# Occupational Safety in Adverse Thermal Environments - Brief Review

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## Abstract
Workers in mining, smelting or baking are constantly subjected to hot environments, humid or dry, affecting them in some way. This article aims to present some results from a literature review about the relationship between environmental conditions (thermal) and occupational safety. For this purpose, was performed a bibliographic research on the subject in accordance with PRISMA Statment. Despite the existence of that relationship be consensual among the different authors, the obtained results suggest that published studies only approach the problem in a qualitative perspective. Therefore it was concluded that there are currently no relevant studies that clearly quantify this relationship and thus further research should be done on the subject.

**Keywords:** Hot Environment, Mining, Thermal Stress.

## 1. INTRODUCTION
In this short paper it is addressed the problem of the relationship between hot and humid thermal environments and work. Taking as effective the existence of this relationship it's important to understand how these working conditions influence the risk levels and affect workers' health and safety. With this purpose the following questions were posed:
- Does the thermal environment an important factor in workers performance in safety issues?
- If so, is the relationship between these two variables sufficiently studied and quantified?

In order to answer these questions a literature review was conducted, whose results will be summarized as short review..

## 2. METHODOLOGICAL APPROACH
To achieve the stated objective, it was conducted a bibliographical research, oriented towards interest topics, using the following keywords: "heat", "heat stress", "heat treatment", "high-temperature", "hot environment", "hot temperature", "human health", "mines", "mine accident rate", "mine heat", "safety", "safety index", "thermal", "thermal comfort", "thermal stress", "thermal environment", "thermal index". For that purpose, it was used the search engine Metalib ®. Generally, the keywords were used individually refining the search by combining keywords and restricting its introduction only to the fields 'title' and 'subject' and selecting only documents with the 'abstract' focused on, at least, one of the interest topics. Should be noted that the survey was conducted for papers published between 2000 and 2013, according to the PRISMA statement guidelines (Liberati et al. 2009), using databases (Academic Search Complete, Compendex, Current Contents, ERIC, SCOPUS, Inspec, Web of Science) and scientific journals (from ACM Digital Library, ACS Journals, Annual Reviews, ASME Digital Library, CE Database (ASCE), Emerald Fulltext, IEEE Xplore, ScienceDirect). Finally, the application of this methodology has returned 570,023 documents from which 170 were identified as relevant to the scope of the present study.

## 3. THEMATIC DISCUSSION
The thermal environment is a central element for the working conditions analysis, particularly in sectors with more severe characteristics such as underground mines, metallurgy, foundry, greenhouses, construction, agriculture and fire-fighting, between others. Its influence encompasses three fundamental factors for workers and also for companies (Niemela *et al*. 2002), namely, the safety conditions, productivity levels and, overall, workers health. The present article is primordially focused on the relationship between hot environments and occupational safety. However, some specific references to other identified elements (health and productivity) will be done, as a way to integrate causes and consequences, in an integrative holistic perspective.
About thermal environment and its effects in humans, several approaches have been used for an overall understanding of the problem. Those approaches are based on different subjects, namely, heat balances, effects on workers, methods and indices for monitoring and controlling, technological changes and engineering measures, among others.
From the multiplicity of issues that arise and necessarily has to be taken into account for a comprehensive approach to this problem, will be only addressed those considered the most relevant.
In a qualitative perspective, Ribeiro (2010) states that the adverse effects of heat do not generate pain nor limitations, so the workers tend to ignore the early symptoms of this kind of pathology, which combined with its persistence in workplaces, endangered their health and safety. Lamberts & Xavier (2002) showed that when human beings performed their tasks subjected to heat stress conditions, they exhibit, among other symptoms of overall health debility: changes in psycho-sensory reactions and decrease of production capacity. Under the same conditions, Sá (1999) states that the concentration and physical capacity of workers is affected, which, of course, will compromise the company productivity and, not least, will create favourable conditions for accidents occurrence. Other approaches mention that increasing air temperature promotes the adoption of risk behaviours (Bobko & Chernyuk, 2008) and enhances the occurrence of errors and accidents. According Costa et al. (2011) these effects are clear above 30ºC. In addition to these ideas, in a recent

