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IMPROVING OCCUPATIONAL HEALTH AND SAFETY IN A METAL HEAT TREATMENT SECTOR

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Abstract: Under various heat treatment conditions, pollutants generated by the production process can harm workers' health and safety. A heat treatment facility is a double–whammy for worker safety—you have the intense physical danger of extreme heat combined with the invisible threat of chemical pollutants. These pollutants vary widely, ranging from relatively non–hazardous agents, known as "separators" , to highly hazardous agents that can cause accidents, poisonings, and occupational diseases. Exposure to excessive radiant heat, especially in physically demanding roles, can lead to heat illnesses – heat exhaustion and heat stroke, the most severe, with heat stroke being a medical emergency that can cause organ damage and death or heat cramps and heat rash, milder, but still debilitating – or reduced performance and increased injury risk – High temperatures cause fatigue and reduced concentration, which significantly increases the risk of accidents, burns, and other injuries from operating heavy machinery or handling hot materials. The assessment of occupational accident and disease risks, conducted through analysis procedures and forecasts using probabilistic calculations, significantly enhances workplace safety by providing conclusions on the level of workers' exposure.
Keywords: H&S, treatment furnace, metal treatment, safety, metal materials, Wellbeing

1. INTRODUCTION

Under various heat treatment conditions, pollutants generated by the production process can harm workers' health and safety. That's an important and often overlooked safety concern. Heat treatment processes, which are essential for altering the properties of materials like metals, plastics, and ceramics, unfortunately generate various pollutants and hazards that can significantly harm workers' health and safety. The risks can be broadly categorized into two major areas: Thermal Stress and Airborne Contaminants. The very nature of heat treatment means high temperatures, which directly impacts the working environment and the workers' bodies. On another side, the heating and cooling of materials, often involving various chemicals, release numerous toxic substances into the air.

Recently, on an international level, emphasis on Occupational Health and Safety (OHS) has increased as a way to help organizations reach their goals, reduce economic losses, and remain competitive in an increasingly dynamic global market. This has heightened concerns about assessing risks related to accidents and occupational diseases among workers, as well as establishing necessary measures to eliminate these risks by specialists.

The goals of Occupational Health and Safety (OHS) are broad, encompassing the physical, mental, and social well–being of all people in the workplace. They can be summarized into three primary, interconnected objectives:

- Primary goal: PROTECTION & PREVENTION, as the fundamental goal of OHS, aiming to eliminate or control all forms of risk in the work environment, which prevent workplace injuries and fatalities, prevent occupational diseases and protect property and assets.
- Secondary goal: MAINTENANCE & PROMOTION, focuses on actively improving the health, capacity, and culture within the organization, maintaining and promoting worker health, improving working conditions and developing a positive safety culture
- Tertiary goal: BUSINESS & COMPLIANCE GOALS, achieving the primary and secondary goals naturally leads to important operational benefits, enhancing productivity and efficiency, ensuring legal compliance and increasing the organizational reputation.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

A robust risk assessment system for accidents and occupational diseases is a foundational component of any effective Occupational Health and Safety (OHS) management system. It is a systematic process designed to proactively identify and control hazards before they cause harm. The system is generally based on a continuous, cyclical process, often referred to as the five steps of risk assessment or a Plan–Do–Check–Act (PDCA) cycle.

The goal is to find everything that has the potential to cause harm, whether it results in an immediate injury (accident) or long–term illness (occupational disease).

- Accident Hazards (Safety): Slippery floors, unguarded machinery, exposed electrical wires, working at heights, traffic routes, fire, and explosion risks.
- Disease Hazards (Health): Chemical exposure (fumes, dust, liquids), biological agents (viruses, bacteria), physical hazards (excessive noise, vibration, radiation, extreme temperatures), ergonomic risks (repetitive strain, poor workstation design), and psychosocial factors (stress, violence, bullying).

For each identified hazard, the risk is evaluated to determine its significance, the objective being to eliminate the hazard or reduce the risk to an acceptable level.

According to the risk assessment system for accidents and occupational diseases proposed by Ștefan Pece, "human safety in the work process is considered the state of the work system in which the possibility of accidents and occupational diseases is excluded." In everyday language, security is defined as "the fact of being 'safe' from any danger. Risk is defined as the possibility of encountering danger, or potential danger." Studies and research conducted at the university level significantly contribute to developing essential guidelines for ensuring well–being at work.

