Practical training of rescuers in high temperature and humidity environments in the training facility

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Abstract. Heat is normally generated as a result of metabolic processes taking place in the body. As a result of muscle activity, when working or exercising, a considerable amount of heat is released. The amount of heat generated is proportional to the intensity of activities. Intervention and rescue activities in special conditions can be carried out exclusively by personnel trained and authorized in this regard, personnel using individual breathing protection equipment. The decisive factor in ensuring the success of an intervention and rescue operation in toxic or chemically aggressive environments resides in the optimal and efficient design of a training process of personnel, in correlation, among others, with their testing in high temperatures and humidity environments. The current paper presents the structuring of rescuers' physical effort during training, taking into account high temperature and humidity environments, structuring that aims to make the training process of intervention and rescue personnel in toxic / explosive / flammable environments more efficient. The paper analyses a correlation between changes in the physiological parameters of intervention and rescue personnel and different values of temperature and humidity of the training environment.

Introduction

The activity in special conditions has been developed for preventing further underground or surface damage which threat the staff or property and because the toxic or asphyxiating gases concentrations, vapors or dust established by norms requires the use of respiratory protective apparatus [1].

The performer of direct and dangerous heavy work to save people and protect industrial objectives is the operative intervention and rescue personnel, who uses protective breathing apparatus.

Temperature and humidity are likely to increase due to fires and explosions. Therefore, rescue team members are facing environments with high temperatures during rescue

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operations, such as, the entry into burnt buildings when looking for survivors, firefighting, when building dams and restoring ventilation circuits affected by fires or explosions.

Experimental

The Heat is generated normally as a result of metabolic processes taking place in the body of rescuers. As a result of muscle activity when there are performed working or training activities, there is released a considerable amount of heat. The amount of heat generated is proportional to the intensity of work [2].

The body temperature control is essential, and inability to maintain balance between cooling and overheating can lead to illness and even death.

The temperature control is performed by an area of the brain known as the hypothalamus, which is responsive for the sensors in the body. There are several mechanisms to control body temperature. Conduction, convection, radiation and evaporation maintains the indoor temperature of the body.

The heat exchange takes place through the skin, which can be described as a housing. The deepest tissues are into body cavities (chest, skull and abdomen), being known as central tissues. The hypothalamus regulates the temperature and is trying to keep the central tissue temperature in a narrow range. If their temperature gets too high, then there may occur due to high temperatures the induced illness or even death [3].

Factors to be considered for working in high temperatures and humidity of the rescue personnel:

- External factors: air temperature, relative humidity, temperature of surrounding objects (with radiant heat), skin temperature, air movement, type and amount of worn clothes, exposure time, load with work equipment, equipment weight, the type of breathing apparatus, confined spaces, availability of water for drinking or wetting skin;
- Human factors: age, degree of muscle activity, health state, physical work capacity, physical condition, the inherent ability to work in heat and humidity, experience, personality;
- Specific factors of health: dehydration, obesity, fever associated with diseases or vaccinations, vomiting and diarrhoea, diabetes, heart disease, medications, recent difficult exercises, history of disorders related to high temperature, disease, conditions which prevent sweat, work recently under high temperature and humidity.

Human, as being warm-blooded in normal microclimate, maintains a constant internal temperature of 37^0C which is necessary to carry out the biochemical processes.

Within limits considered normal, exists thermal variation in the body due to the work, lifestyle, physiological states etc. as to the different organs and at different points on the body surface.

Body temperature balancing is achieved by means of blood circulation and because the thermal conductivity of the tissues. This is done by thermal stability of relative thermoregulation process and is controlled by the nervous system at its different levels.

In the framework of accommodating body to the microclimate variations of the environment through thermoregulatory function, there is a zone in which thermal comfort or thermal neutrality is obtained by effortless thermoregulation [4].

The limits of thermal comfort vary with the effort which increases heat production, and clothing, which makes the possibility of removing it.

To idle state with light clothing, a feeling of comfort is achieved at a temperature of 25^0C and 10^0C air for hard work. Thermal sensation is not given only by air temperature and humidity but also by its speed of movement and changes regime in caloric acting on the body [5].

On both sides of the thermal neutral zone, the body must fight the heat in the environment in order to be able to maintain normal temperature. Adjustment possibilities of the body in

these circumstances are limited, but the body limits where it manages longer to keep warm blooded, correspond the upper or lower critical temperatures beyond which the body enters hyperthermia.