work, Yi & Chan (2013) state that heat stress has physiological effects on workers, can lead to a reduction of productivity and working enthusiasm, increase the rate of incidents and diseases caused by heat, which can lead even to death.
The examples given allow answering positively to the first raised question, ie, it appears being consensual that the thermal environment (hot) has a negative and decisive influence on the workers' safety conditions.
It should be noted that the generality of the authors refer to the subject in a descriptive perspective, not quantified, which leads to a another question: is the relationship between these two variables well-known?
In fact, the conducted bibliographic research did not provide the information required to measure the "intensity" and "depth" of the interaction between thermal environment and occupational safety.
Indeed, were identified several studies that quantify the effects of such environments on health (Barr, Gregson, & Reilly, 2010), (Schulte & Chun, 2009), (DeVaul, 2008), or on productivity loss (Wyon, 2010), (Seppänen, Fisk, & Faulkner, 2005), (Eston, 2005), but not to the occupational safety, in the requested terms. Behind this gap there are several causes or factors, among which it must be considered as the most determinants the following ones:

- Occupational safety is a variable very difficult to quantify. Accidents are multifactorial and discrete events, being, by that, very difficult to isolate the effect of one only factor. There are several attempts to do that, but the problem is far to be solved.
- The performance in this field depends on used equipments (Dragosavuevic, Ivkovic, & Miljanovic, 2010), physical measurements (Bates, 2005) and in the work organization (Szwedzicki, 2003) adopted to increase safety in the production process for each one of the operations; also the characteristics, training, attitudes and behaviours of individual workers are important (Barr, Gregson, & Reilly, 2010; Liu & Zhang, 2011). The variety of factors to consider, multiplies the number of possible responses to a given thermal environment's reality, requiring the collection of a broad set of data (in quality, quantity and time) in order to remove the effects of eventual biases produced by the other variables.
- There are no known studies that directly correlate occupational safety and thermal environment in a quantitative base. The values and ratios (e.g. incidence, frequency, severity) as determined in the available quantitative studies (for instance in Sanmiquel, Freijo, Edo & Rossell (2010)) arise from the combination of all the factors conditioning the variable "safety" and, therefore, is not possible to identify the contribution of each isolated parcels and hence take apart the effects of the thermal environment. Complementarily, another constraints to the measurement of that variable is the profusion of metrics used in the evaluation, such as, for example, the number of lost working days (Kukic, Ikanovic, & Kudumovic, 2009), the accident frequency rates (Vazirinejad & Esmaeili, 2009) or the cost of medical care (Houtven, *et al*. 2010). It can be pointed that does not exists an universal calculation method, which prevents the comparative analysis of results and precludes the validation of the information consistency.

The above description highlights the practical difficulties of establishing a cause / effect relationship between the two variables under consideration. In short, the difficulty in overcoming the presented constraints leads to the absence of quantitative information available and validated, needed to isolate the effect of the thermal environment conditions in workers safety. So the answer to the second question is negative. There is the need and the space for the development of future studies aiming to quantify the interaction between the two variables and to support the qualitative consensus on the subject.

## 4. CONCLUSIONS

The importance and impact of the thermal environment on the workers safety conditions is consensual evidence. However, this finding is also based on qualitative information. This problematic is not easy to solve and the discussion remains open. Despite the existence of research groups all over the world investigating problems related to hot and very hot environments remain unquantified their effects on occupational safety. This situation will have to be solved, due to the intensification of problems related to the predicted climate changes and the current realities of the markets in which the workers and companies are moving.
*It is time to recognize the importance of heat stress as a public health issue and conduct scientific studies, (...) to formulate guidelines regarding to the safety measures to adopt"* (Dash & Kjellstrom 2011). In particular the mining sector, the i*nvestments in safety are good as gold (...) the mining companies that do not have this into account will probably fall* (Logsdon 2009).

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