As a result of these significant changes, it can be stated that in recent decades, studies have shown that in the industrial sectors where thermal treatment of metallic materials occurs, a series of polluting substances are emitted into both the working and natural environments, affecting all environmental factors: air, water, soil, subsoil, flora, fauna, living beings, and the relationships between them. If these substances are not monitored and measures are not taken to ensure the necessary protection, their impact could be severe and may be transmitted to the human body above a certain tolerance level, leading to occupational diseases [5].

2. ASSESSMENT OF THE RISKS OF ACCIDENTS AND OCCUPATIONAL DISEASES IN SECTORS WHERE HEAT TREATMENT OF METALLIC MATERIALS IS CARRIED OUT

Heat treatments are technological processes regarded as highly polluting to air, water, and soil. In fact, the correlation is direct: the high–energy and often chemical–intensive nature of the industrial thermal cycle necessary for materials heat treatment inherently results in significant emissions of air pollutants and the generation of hazardous waste and thermal discharges if not managed with appropriate pollution control technologies. This pollution arises because, during heat treatment, the material undergoes a thermal cycle (Figure1) of heating, maintaining a specific temperature, or fluctuating around a temperature, followed by cooling in particular environments.

Heat treatment is a crucial process in metallurgy that involves heating and cooling materials to ac hieve desired properties without changing their chemical composition. The thermal cycle typically consists of three main stages: heating, soaking, and cooling. This process produces emissions of pollutants, impacting the working environment to varying degrees. In the heat treatment hall, several types of heat treatment furnaces are available: primary heat treatment (around 800°C), which includes:

- normalizing and dehydrogenating forged steel;
- treatments for rolling rolls and cold strips, which involve improvement operations (hardening and high tempering),
- double frequency surface hardening, cooling below 0°C, and stress relief;

— heat treatments for enhancing heavy drill rods and turbine rotors, which entail carburizing and nitriding; heat treatment in a molten salt bath; and heat treatment of parts after reworking, which includes homogenization annealing and various thermochemical treatments [6][7].

The thermal cycle of heat treatment (referring to industrial processes like annealing, hardening, tempering, etc., for materials like metals) correlates with pollution primarily through the direct (chemical pollution) and indirect (air pollution from fuel combustion) process emissions. The heating required for the thermal cycle is a significant source of pollution. Heat treatment furnaces, typically powered by fossil fuels (like natural gas or oil) or electricity from power plants, release carbon dioxide (CO2) as a primary by–product of combustion. Combustion of fuels also generates other harmful air pollutants, including:

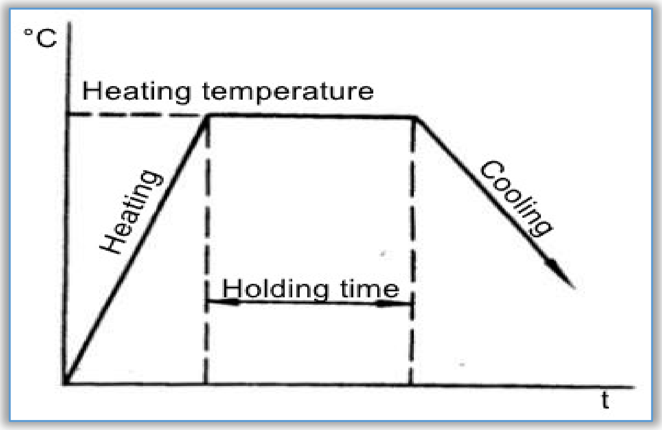

Figure 1. General thermal cycle of any heat treatment

— nitrogen oxides (NOx), formed at high temperatures in the furnace.
— sulfur oxides (SOx), which depends on the sulfur content of the fuel.
— particulate matter (PM), as fine solid particles.
— carbon monoxide (CO), a result of incomplete combustion.

