Advanced methods of practical training of intervention and rescue personnel in toxic / explosive / flammable environments

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Abstract. In the activity of intervention and rescue, practical training has the primary role, thereby making it possible for rescuers to be permanently prepared to intervene in case of major incidents, accidents or events. In addition to classic training methods, namely training carried out in installations within production platforms, equipment endowment of the Rescue Risks Laboratory, allows different modern training scenarios to be developed using virtual reality or the mobile training ground. Virtual reality is increasingly present in training in many fields of activity, considering the fact that in the virtual environment dangers that cannot be created in reality (explosions, fires, falls from great heights) can be easily simulated and, thus, fear of such dangers can be outrun. Endowments of mobile training ground allow training scenarios to be created that emphasize the degree of physical preparation of rescuers, taking into account their physiological parameters that are monitored throughout the entire training. The paper aims to highlight the practical training of rescuers through modern training means resulting in their occupational selection and training of rescue teams that will intervene in critical situations.

1. Introduction

When, as a result of accidents (Fig. 1), toxic gases are released or there is a qualitative change in the composition of air, in order to protect the respiratory tracts of people caught in this area or of people who intervene to rescue those caught in the area where the incident occurred, it is necessary to use respiratory protection devices [1].

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Fig. 1. Accident with releases of toxic gases

Breathing protection devices, both those based on closed-circuit oxygen and those based on compressed air, offer the possibility for intervention and rescue personnel to intervene in the damaged area without taking into account the concentration of toxic gases.

The activity of intervention and rescue in toxic / explosive / flammable environments can only be carried out by authorized personnel in accordance with the legislation in force, personnel using individual breathing protection devices [2].

Practical training of the intervention and rescue personnel has the primary role in intervention and rescue activities, practical training that must be done, according to the Normative on management of the intervention and rescue activity in toxic / explosive / flammable environments, at least 3 hours per month, within the employer's own installations, next to which the rescue station operates. The monthly training mainly focuses on developing the rescuers' motor skills, physical and mental qualities, the way they use the breathing protection device, basic factors in the success of an intervention.

During training, the possibility of training in an area of confined spaces as well as the psychophysiological factors of rescuers are of particular importance, such as pulse, blood oxygen saturation, blood pressure, factors that cannot be monitored during their training in employer's own facilities [3]

Within the Rescue Risks Laboratory within NRDI INSEMEX Petroșani, two modern pieces of equipment for training rescuers were purchased, respectively the mobile training ground for rescuers and the training system using virtual reality, equipment through which different training scenarios can be created.

The current paper presents modern methods of training intervention and rescue personnel in toxic/explosive/flammable environments, by using the Mobile rescuers' training ground and by using the Virtual reality training system, equipment with the help of which the physical capacity of rescuers, as well as their physiological parameters can be monitored. Also, through the mobile training ground, rescuers' ability and manner of intervention in confined spaces can be monitored, which is very difficult to achieve during training carried out in employers' facilities [4].

2. Training methods using the Virtual Reality training system

Virtual reality is increasingly present in the training in many fields of activity, considering the fact that the virtual environment may easily simulate dangers that cannot be created in real life.

Using virtual reality can create a higher level of training compared to classical training methods only, being a complementary method of training and practical training of intervention and rescue personnel in toxic / flammable / explosive environments, but which cannot fully replace real-life training with the use insulating devices. In the virtual space, foremost, the theoretical knowledge of rescuers can be tested by creating scenarios of dangerous events and observing how the team intervenes.

In accordance with legal provisions and intervention and rescue procedures, before the rescuer begins the intervention, he must put on his breathing protection device and check its main parameters. In this sense, within the virtual reality training system, a scenario was created for fitting and checking the compressed air breathing protection device, mainly following the steps that the rescuer takes in the fitting and checking process. Because an important role in the implementation of a scenario with the help of virtual reality is played by the way the rescuer is accustomed to using VR equipment (controllers, head-set with glasses) and taking into account the fact that within intervention and rescue stations staff's average age is relatively high (personnel less familiar with VR technology), we will not take into account the time during which the rescuer puts on and checks the breathing protection device, but instead we will observe the order of putting on the device and its verification according to the procedures in force [5].

Because the scenario is carried out through a software program, we are able to allow the personnel who perform the scenario of putting on and checking the insulating device to go through the entire scenario and, at the end of it, to be presented with any irregularities that do not correspond to the correct procedure. Also, the rescuer will not be able to perform a future step in this fitting and checking process until the previous step is performed correctly (Fig. 2).

Fig. 2. Respiratory protective device fitting and checking scenario

When the scenario regarding the fitting and checking of the breathing protection device through reality is performed correctly, it is possible to proceed to the next stage of the training method through the VR training system, namely the scenario through which the rescuer will have to go through a training ground in confined spaces, that reproduces on a smaller scale an industrial area with closed spaces, pipes, tanks, cable channels, ramps as well as various blockers to make it more difficult to cover. The Rescue Authorization Group within INCD INSEMEX Petroșani has a standing training ground in confined spaces and uses it for the training of intervention and rescue personnel who are trained / retrained at the headquarters of the Institute [6].

