Identification of quantifiable biological parameters for rescue personnel in the context of relational analysis of hazardous environments

Lorand Toth[1*], *George Artur* Găman[1], *Daniel* Pupăzan[1], *Alin* Irimia[1], and *Izabella* Kovacs[1]

[1]National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroşani, 32-34 G-ral Vasile Milea Street, Petroşani 332047, Romania

Abstract. The previous events in the industry reflect the need to take action to stop or at least slow down the development of damage and to prevent or reduce, as far as possible, their extent. In the case of breakdowns in industrial technological processes, their management requires, in addition to plant maintenance personnel properly trained for such situations, the participation of specialized personnel for interventions in hazardous environments. To form an image, the intervention is described as a set of actions in the facilities of a technological flow in which an event out of technological control was triggered, which aims to stop the negative consequences. The systemic approach of the correlation of hazardous substances in connection with the hazardous environment, of the relationships between the hazardous environment, constructions, technological installations and personnel as well as the identification of the effects of hazardous environments allows the crystallization of a relational analysis of hazardous environments. In this context, rescuers involved in the liquidation of damage must have a high degree of practical and physical training. During the training / interventions, rescuers have the opportunity to constantly monitor their physiological parameters through wearables. This paper aims to identify quantifiable biometric parameters for rescue and rescue personnel in the context of relational analysis of hazardous environments.

1 Introduction

Industrial technological processes are complex processes through which very wide spectrum finished products are developed, products without which today's society would not exist. These products are based on complex physical-chemical transformations, in which, in addition to main useful substances, the obtaining of which is pursued, secondary substances also result, many of which have a number of properties due to which their free presence in the environment is not desired [1].

* Corresponding author: lorand.toth@insemex.ro

On other hand, as a result of technological imperfections, non-performing technical equipment and, not infrequently, obsolete technical equipment or malfunctions, such substances escape the control of technological installations and are spread in the environment in appreciable quantities. The presence of these substances, under various granulations, forms of aggregation, at different temperatures, creates complex difficult situations, with unpredictable evolutions, in which both the personnel serving technological installations, as well as the actual and nearby installations, as well as the environment are in danger of damage or even destruction. This requires a more constructive attitude of business management, to control any situations that arise during technological processes and properly manage those that may harm the environment, staff and even their own technological installations.

The hazardous environment is the result of correlations between normal natural environment and various hazardous substances that have occurred accidentally or in a certain area. Also, the dangerous environment mediates the production of negative effects, which means that it is in fact the intermediary that makes the action of the dangerous substance possible, by carrying out and transmitting dangerous characteristics to the receiver (personnel, installations, constructions).

Although, intermediation manner is different in the case of substances which, when mixed with air, form environments conducive to explosions, because the support (normal natural environment) actively participates in reactions producing harmful effects, unlike other dangerous substances, in which the support is passively correlated with them, however, the supporting role remaining obvious.

Under the influence of hazardous substances, the natural environment changes its characteristics, taking over theirs, which allows hazardous environments to be classified according to the hazardous substances at their origin. Thus, the following types of hazardous environments can be distinguished: explosive environment, toxic environment and aggressive environment, with its forms (thermal aggressive and chemical aggressive).

For a clearer identification, the notions specified above can be defined as follows:

Explosive environment is the hazardous environment that results from the mixing of a substance (s) or vapor (s) with atmospheric air at ambient temperature and pressure and which, within certain concentration limits, in the presence of thermal energy sufficient to represent a trigger, manifest by chemical reactions of explosive nature.

Toxic environment is a dangerous environment resulting from the influence of dangerous substances present, dispersed in a certain area and which, in direct contact (touch, swallowing or inhalation) with living organisms, causes intoxication [2].

Aggressive environment is the dangerous environment resulting from the influence of compact or dispersed substances present, in the atmosphere of a certain area, and which has the property to attack and destroy, by thermal or chemical effects, physical integrity, buildings and installations in that area.

