

Research on the response of rescuers during interventions in high temperature and humidity environments within the Petrobrazi refinery

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Abstract. Intervention and rescue missions conducted in environments with elevated temperature and humidity levels can only be performed by personnel who are appropriately trained and certified, and who utilize individual respiratory protective equipment. A critical factor in the success of such operations—particularly in toxic, explosive, or flammable settings—is the continuous improvement and optimization of training protocols for intervention and rescue teams. This includes conducting performance evaluations under simulated conditions that replicate high thermal and humidity stress. The present study explores scientific research on the physiological responses and parameter variations observed in intervention and rescue personnel operating in thermally and environmentally challenging conditions. In recent decades, the accelerated pace of industrial and economic development has brought increased attention to occupational and industrial hazards, as well as to the growing complexity and diversity of associated risks. Operations carried out in hazardous environments—especially in scenarios involving accidents or system failures that may compromise the safety of personnel or assets, and where concentrations of toxic or asphyxiating substances exceed regulatory thresholds—necessitate the use of specialized respiratory protective equipment to ensure personnel safety and operational efficiency.

1 Introduction

As a consequence of the accelerated economic development, the problems of professional and industrial risk, as well as the level of diversification of the real risk, have become more and more important.

Human safety in the work process is considered to be that state of the work system in which the possibilities of occupational accidents and diseases are excluded. Therefore, security and risk are two abstract, opposite concepts that are mutually exclusive.

In reality, due to the characteristics of any work system, such absolute states cannot be achieved. In practice, there is no system in which the potential dangers of accidents or

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diseases are completely excluded. There is always a "residual" risk, even if only because of the unpredictability of human action.

The production activity within the PETROBRAZI platform (fig. 1) takes place in special conditions, created as a result of possible accidents that can lead to exceeding the concentrations of gases, vapors and/or toxic or asphyxiating dusts established by legislation, which endanger the personnel or material assets existing within the organization, requiring the use of breathing protection devices.



Fig. 1. Petrobrazi Refinery

The object of activity of the combined company is the processing and superior valorization of crude oil and other petroleum products resulting from the primary processing and treatment of oil. The following categories of substances are obtained as finished products:

- fuels (gasoline and diesel) and oils;
- fuels (fuel oil and CLU);
- LPG (propane, butane, etc.);
- aromatic products (benzene, xylene, toluene);
- solvents.

The industrial platform, which includes technological installations, storage tanks and containers, located in the open air, occupies an area of 3,657,808 m². The platform is composed of two main sectors - the refinery and petrochemicals - and technological equipment and machinery that provide the utilities necessary to carry out the technological processes (electricity, steam, water, technological and instrumental air, etc.).

Therefore, as a result of the technological process, breakdowns or dangerous incidents may occur, which require rapid measures to protect the industrial objective, remedy the malfunctions and rescue any people caught. In such situations, the intervention of specialized rescue personnel, properly trained and equipped with breathing apparatus, capable of operating in difficult conditions, is required (fig. 2).



Fig. 2. Petrobrazi Refinery - rescuers

In the aftermath of fires or explosions, the surrounding atmosphere often becomes characterized by elevated heat and moisture levels. Under such conditions, technological intervention and rescue teams are frequently exposed to extremely hot environments while performing their duties. These situations may involve entering burning structures, locating survivors, extinguishing flames, or restoring ventilation systems damaged by the incident. Heat generation within the human body is a natural outcome of metabolic activity. During intense muscular effort—such as training or physically demanding tasks—the amount of heat released rises substantially, in direct proportion to the intensity of the exertion. Maintaining a stable body temperature is essential, as both overheating and excessive cooling can result in severe health risks or even death. A variety of external and individual elements influence how effectively the human body adapts to hot and humid environments:

- Environmental conditions: ambient temperature, relative humidity, radiant heat from surrounding objects, airflow, type and amount of clothing, duration of exposure, workload, weight of carried equipment, breathing apparatus used, confined spaces, and access to water for hydration or cooling.
- Individual characteristics: age, level of muscular activity, overall health, physical work capacity, fitness level, tolerance to heat and humidity, prior experience, and psychological profile.
- Specific health aspects: dehydration, obesity, fever caused by illness or vaccination, gastrointestinal disturbances, diabetes, cardiovascular disease, medication use, recent intense exercise, history of heat-related disorders, inability to sweat, or recent exposure to high temperature and humidity conditions.