The training scenario is carried out in accordance with the standard intervention procedures of INCD INSEMEX Petroșani and includes the following stages:

- informing the rescuer about the major incident and the task to be performed;
- equipping with the breathing protection device that was fitted and checked according to the previous scenario;
- taking control of the gas detection device;
- entering the training ground and measuring gases with the detector provided, both at the entrance and along the entire route;
- along the entire route, permanent monitoring of the air pressure in the compressed air cylinder as well as the environmental factors encountered (smoke, humidity, fire or incandescent areas, etc.), sending forward information found and making decisions required in such situations;
- moving on the route established at the beginning of the scenario or making decisions if this is not possible or if explosive gases above the maximum allowed limits are detected on the route.

The training scenario includes moving in the virtual system while observing the height regime of the route, climbing tanks' ladders, going up / down between the levels within the training ground, practicing how to use the measuring and gas control equipment (Fig. 3).

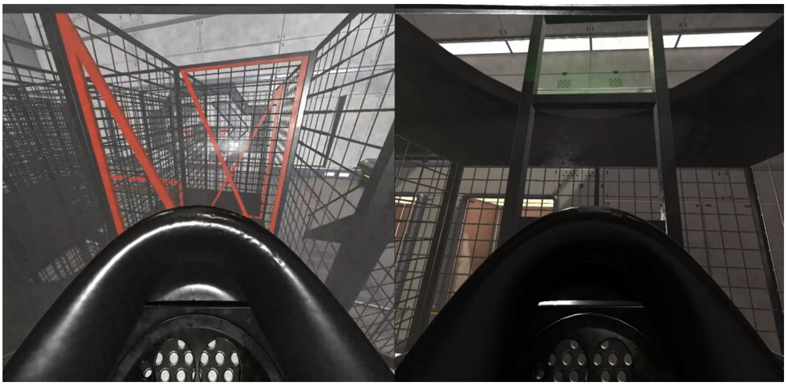

Fig. 3. Confined spaces training ground scenario

If the rescuer does not execute the procedure correctly, the training scenario provides alerts or he cannot continue moving until he performs the correct actions or makes the good decision. With the hardware equipment (laptop), during training, certain additional options can be introduced such as:

- the smoke option, which makes the visibility in the training ground more and more low so that the rescuer's reactions to such an incident are tested.
- the option of explosive gases above the maximum allowed limits, which implies the rescuer's (respectively of the rescue team) withdrawal from the area; through this option decision making skills of rescuers, respectively team leaders are tested.

Carrying out such training using the |VR training system through provides the opportunity to improve safety related to the rescuer's intervention, to check certain reactions in extreme situations (explosions, dense smoke, gas concentrations above allowed limits), situations which are very difficult, even impossible to achieve in a real-life training.

3. Training methods using the rescuer's mobile training ground

The mobile training ground for rescuers is a modern training system for intervention and rescue personnel in toxic/explosive/flammable environments, recent endowment of the Rescue Risks Laboratory, intended to lead to the improvement of the training/retraining process of rescuers [7].

The mobile training ground (Fig. 4) is very complex, consisting of a semi-trailer with a length of 13.5 meters, which is divided into two compartments each with separate access, one equipped with fitness equipment and a control desk, and the second with a training ground of confined spaces simulating cable ducts, piping, niches, tank areas.

Fig. 4. Mobile training ground for rescuers

Specifics of the training in such a mobile ground differs from the training that intervention and rescue personnel carry out in their own facilities considering that the mobile ground, through the equipment it’s endowed with, allows permanent monitoring of rescuers' physiological parameters (pulse, blood oxygen saturation, blood pressure, the amount of kcal consumed, etc.). At the same time, in the confined spaces compartment, an atmosphere with reduced visibility can be created by injecting the space with smoke, high temperature (in the compartment there is a resistance of 6 kw that creates heat), high humidity, noises specific to disasters [8].

A first training scenario in the mobile training ground provides for registration of the rescuer (the rescuer's file) in the laboratory’s database (surname, first name, number of the rescuer's ID if he is undergoing retraining, the air pressure in the cylinder). After registering in the database, the rescuer will carry out a part of the training in the fitness area, passing each machine in turn (infinity ladder, ergometer, stepper, treadmill and bicycle) for 4 minutes, all of which have predefined characteristics (speed, incline, number of pulls, distance travelled, etc.), which means that all rescuers will work in the fitness area under the same conditions (Fig. 5).

