure levels can be so high that leads to serious ARS so it is not risk-taking rather a potential suicide.

Moreover, in Hungary personal dosimeters are not involved in personal protective equipment which makes the determination of the exposure more difficult.

7. CONCLUSION

Working out of the problem sketched above is impossible here because of the large number of variables but with giving some part-answers and guidelines interventions can be safer. Knowing the complex 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. Nevertheless, firefighters are still the very first responders so they must be prepared for reconnaissance and quick-reaction. 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 personal dosimeters.

The main consequence is that it is well-founded to supply the staff with personal dosimeters even though REs rarely happen. Moreover, the exact classification of the incident is crucial which helps to alarm the appropriate power at the initial stage of the intervention.

ACKNOWLEDGEMENTS

Above research was supported by the project titled: "Public Service Development Establishing Good Governance, PADOP-2.1.2-CCHOP-15-2016-00001" at the National University of Public Service, Budapest, Hungary.

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