During physical exertion, the body adapts through both nervous and neurohormonal regulation. These mechanisms trigger functional adjustments across various systems, with the cardiovascular system showing the most prominent changes. A key cardiovascular adjustment is the acceleration of the heartbeat, which can progress from an average resting range of 60–70 beats per minute up to 120–150 beats per minute during strenuous activity.

2 Research on the way rescuers are trained in the Petrobrasi Refinery

During response and rescue operations, team members frequently cover significant distances while transporting materials, equipment, resuscitation devices, first aid kits, and breathing apparatus [1].

In the context of the oil industry, rescuers are further equipped with protective clothing, including overalls, safety belts, boots, and helmets, in addition to respiratory protection [1,2].

All of these factors, combined with the individual's physical condition, can affect the rescuer's capacity to function in high-temperature and high-humidity environments [2]. Such conditions may result in heat stress, a potentially life-threatening situation [3].

Proper emergency preparedness—including established procedures and specialized training for rescue personnel—enhances the likelihood of successfully completing critical tasks while simultaneously minimizing the risk of heat-related illnesses among team members [3,4].

To investigate the physiological responses of humans under challenging conditions, experimental trials were conducted at the Training Range [4]. These trials involved a team of three rescuers equipped with compressed-air, positive-pressure breathing apparatus [5].

The exercises were performed in practical scenarios, during which two primary physiological parameters—blood oxygen saturation and heart rate—were continuously monitored, alongside changes in visibility, ambient temperature, and humidity [6].

The research included a series of practical tests through the PETROBRAZI refinery training ground, conducted in a simulated environment with smoke, high temperatures and humidity [7,8]. This environment was created with the help of an electric heat generator, smoke machine and humidifiers.

Measurements of blood oxygen saturation and pulse (fig. 3) were made individually for each rescuer [9], starting with an ambient temperature of 20°C and a humidity of 45%, the values being gradually increased in steps of 5°C, up to a maximum of 45°C and 70% humidity.



Fig. 3. Measurement of blood oxygen saturation and pulse rate

3 Monitoring of rescuers during interventions in environments with high temperature and humidity

3.1. Activity No. 1 – walking through the training range at the Petrobrazi refinery using the smoke and temperature machine

As part of this activity, the rescuers went through the training range of the PETROBRAZI refinery, the range being flooded with smoke and high temperatures (fig. 4).



Fig. 4. Walking through the training range at the PETROBRAZI refinery using the smoke and high temperature machine

For this activity, the oxygen saturation in the blood and the pulse are represented in table 1.

Table 1. Blood oxygen saturation and pulse rate

No. crt	Ambient temperature	Rescuer 1		Rescuer 2		Rescuer 3	
		Pulse	SpO ₂	Pulse	SpO ₂	Pulse	SpO ₂
1	20°C	80	98	79	97	69	98
2	25°C	90	96	89	95	82	96
3	30°C	102	92	97	97	99	96
4	35°C	115	93	105	94	110	95
5	40°C	130	91	120	94	126	94
6	45°C	145	92	140	93	142	92

From the investigations carried out within this activity (table 1), it was observed that as the temperature increases, the rescuers' pulse also increases, and the oxygen saturation in the blood decreases (fig. 5).

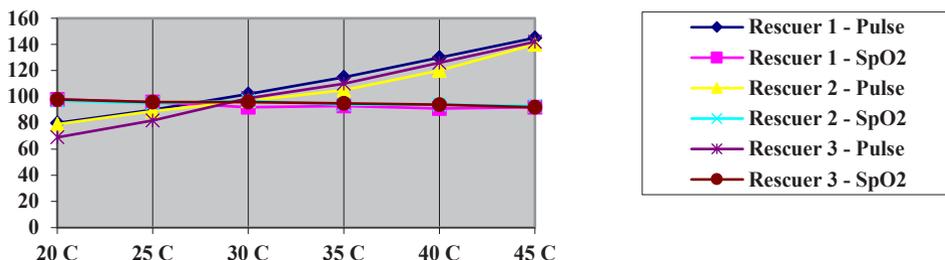


Fig. 5. Variation of pulse and SpO₂

3.2. Activity No. 2 – walking through the training range at the Petrobrazi refinery using the smoke, temperature and humidity machine

As part of this activity, the rescuers walked through the training range at the PETROBRAZI refinery, the range being flooded with smoke, high temperature and humidity (fig. 6).