2 Relationship analysis of hazardous environments

2.1 Hazardous substance - hazardous environment correlation

Aspects presented in the introductory part show that the environment is the support on which interpose hazardous substances released as a result of anthropogenic activities. Without the support of the environment, hazardous substances would find it more difficult to come into contact with living things or buildings and facilities that they endanger. The relationships that are created between hazardous substances and the environment, mainly as their material support, are characterized by two correlational ways.

The passive correlation is the one in which the environment plays the role of simple support on which dangerous substance sits (usually by diffusion), without the two components interacting in any way or their mixture generating any new characteristic in relation to initial characteristics of each component [3].

Ways to achieve this type of correlation are the diffusion of gases, vapours, particles in the air, dissolution of dangerous substance in water, infiltration of dangerous substances into groundwater and deposition of immobile or mobile (fluid) layers of dangerous substances on the ground. In order to have an overview, in the next section the passive correlations mentioned above will be presented in detail.

Diffusion of gases or vapours of hazardous substance into the atmosphere is a simple dispersion of a hazardous gaseous substance or hazardous vapours by their own structure, the mixture thus created not acquiring other hazardous characteristics. Most toxic and some chemically aggressive environments occur this way.

Diffusion of fine solid particles of hazardous substance into atmosphere is mainly similar to diffusion of gases or vapours, except that in static air masses it is less pronounced, with deposition tendencies. The environments thus generated are toxic or chemically aggressive. In both cases, airborne density of hazardous substances in question plays a major role, depending on spatial dispersion of the mixture.

Dissolution of hazardous substances in water is a diffusion of the soluble hazardous substances' molecules (regardless of its initial state of aggregation), with consequences identical to the previous two cases. The mixture thus created, as a hazardous solution, can act as such but also as hazardous vapours, the environment generated being toxic and chemically aggressive.

Deposition of immobile or mobile (fluid) layers of hazardous substances on the ground produces direct contact effects, between the deposited hazardous substance and living things (plants, animals, people) or buildings and installations in the area, giving rise to (thermal and chemically) aggressive environments, but also and toxic environments [4].

The active correlation is that in which, after the diffusion of dangerous substances into the environment, through interaction of the two components, the environment, in addition to the supporting role, acquires new hazardous characteristics, not specific to either component taken separately.

In this type of correlation, it is very important to analyse the ways in which dangerous substances and usual substances that make up the environment interact. In order to have an overview, in the next section the active correlations will be presented in detail.

Diffusion of gases or vapours of dangerous substance into the atmosphere confers radically altered characteristics to the mixture, compared to initial hazard characteristics of the substance in question. The mixture thus created acquires, in addition to hazardous characteristics of the substance, other characteristics as a result of the interaction between atmospheric oxygen and molecules of dangerous substance.

Diffusion of fine solid particles of hazardous substance into the atmosphere is similar to the diffusion of gases or vapours, but, as with passive correlation, static air masses facilitate deposition, especially under conditions of large differences in density.

Dissolution of hazardous substances in water is often a chemical reaction in which water molecules and those of hazardous substances combine, resulting in reaction products with different hazard characteristics than the original substance.

Absorption of moisture by hazardous substances from the atmosphere has the same mechanism as in the case of dissolution of hazardous substances in water, the difference being that transformations occur relatively slowly and the dissolved substance can easily be transformed into vapours with hazardous characteristics either identical to those of the original substance, either different [5].

Deposition of dangerous substances on or in the soil presupposes that the dangerous substance, in powdery or liquid state, ends up spreading on the soil surface or even in a layer of a certain depth in the soil, where, interacting with it, changes its properties.

2.2 Relationships of the hazardous environment with personnel, constructions and technological installations

Between the environment, having certain hazardous characteristics and personnel, constructions and installations with which it comes into contact, certain types of relationships are established, in which the environment in question exerts its harmful effects.

The study of these relationships is necessary, being the rational foundation of protection methods for personnel, constructions and installations in case of occurrence of dangerous environments [6].

Considering the report by which the effects of hazardous environments may occur on personnel and / or constructions and installations, we distinguish between a direct report and an indirect report.