Heat accumulation of body represents the amount of heat produced by metabolism and heat received from the environment.

The heat produced by the body has two parts: the first is related to metabolism at rest and the second one is variable in relation with muscular effort applied.

The heat received from the environment varies widely in relation to the characteristics of the workplace microclimate.

To maintain thermal balance under conditions of excessive heat microclimate, the body intervenes by reducing heat production and by favouring heat loss to the environment.

The heat of the body's internal environment is released to the environment only slightly by breath, urine or faeces, mostly being transferred through the skin.

Sweat secretion reflex is triggered, regardless whether or not it evaporates perspiration. The amount of sweat removed from the body varies with the ambient temperature, effort, the type and degree of clothing and workout.

For the evaporation of one gram of water is required a heat amount of approx. 0.6 Kcal., which explains the loss of heat in this way, favoured by the movement of air.

In thermal dispersion, skin fulfils a dual function: heat accumulation from the environment and disposal of heat outside.

This dual function is performed by two antagonistic physiological mechanisms. The first mechanism is the blood supply to the skin leading to heating teguments and leading to temperature difference from the environment required by yielding heat conductivity, convection, radiation, maintaining skin around a layer of warm air, which favours evaporation of perspiration [6].

The second mechanism is sweating, which increases the surface area of the skin moist and cools through evaporation of sweat.

Antagonism between the action of heating the skin through the blood stream and cooling them by evaporation of sweat becomes a particular problem in the working environment, where the warm microclimate is associated with physical effort, in which case it establishes another thermal balance, different from the idle state. Skin temperature increase is limited by the need to maintain the temperature difference between the body surface and internal organs to remove heat from inside the body through the skin.

These antagonistic functions to maintain homeotherm in a warm environment with greater physical effort, subject the body organs to a special request of thermoregulation which under certain conditions cannot be satisfied. In these circumstances, when the circulatory capacity cannot meet the needs of both thermoregulation and oxygenation needs, and to eliminate the catabolite imposed by increased muscle activity, thermolysis processes shall prevail to the detriment of the needs of the exercise. Reduce working capacity intervenes as a first signal of thermal overload of the body and still will appear morbid disorders or conditions related to the thermoregulation.

During exertion, the body's adaptation is ensured on the one hand by setting nervous control and secondarily by neuro-hormonal control. It produces a series of changes in organs and systems in the body as an expression of functional adaptation trend changes, which externalizes most strongly in cardiovascular activity. The way to adapt, which attracts the best attention, is accelerating heart rate, heart rate increased frequency reflecting its growth rate. Heart rate can reach a level of 60-70 beats per minute at 120-150 beats per minute in exceptional cases, to great efforts.

Rescuers behaviour in environments with high temperature and humidity in the training facility

In rescue operations team members are traveling long distances carrying heavy loads, such as tools, rescue equipment, victims and stretchers [7].

Both in underground and surface rescue situations, in addition to wearing protective breathing apparatus, rescuers are equipped with protective overalls, belts, front flashlights, boots and helmets.

All the factors listed above, coupled with the rescuer's physical condition may contribute to its inability to cope with high temperatures and humidity environments. This can lead to heat stress, a condition that is life-threatening.

Preparing for emergencies, including procedures and training for rescue team members will optimize the probability of carrying out essential tasks and at the same time will prevent the development of diseases induced by high temperatures by those who perform this type of work.

To highlight changes in oxygen saturation in the blood and pulse, were carried out tests in the training facility for a team of three rescuers using breathing apparatus with open circuit based on air and positive pressure.

Testing was conducted in a training exercise, determining the two parameters, blood oxygen saturation and pulse, conducted for different activities depending on ambient temperature and humidity.

Determination of blood oxygen saturation was achieved by using WK D50 oximeter. Oximetry is used for the management and proper dosage of amount of work performed in the training facility by rescuers.

Three computer systems were used, disposing of specialized software. The oximeter is connected to the computer system via USB port.

The pulse determination was made using pulse telemetry system for measuring HRT-SYS. Pulse telemetry measurement system HRT-SYS is used to measure pulse of rescuers in the training facility and it allows continuous monitoring of progress for six people.

Testing was conducted for three activities:

- ergometers tractions;
- walking on ergonomic treadmill;
- going up and down on the stairs.

In order to achieve environments with high temperatures and humidity in the training facility of INCD INSEMEX Petrosani, there were used an electric heat generator and air humidifier.