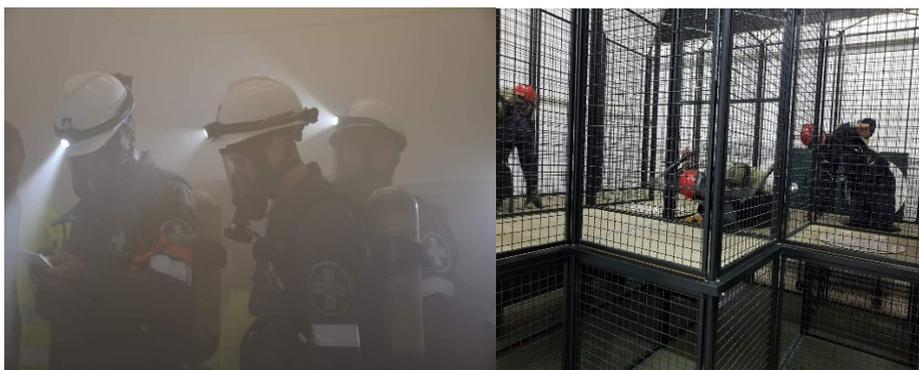


Fig. 6. Walking through the training range at the PETROBRAZI refinery using the smoke, high temperature and humidity machine

For this activity, the oxygen saturation in the blood and the pulse are represented in table 2.

Table 2. Blood oxygen saturation and pulse rate

No. crt	Ambient temperature	Ambient environmental humidity	Rescuer I		Rescuer II		Rescuer III	
			Pulse	SpO ₂	Pulse	SpO ₂	Pulse	SpO ₂
1	20 ^o C	45 %	80	97	79	97	69	98
2	25 ^o C	51 %	104	95	92	95	85	97
3	30 ^o C	59 %	112	93	99	96	99	96
4	35 ^o C	63 %	125	92	114	95	116	95
5	40 ^o C	67 %	146	91	126	93	128	94
6	45 ^o C	71 %	152	91	148	92	149	94

From the investigations carried out within this activity (table 1), it was observed that as the temperature and humidity increase, the rescuers' pulse rate also increases, and the oxygen saturation in the blood decreases (fig. 7).

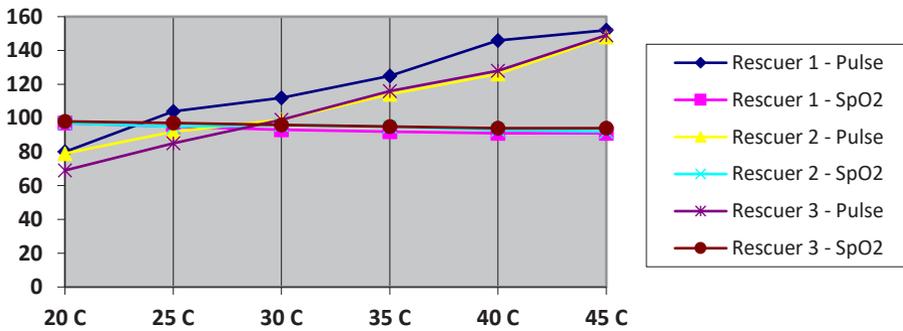


Fig. 7. Variation of pulse and SpO₂

4 Conclusions

The tests carried out included different degrees of effort (activities 1 and 2) which highlighted the fact that the change in the physiological parameters of the rescuers is directly influenced by the amount of work done, the weight of the individual protective equipment as well as the environmental factors (temperature and humidity).

Considering the above, for the rescuers to carry out their work in safe conditions, a value of 45^oC was established as the temperature limit in the intervention area.

The results obtained from the stress tests showed a clear correlation between the level of physical activity carried out and the increase in heart rate, body temperature and oxygen consumption, indicating an increased risk of heat stress in conditions of high temperature and humidity.

The physiological parameters analyzed (oxygen saturation, pulse, temperature) demonstrated a significant variation depending on the degree of effort and microclimatic conditions, underlining the need for continuous monitoring of the rescuer's condition during the intervention.

Sustained physical exertion in combination with exposure to high temperatures can lead to heat exhaustion, which justifies the use of several technical intervention and rescue teams, so that none of the rescuers become excessively tired.

Research on the response of rescuers to interventions in environments with high temperature and humidity confirms the importance of periodic training in simulated heat stress conditions, contributing to the physiological adaptation of rescuers and reducing risks during real interventions.

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