Fig. 5. Rescuers' training in the fitness area

The telemetry system, endowment of the mobile training ground, constantly monitors the physiological parameters of the rescuer, before the start of the training, having the possibility to set the minimum and maximum values of the heart rate in the control panel, and if the rescuer leaves these limits, there will be audible alerts and training will stop for the rescuer in question. Through the control panel, the energy consumed by each individual rescuer on each individual type of fitness device can be tracked.

After the rescuer passes through all five fitness devices, he will enter the confined space compartment and walk the confined space maze twice, the first time with normal visibility without smoke and the second time with the compartment flooded with smoke, with the heat resistance in action, with strobe lights on and speakers playing disaster noises. At the end of this training scenario, pressure of compressed air in the device's cylinder at the end of the training, the maximum values of heart rate recorded by rescuers during training, the energy consumed by adding the kilocalories recorded by devices, where possible and the total training time will be recorded in the rescuer's file.

If there are rescuers who consume the entire reserve of air in the cylinder and do not manage to go through all the stages of the training previously described, the time when the training ended will additionally be recorded in their file.

Another training scenario in the mobile training ground includes the same steps as the previous one in terms of rescuers' file entries and the training part within the fitness equipment compartment, but unlike the first scenario the enclosed space maze part will be performed by all rescuers until the entire reserve of compressed air in the cylinder is used up and the effective time of using the insulating device in training conditions will be recorded in the rescuer's file. This scenario highlights, for each individual rescuer, the actual time of using the breathing protection device provided, in conditions as close as possible to a real intervention, which helps to organise rescue teams so that there are compatibilities, both physical and in terms of physiological parameters, between the rescuers that make up the team (Fig. 6).

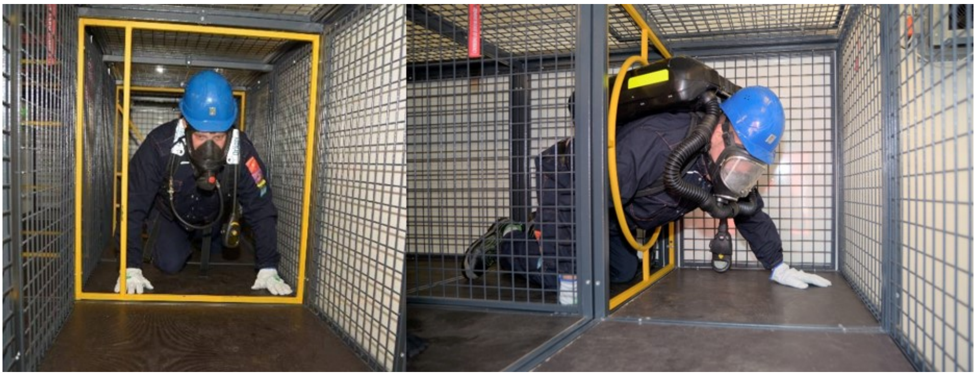

Fig. 6. Rescuers' training in the confined spaces area

For mining rescuers equipped with oxygen-based closed-circuit breathing apparatus whose autonomy is higher than compressed air-based ones, the steps described in the previous scenarios are kept but the training times in the fitness area of mobile training ground and the times they will pass through the confined space area are enhanced.

Conclusions

Carrying out practical exercises related to the stages of training / retraining for intervention and rescue personnel in toxic / explosive / flammable environments through methods described in this paper will lead to an increase in the capacity for intervention and rescue in case of major incidents, breakdowns, explosions, accidents, disasters, etc.

Mobility of equipment that these training methods are based on, namely the VR training system and the mobile training ground for rescuers allows the practical exercises to be carried out within the training / retraining sessions held at the locations of economic employers through the scenarios presented.

By using these training methods for all the personnel of an intervention and rescue station within an economic agent, rescuer selection procedures for organising rescue teams can be implemented so that there is compatibility between team members both in terms of physical ability, reaction in extreme situations (explosions, exceeding the maximum allowed concentrations of explosive gases) that can be re-created through virtual reality as well as in terms of physiological parameters that the rescuer achieves during training.

During training in the mobile training ground, by drawing up the rescuer's file and saving it in the database, it is possible for the person in question to be active as a rescuer in an authorized Rescue Station, to demonstrate their ability of intervention, a fact that allows conducting research studies by personnel categories (surface intervention and rescue personnel, mine rescuers) by age, profession, etc.

By training with the help of the training system based on virtual reality, it is possible to simulate extreme situations (explosions, fires, working at heights), situations that are impossible to re-create in real-life training, and by studying the reactions of each individual rescuer, it is possible to develop studies in parallel and perform psychological tests for each rescuer before and after training based on virtual reality.

Acknowledgements

This work was carried out through the "Nucleu" Program within the National Plan for Research, Development and Innovation 2023-2026, with the support of the Romanian Ministry of Research, Innovation and Digitalisation, project no. 23 32 01 02, title: Development of assessment, testing and intervention methods for explosive atmospheres generated by facilities for the production, storage, transport and use of hydrogen.

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