Measurements were conducted on blood oxygen saturation and pulse for every rescuer in part, at 20^0C ambient temperature. Measurements were repeated in many stages of 5^0C temperature increase to a maximum of 45^0C (Fig. 1).

Fig. 1. Measurements achievement

Activity no. 1 - ergometers tractions

In this activity, rescuers have conducted one session of ergometers tractions, lifting a 20 kg weight, at 1,2 meters height, each session having 50 tractions for one threshold temperature and humidity in the training room (Fig. 2).

Fig. 2. Ergometers tractions

For the ergometers tractions activity, blood oxygen saturation and pulse rate are shown in Table 1.

Table 1. Determinations on ergometers tractions

No.	Environment temperature	Environment humidity	Subject 1		Subject 2		Subject 3	
			Pulse	SpO_2	Pulse	SpO_2	Pulse	SpO_2
1	20^0C	45 %	80	98	79	97	69	98
2	25^0C	51 %	102	96	89	95	82	96
3	30^0C	59 %	113	92	97	97	99	96
4	35^0C	63 %	123	93	110	94	112	95
5	40^0C	67 %	145	91	128	94	126	94
6	45^0C	71 %	155	92	149	93	151	92

Under activity. no 1 - ergometers tractions was noticed that once with the temperature and humidity rise, rescuers pulse increases and blood oxygen saturation decreases (Fig. 3).

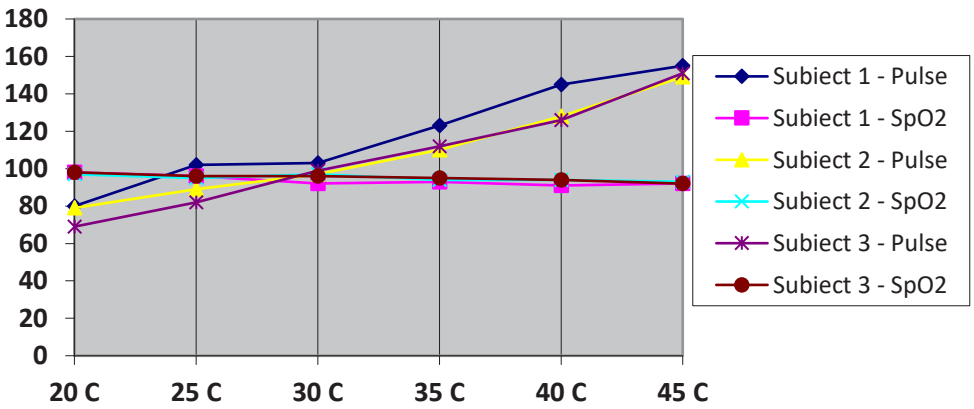

Fig. 3. Changes in heart rate and SpO_2 on ergometers tractions

Activity no. 2 - walking on ergonomic treadmill

In this activity rescuers performed simulated walking on the ergonomic treadmill with a speed of 5 km / h, for 5 minutes to one threshold temperature and humidity in the training room (Fig. 4).

Fig. 4. Walking on ergonomic treadmill

For walking on ergonomic treadmill activity, blood oxygen saturation and pulse rate are shown in Table 2.

Table 2. Determinations for walking on ergonomic treadmill

No.	Environment temperature	Environment humidity	Subject 1		Subject 2		Subject 3	
			Pulse	SpO_2	Pulse	SpO_2	Pulse	SpO_2
1	20^0C	45 %	80	97	79	97	69	98
2	25^0C	51 %	104	96	92	95	85	97
3	30^0C	59 %	112	94	99	96	99	96
4	35^0C	63 %	125	93	114	95	116	95
5	40^0C	67 %	146	91	126	94	128	94
6	45^0C	71 %	152	92	148	93	149	94

Under activity no 2 - walking on ergonomic treadmill, it was observed that once with the temperature and humidity rise, rescuers pulse increases and oxygen saturation in the blood decreases (Fig. 5).