In addition, the specific chemicals used or generated during certain thermal cycles contribute directly to pollution. Many heat treatments use specific gas atmospheres to prevent oxidation (e.g., endothermic, exothermic, or nitrogen–based atmospheres), which can contain toxic and flammable gases like CO and hydrogen (H2). If not properly controlled, these are either flared (burnt off, producing more CO2 and NOx) or, if released untreated, pose a direct environmental and health hazard. Also, spent quenching media (especially oil and salt/cyanide solutions) become hazardous waste requiring complex and environmentally safe disposal to prevent soil and water contamination.

Each type of heat treatment involves a specific technological process and corresponding equipment, each with a different environmental impact. During various production activities, atmospheric pollutants affecting the respiratory tract vary significantly, from relatively non–dangerous agents, called “separators,” to hazardous agents that can cause accidents, poisonings, and occupational diseases [3]. To conduct risk assessments that meet accepted safety standards, the values listed in national standards are primarily considered, especially in the chapter “Air in protected areas – Quality conditions” [9], which provides the maximum permissible concentrations, as shown in Table 1 below.

Table 1 – Maximum permissible concentrations of very hazardous agents

Substance	Concentration maximum allowed (CMA)	
	Short–term average [30 min] [mg/m^3]	Long–term average [daily] [mg/m^3]
Suspended powders	0,5	0,15
CO	6,0	2,0
SO_2	0,75	0,25
NO_2	0,3	0,1

The pollutant concentrations resulting from the investigations are compared to the maximum concentrations allowed in the workplace atmosphere, according to the provisions on minimum requirements for health and safety at work, to ensure the protection of workers from the risks posed by chemical agents [10, 11].

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

In a heat treatment furnace, the pollutants analyzed include nitrogen dioxide, sulfur dioxide, carbon monoxide, suspended dust, and hydrocarbons. The pollutant emission levels were estimated following the World Health Organization's standards [12].

Table 2: The level of emission values accepted

Pollutant	Limit value European Law 462/93 [mg/Nm3]
CO	100
SO_2	35
NO_2	350
Suspendend powders	5

The effects of pollutants on the body are divided into acute (immediate) effects, which happen shortly after exposure, and chronic (long-term) effects, which develop after extended exposure. Fine or coarse industrial dust can be present as suspended dust or as settled dust.

Specific pollutants include nitrogen oxides, carbon monoxide, dust, iron oxides, and alumina, among others [6] [7] [8]. Since workers are exposed when specific values exceed accepted exposure limits, it is crucial to implement measures to protect them by providing appropriate protective equipment and work tools that sufficiently meet the required level of protection.

Monitoring pollutant concentration changes over 12 hours for a furnace with a maximum load of 500 tons used in thermal treatments. The furnace has eight burners with a nominal gas flow rate of 1800 Nmc/h and three flue gas exhaust stacks.

The monitored exhaust pollutants include sulphur dioxide, carbon monoxide, nitrogen dioxide, and particulate matter. The MAXILYZER analyser used allows for the direct determination of the following parameters during measurements:

- CO concentration, in ppm;
- NO2 concentration, in ppm;
- SO2 concentration, in ppm;
- PM concentration, in ppm.