The direct report represents the direct contact of personnel, installations / buildings with the dangerous environment. In this case, the action procedures are: radiant transfer (irradiation action), superficial touch (surface contact), embedding (encompassment), penetration (infiltration, suction, inspiration) and chemical combination (erosion, corrosion, burns) [7].

Indirect report is the type of report in which the hazardous environment does not come into action when in direct contact with people and / or buildings and installations, being conditioned by a trigger [8].

Such a report is specific to the explosive environment, this type of environment arising from the mixture of explosive vapours with atmospheric air, usually indoors, but also outdoors, in the vicinity of transport, use or production of vapours or gases having explosive characteristics, when leaks are major (specific to damage).

Explosive environment's occurrence mechanism is characterized by the time required to reach and classify the concentrations between explosion limits, and once produced, the explosive environment does not manifest its specific harmful effects in the absence of an initiation source. The danger is present as potential danger, it is perfectly quantifiable, depending on parameters of the explosive mixture created (concentrations, temperatures, volumes, masses, etc.), the only probabilistic aspect being the emergence of the initiation source. Thus, specific procedures by which hazardous environments indirectly manifest their presence are incorporation and penetration [9].

2.3 The effects of hazardous environments

As a mediator of the harmful potential in each hazardous substance, the basic effect of the hazardous environment is to create a state of major risk for hazard occurrence, by reducing the probability of triggering the hazardous phenomenon to the probability of a single factor, the trigger. The simplification resulting from these considerations allows, based on the notion of potential danger, a detailed analysis of the consequences of realizing the dangers posed by hazardous environments. Such an analysis will contain all the harmful effects, with a proper assessment of the amount of each effect [10].

Analysis of the overall harmful effects for the assessment of potential hazard implies the need to determine, first of all, qualitatively, all the categories of harmful effects in order to continue to perform their quantitative determination.

From a qualitative point of view, each type of hazardous environment is manifested by direct effects or sometimes by side effects, but differentiated on a case-by-case basis. The harmful effects of hazardous environments branch out into consequences, which in turn represent the suffering, shortcomings, damage caused to people, buildings or installations [11].

In order to systematize the harmful effects, it is necessary to have knowledge of the classification of hazardous environments. Thus table no. 1 summarizes the classification of hazardous environments, according to hazard characteristics of substances in their structure [12].

Table 1. Classification of hazardous environments according to hazardous characteristics of substances in their composition.

<table>
<tr><td colspan="8">DANGEROUS ENVIRONMENTS
consisting of:</td></tr>
<tr><td colspan="4">ONE DANGEROUS SUBSTANCE</td><td colspan="4">MORE DANGEROUS SUBSTANCES</td></tr>
<tr><td colspan="3">SINGLE DANGER CHARACTERISTICS</td><td>MORE DIFFERENT DANGER CHARACTERISTICS</td><td colspan="3">SINGLE COMMON DANGEROUS CHARACTERISTICS</td><td>ONE OR MORE DIFFERENT DANGER CHARACTERISTICS</td></tr>
<tr><td colspan="3">SIMPLE ELEMENTAL ENVIRONMENTS</td><td>COMPLEX ELEMENTAL ENVIRONMENTS</td><td colspan="3">SIMPLE COMPOUND ENVIRONMENTS</td><td>COMPLEX COMPOUND ENVIRONMENTS</td></tr>
<tr><td>EXPLOSIVE</td><td>AGGRESSIVE</td><td>TOXIC</td><td rowspan="2"></td><td>EXPLOSIVE</td><td>AGGRESSIVE</td><td>TOXIC</td><td rowspan="2"></td></tr>
<tr><td>THERMIC</td><td colspan="2">CHEMICAL</td><td>THERMIC</td><td colspan="2">CHEMICAL</td></tr>
</table>

In the current paper, when analysing the potential danger posed by hazardous environments, the priority was represented by the qualitative aspect of harmful effects, respectively their identification and pattern of action (manifestation).
Table 2 shows the effects of hazardous environments (explosive, chemical aggressive, thermal aggressive, toxic) with specific consequences and effects.