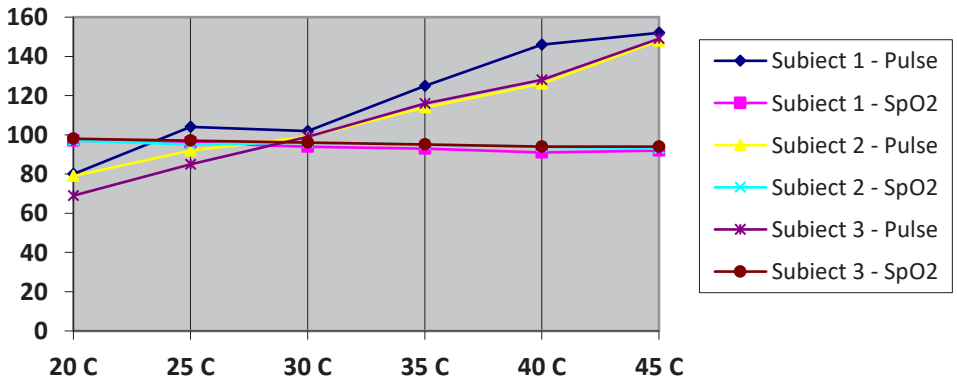

Fig. 5. Changes in heart rate and SpO_2 at walking on ergonomic treadmill

Activity no. 3 - going up and down on the stairs

In this activity rescuers climbed down stairs with 5 steps repeating 40 times the activity for one threshold temperature and humidity in the training room (Fig. 6).

Fig. 6. Going up and down on the stairs

For going up and down on the stairs activity, blood oxygen saturation and pulse rate are shown in Table 3.

Table 3. Determination on displacement on the ladder

No.	Environment temperature	Environment humidity	Subject 1		Subject 2		Subject 3	
			Pulse	SpO_2	Pulse	SpO_2	Pulse	SpO_2
1	20^0C	45 %	84	97	79	97	69	98
2	25^0C	51 %	105	96	92	95	85	97
3	30^0C	59 %	118	94	97	96	99	96
4	35^0C	63 %	125	93	114	94	114	95
5	40^0C	67 %	144	91	128	94	128	94
6	45^0C	71 %	149	92	146	93	147	95

Under activity no 3 - going up and down on the stairs, there has been noticed that once with temperature and humidity rise, the rescuers pulse increases and oxygen saturation in the blood decreases (Fig. 7).

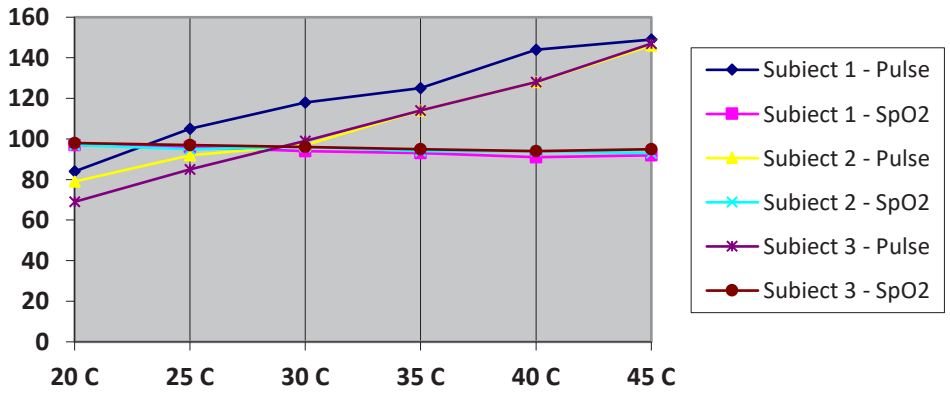

Fig. 7. Changes in heart rate and SpO_2 for going up and down on the stairs

Conclusion

The activity in special conditions has been developed for preventing further underground or surface damage which threat the staff or property and because the toxic or asphyxiating gases concentrations, vapors or dust established by norms requires the use of respiratory protective apparatus.

The Heat is generated normally as a result of metabolic processes taking place in the body of rescuers. As a result of muscle activity when there are performed working or training activities, there is released a considerable amount of heat. The amount of heat generated is proportional to the intensity of work.

To highlight changes in oxygen saturation in the blood and pulse, were carried out tests in the training facility for a team of three rescuers using breathing apparatus with open circuit based on air and positive pressure.

Within three activities: ergometers tractions, walking on ergonomic treadmill and going up and down on the stairs was observed that as the temperature and the humidity rises in the training room, the pulse of rescuers increases and oxygen saturation in the blood decreases.

Tests carried out within the training facility allowed to establish a link between changing physical parameters of rescue personnel and environmental conditions (temperature and high humidity), which will allow the identification of limits of temperature and humidity to which rescuers can operate safely.

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