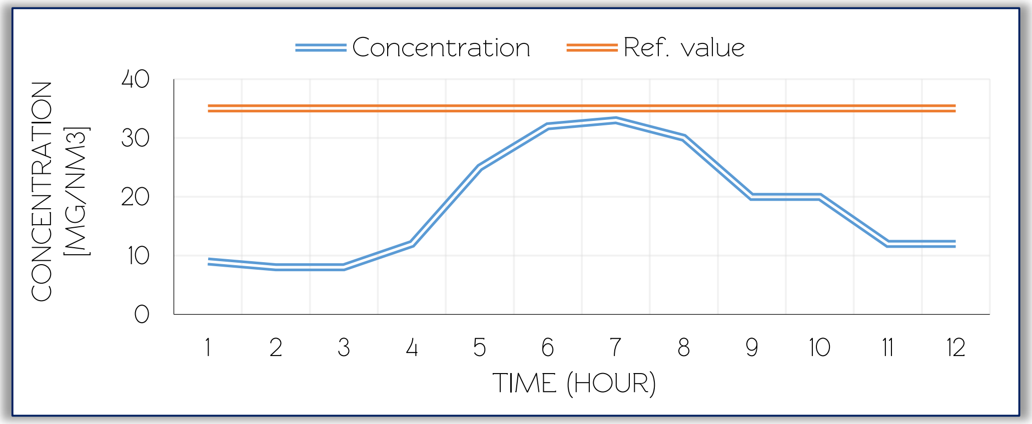

Figure 2. Evolution of SO_2 concentration

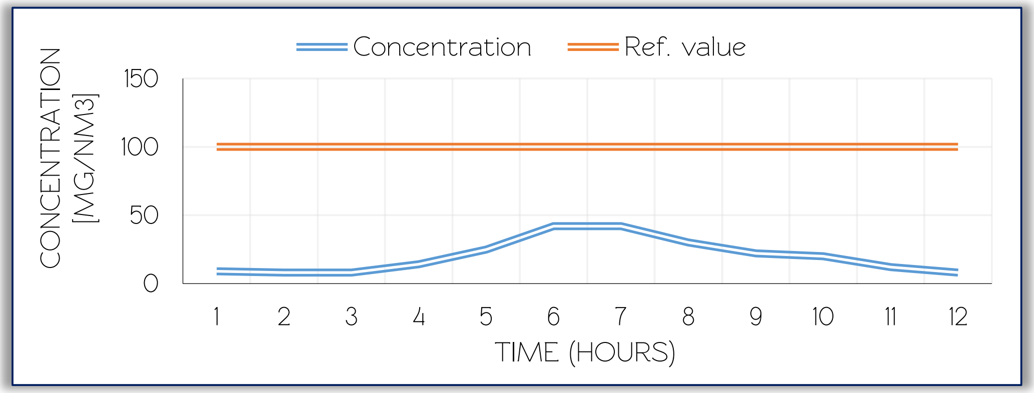

Figure 3 Evolution of CO concentration

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

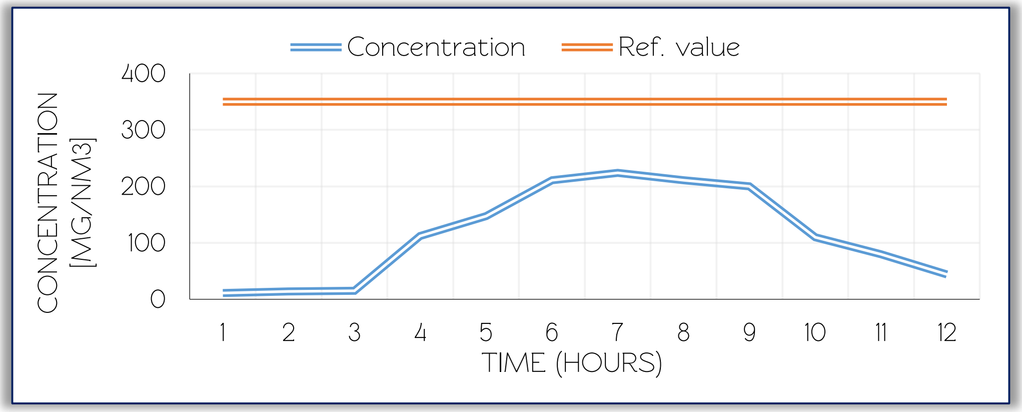

Figure 4. Evolution of NO_2 concentration

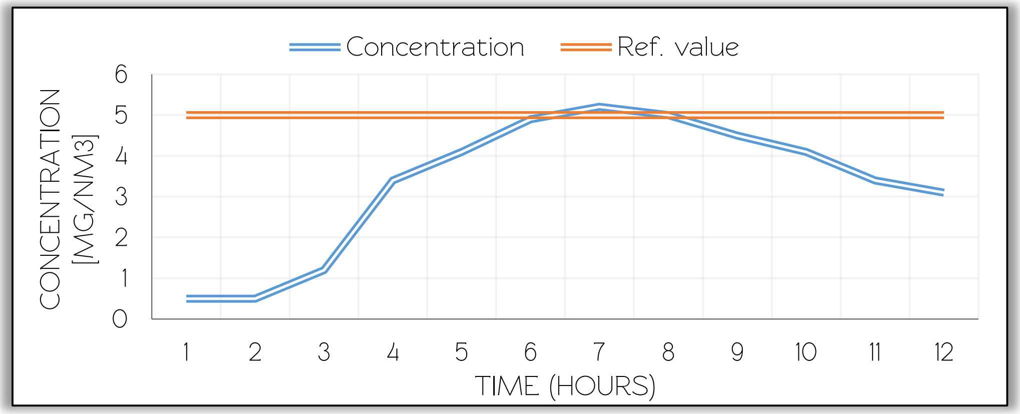

Figure 5. Evolution of industrial powder suspender concentration

3. CONCLUSIONS AND DIRECTIONS FOR ACTION

As a primary conclusion, it is crucial to thoroughly evaluate individuals' exposure levels in heat treatment sectors through a comprehensive risk assessment for injuries and occupational diseases. A comprehensive risk assessment for evaluating individual exposure levels in heat treatment sectors needs to consider thermal stress from the heat itself and chemical exposure from the processes. The comprehensive assessment provides the data needed to move from simply knowing a hazard exists to actively managing and quantifying the individual risk. In the scenario shown in Figure 5, where safety limits are briefly exceeded, the risk assessment must result in additional collective protection measures and specific safety requirements for the equipment used by workers. Acclimatization is an important factor – assess if workers are acclimatized to the heat (this takes time, usually 1–2 weeks), unacclimatized workers having lower exposure limits – and, also, the health surveillance – identifying individuals with pre–existing conditions (e.g., cardiovascular disease, diabetes, certain medications) that make them more susceptible to heat stress.

A second conclusion is that implementing a new ventilation system is essential for effectively removing suspended dust from the activity hall. The final, and arguably most important, part of the assessment is determining how to control the risks. The system should be designed to maintain safe working conditions by extracting dust–laden air from the work areas and facilitating the controlled flow of fresh, treated air, ensuring high–quality local exhaust ventilation, being correctly designed and maintained to capture fumes/heat at the source (e.g., furnace doors, quench tanks). Implement mandatory, acclimatization–based work–rest schedules is an Administrative Control step.