Table 2. Effects of hazardous environments (explosive, chemical aggressive, thermal aggressive, toxic).

EXPLOSIVE ENVIRONMENT	
Direct effects	**Side effects**
Explosion, with consequences: demolition, dislocation, deformation, rupture, dismemberment, collision, injury, death and any possible consequences due to high shocks and high temperatures;	***Intoxication,*** with consequences: coma, death and any other forms of generalized discomfort, with diminished to extinction of vital functions; ***Chemical aggression (damage),*** having as consequences: skin irritations, chemical burns of skin and organic tissues, erosions and corrosion of metals or other elements of constructions and installations, the attack of plasters and the deep disintegration of construction masonry;

CHEMICAL AGGRESSIVE ENVIRONMENT	
Direct effects	**Side effects**
Chemical aggression (injury), with the consequences mentioned above;	***Intoxication, Explosion*** with specific consequences;
THERMAL AGGRESSIVE ENVIRONMENT	
Direct effects	**Side effects**
Aggression (thermal damage), resulting in: thermal burns, carbonization, ignition of combustible substances, plasticization of metals, melting and vaporization of solids, explosive decomposition and recombination and any other possible consequences under the influence of liquid or solid incandescent materials or high temperatures;	***The mass explosion*** of incandescent materials, either by rapid thermal decomposition and violent recombination of water, or by the expansion of moisture formed by moisture under the influence of high temperatures with all the consequences, the spread over a large area of incandescent particles;
TOXIC ENVIRONMENT	
Direct effects	**Side effects**
Intoxication with specific consequences;	***Chemical aggression (injury),*** with specific consequences;

3 Identification of physiological parameters of interest in the activities performed by rescuers

The simplest concept that includes monitoring biometric parameters of rescuers during training / interventions is represented by wearables / smartwatches. These devices contain sensors that track, on one hand, the physical activity carried out during rescue training sessions, and on the other hand, the variation of the physiological parameters [13].

In order to have an overview of a training session conducted by rescuers, we need to identify the types of sensors used both for monitoring fitness activities and for monitoring biometric parameters. Thus:

Heart rate monitor - an essential component of a modern fitness tracker that allows one to see how much the heart is working while walking, running and pausing. It is an excellent tool for discovering heart problems that target low, high or irregular heart rate.

Heart rate - defined by the number of heart cycles per time unit (per minute, by convention) is quantified in the range of 25 - 240 beats / minute. It accelerates during exertion or during stress (physical and / or mental), under the effect of a stimulation of the sympathetic nerve and the action of certain hormones (adrenaline, noradrenaline) on the sinus node. It is slowed down by stimulating the pneumogastric (or vagal) nerve whose tone predominates at rest. It is modulated by breathing: accelerating on inspiration and slowing down on exhalation.

Echocardiograph - device used to scan the electrical signals of the heart. Specifically, it measures the time and strength of these signals.

Electrocardiogram (ECG) - recording / interpreting the electrical activity of the heart muscle fibres, this parameter representing an amplitude (measured from the peak of the R wave to the peak of the S wave) of the QRS complex.

Blood oxygen monitor - sensor that measures the amount of oxygen in blood (SpO2), those on smart watches being as accurate as those used in the medical field. Some smartwatches have a relative SpO2 sensor to estimate oxygen saturation and see how well the heart is pumping blood throughout the body. Data obtained is also used to monitor respiration.

Respiratory rate - defined as the number of respiratory cycles (inspiration and expiration) per minute quantifiable in the range of 4 - 70 breaths / minute. Respiration is a vital function of the human body, which takes place continuously and cyclically and has the role of ensuring the two-way exchange of gases between body and air. O_2 is brought in by breathing from the external environment and it is supplied to cells, and CO_2 resulting from cellular metabolism is eliminated into the atmosphere.

Gyroscope - a sensor that uses gravity to measure orientation and rotational speed. In smartwatches, a gyroscope is used to determine the orientation at a given time. It also plays a role in detecting falls.

Position of the rescuer - the position to be taken into account when describing various anatomical elements and relationships between them, quantified in degrees from the vertical in the range of ± 180°.