As future development directions, we recognize that technical evolution and advancements in IT technologies, including materials science, will significantly enhance the assessment of H&S risks, reduce occupational exposure risks, and protect workers through humanoids designed and engineered with advanced technology. That's an important factor—the technical evolution of IT has genuinely revolutionized how we approach Health & Safety (H&S) risk assessment. This progress will shift risk assessment focus from solely on accidents and occupational illnesses to also include technological risks. In short, IT advancements have enabled a switch from "What happened?" to "What *will* happen?", making H&S risk assessment a continuous, intelligent, and deeply integrated part of daily operations. That's a sector – metal heat treatment – where Occupational Health and Safety (OHS) isn't just a legal checkbox—it's absolutely critical for the survival and quality of the business. The metal heat treatment sector faces a uniquely severe combination of classic industrial hazards. Improving OHS is important because it directly addresses the catastrophic potential of these risks and yields significant benefits. The core processes of metal heat treatment involve risks that can be instantly fatal or cause life-altering injuries. Improving OHS is paramount to controlling these "worst-case" scenarios:

- Thermal Hazards: Direct contact with furnaces, hot metal, or molten salt baths can cause immediate, severe burns. Prolonged exposure leads to heat stress, heat exhaustion, and heat stroke, which are serious medical emergencies.
- Chemical/Explosion Risks: The use of controlled atmospheres with gases like natural gas, carbon monoxide, or hydrogen creates a constant risk of fire or explosion if leak detection or ventilation fails. Quenching operations, especially with oil or molten salt baths, pose a risk of a violent steam or oil explosion if water contamination occurs.
- Respiratory Hazards: Heating metals or using chemical quenchants releases toxic fumes, mists, and fine particulates. Inhalation can lead to acute symptoms or long-term diseases like lung damage.
- Mechanical and Electrical: Handling heavy parts, operating powerful machinery, and working with high-voltage equipment (like induction furnaces) introduce risks of crush injuries, lacerations, and fatal electric shock.

Beyond the moral and legal imperative to protect workers, superior OHS performance is a non-negotiable business advantage in the heat treatment sector. OHS is inextricably linked to process control. In essence, in heat treatment, safety is quality, and quality is business. We can't separate the two because a single failure in process safety can ruin a part, a machine, or a life.

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ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

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