Accelerometer - this sensor measures acceleration and motion. It is a useful component when tracking training data because it detects changes in speed along each axis of the accelerometer and can measure G forces, a useful unit for identifying falls.

The accelerometer can determine the position of the rescuer during training, thus determining the orientation of the body in the vertical (X), lateral (Y) and sagittal (Z) planes. Thus, 0° = vertical subject; 90° = predisposed subject (face down); -90° = subject lying on his back (face up); ± 180 ° = inverted subject. There may be a gap of ± 5 -15° from 0 for a 'vertical' subject due to variations in torso shape and actual posture.

Other important aspects of monitoring rescuers' training / intervention are, also, the number of steps taken, the impact estimated by the amount of effort put in, and the type of long-term, under-maximal, medium and low-intensity effort that takes place in a balance between requirements and supply of oxygen at muscular level (aerobic effort) or maximum intensity, short duration effort, in which strength and speed predominate, this type of effort taking place in oxygen debt (anaerobic effort).

Figure 1 shows smartwatches that allow the determination of parameters of interest for monitoring a range of physical effort in a training / rescue intervention (pulse, temperature, ECG) [14].

Figure 1. Different smartwatches that allow the monitoring of biometric parameters in the case of training performed by rescuers.

4 Advanced health metrics tracked during a rescuer's intervention / training session

Smart watches have made the transition to fitness devices. From ECG readings to SpO2, smart watches can do things that only devices, such as a pulse oximeter or an ECG monitor, would have done before. In the following, the most important physiological indicators will be presented in order to create a database for each rescuer in order to quantify the quality of training or intervention [15].

The electrocardiogram (ECG) is the test that records the time and intensity of the heartbeat's electrical signals. The ECG checks these pulses to get a heart rate and to see if the heart's atria and ventricles are in synchronous rhythm. If a rescuer does not have a regular rhythm, he may be suspected of atrial fibrillation (a form of irregular rhythm).

Body composition tracking tool that tracks the percentage of fat, muscle and water content in the body.

Oxygen saturation is an estimate of the amount of oxygen in the blood. SpO2 values between 90-100% are acceptable, 95-100% being ideal, indicating good blood oxygenation, needed to provide the energy that muscles need to function. These readings are also useful for those with an active lifestyle or for anyone suffering from sleep apnea. Wearables / smartwatch come with SpO2 optical sensors that use red and infrared light sensors to analyse blood colour. The degree of oxygen saturation causes variations in blood colour.

Skin temperature - This is slightly different from the core temperature (inside the body) which is usually measured with a thermometer. It takes a few days to estimate the base skin temperature and then start measuring temperature variations using the temperature sensor.

Respiration monitoring - Each breath is coded into heart rate variability (HRV). The ability to analytically extract respiration rate from HRV data depends on heartbeat data.

Stress level - wearables / smartwatches get scores / stress levels, using respiration monitoring, by using different approaches and statistics of heart rate.

Body Battery (energy reserve monitoring) aims to help manage personal energy resources. This translates into knowing when a sustained physical effort can be made and when it is wiser to reduce the effort. By correlating the effects of physical activity, stress and relaxation, the concept of Body Battery allows the quantification of activities and effort.

5 Conclusions

As a result of technological imperfections or non-performing technical equipment substances escape the control of technological installations and are spread in the environment in appreciable quantities.

The presence of these substances, under various particle sizes, forms of aggregation, at different temperatures, creates complex difficult situations, with unpredictable evolutions, in which both the personnel serving the technological facilities and the facilities themselves, as well as the environment are in danger of damage or even destruction.

The relational analysis of hazardous environments allows a successful approach in concrete directions of solving interventions from the early stages.

During training / interventions, rescuers have the possibility to constantly monitor their physiological parameters (heart rate, blood oxygen saturation, etc.) with the help of wearables / smartwatch.

By downloading biometric data from wearables / smartwatch devices, graphs can be generated by combining various monitored parameters for energy / physiological analysis of the training / intervention performed.

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