A Safe and Sustainable Development in a Hygiene and Healthy Company Using Decision Matrix Risk Assessment Technique: a case study

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Keywords

Abstract

Overall risk rate
This article describes the process of improving risk management practices in a foundry of the ALFET Company (Algeria). The proposed methodology is based on the decision matrix risk assessment technique. This technique allows making a risk assessment for each source of risk (machine, man, environment, and management), which leads to the determination of the overall risk rate during the activity by a new concept. The latter giving a comprehensive vision of occupational health and safety, and compares it with the ALARP principle to determine the acceptability of risk. The main goal of this work is to inculcate a culture on the effects of changing behaviors and attitudes, to disseminate the culture of continuous and sustainable progress within the enterprise, and to ensure that a good atmosphere is maintained in the workplace. It aims to protect and promote the health and safety of workers and the working environment in order to promote a safe and sustainable development company. Our work shows that the working environment is tolerable in terms of health and safety at work. However, to promote a safe and sustainable development in company, an action plan based on the evaluation of the field and feedback through priority actions is recommended for continuous improvement in OSH. Toward the workplace should be continuously monitored to detect risk factors as early as possible before they have negative effects.

Occupational health and safety

Environment

Sustainable development

Evaluation

Prevention

1. Introduction

According to an analysis, one of the most affected areas in the City of Tiaret is the Algerian Foundry ALFET [1], and in particular, the working environment in the foundry. From now on, every organism is responsible for the occupational health and safety of its workers in all the aspects related to work [2]. This responsibility includes promoting the wellness and preserving the physical and mental health [3] according to a comprehensive and coherent prevention policy. On the basis of this legislation, and as an illustration of this work, the study of this company will be detailed. It is recommended to identify and upstream all the risk factors having negative impacts on the working climate and the health of workers, and any alteration in the worker’s state of health affecting his functional abilities and his work [4, 5]. The consequences of these factors now lead to functional limitations that affect the quality of work life and quality of work and even the company’s perceived performance: sustainability and development [6, 7]. As a result, these conditions must be controlled by the employer in order to offer the employees a quality-working environment or even to increase the so-called positive atmosphere conducive to the productivity and competitiveness of the enterprise [8]. Subsequently, the magnitude knowledge of the risk factors present in the organization allows for an overview, a “risk mapping” of the organization, which is crucial for choosing the best direction to take in prevention [9, 10]. In addition, it makes
additional arguments about the need for action. The portrait of risk factors provides an opportunity to identify concrete problems, rooted in the specific characteristics of the organization on the spot and in the experience of employees. Taking a portrait involves identifying certain management practices that have a negative impact on the working environment, and the well-being and health of the workers [11]. However, the working environment of foundries is dangerous and characterized by spontaneous exposure to multiple occupational chemical, physical, mechanical hazards, etc. [12, 13]. In addition, the employees working in confined and poorly-ventilated areas have no vocational qualifications. This exposes them to many occupational risks. Therefore, a risk assessment is necessary, objective of the work. The latter consists of identifying the hazards and analyzing the conditions of exposure to these hazards. It emphasizes on the idea of preventing the occurrence of accidents and occupational diseases rather than simply identifying and analyzing accidents and detecting the existing pathologies. It is the initial and essential step in preventing occupational accidents and diseases within the company [14]. The number of work accidents recorded at the ALFET smelter is increasing rapidly and continuously from one year to the next, and even 22 accidents in 2013 to 68 accidents in 2018. What justifies this study, and to carry out an assessment of the occupational risks in the sector of the foundry and in particular to protect and promote the health and safety of workers, protect the environment and promote a safe and sustainable development.

2. Work methodology

The proposed work methodology is based on the DMRA (Decision Matrix Risk Assessment) technique (Figure 1). It is a systematic approach to risk estimation that involves measuring and categorizing risks on the basis of informed judgement, both in terms of probability and consequences and relative importance [15, 16]. This is a quantitative and graphical method that can help the risk managers to prioritize and manage the key risks [17]. This technique allows conducting a risk analysis and assessment for each risk source (machine, human, environment and management), then the overall risk rate during the activity proposed by a new concept is determined (Formula 1).

\[
\text{Overall Risk Rate} = R_{\text{Machine}} \times R_{\text{Human}} \times R_{\text{Management}} \times R_{\text{Environment}}
\]

Furthermore, based on the principle, zero risk does not exist [21], and Equation (1) can be proposed in order to determine the level of overall risk during the activity.

Figure 1. Risk matrix [16].
determined by comparing that with the ALARP principle (as low as reasonably practicable) [22]. The method of work proposed in this article is illustrated and clearly clarified in Figure 2.

For a more accuracy, a risk zone model is proposed to locate the perception level of overall risk, and even manage to identify the priority actions to be started and where we must act (Figure 3).

![Figure 2. Diagram illustrating the working methodology.](image)

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For a more accuracy, a risk zone model is proposed to locate the perception level of overall risk, and even manage to identify the priority actions to be started and where we must act (Figure 3).

![Figure 3. Proposed example of risk areas to determine overall risk.](image)

**Figure 3. Proposed example of risk areas to determine overall risk.**
The idea behind this proposed model is to multiply the 4 sources of risk (each source at a Green-Yellow-Red risk level) to determine the overall risk level.

3. Case study: ALFET foundry
This work was conducted in an ALFET foundry company.

3.1 Presentation of company
The Algerian foundries is a subsidiary of the foundry group of Algeria FONDAL located in the City of Tiaret in the west of Algeria. It was created in 1983. Its production capacity is 830 Tonnes/year of Cast iron and 4000 tonnes/year steels. ALFET’s sectors of activity:
- Cement industry sector: manufacture of the manganese steels, impact parts...
- Steel industry sector: manufacture of all-dimensional coating plates, all-dimensional casting mothers...
- Buildings, Quarries, and Mine sector: manufacture of wear blades and various blade doors, jaws, and crushing hammers of different dimensions.
- Agricultural machinery sector: manufacture of pulleys, Coils, Disc Plates, Grid Bars, and Service Spares.
- Mechanical and public works: Manufacturing various parts for public work equipment and miscellaneous parts for hydraulic equipment.

The Algerian foundries of Tiaret use many types of sand, which are used to make molds and cores for molding these metal parts. Mostly siliceous sand (original sand) supplemented by binders according to the intended applications and the type of alloy [23] (Figure 4).

Figure 4 illustrates the actual working situations at the Algerian foundry, and shows some equipment and operations of their production. This work was conducted at workshops and workplaces at the ALFET foundry. The first findings were poorly lit rooms and overcrowded ground and traffic areas. There was no storage space in all workshops. No workshop had an adequate ventilation and air conditioning. Bad smells and warm atmospheres were present in all the workshops. This motivated this work, the purpose of which was to carry out an occupational risk analysis and assessment in this foundry in order to put in place a more efficient plan that meets the industrial hygiene and safety expectations.

3.2 Statistics of accidents at work recorded at ALFET:
The data collection and the statistics on accidents at work were realized by means of the National Social Insurance Fund (CNAS) and supplemented by visits to workshops in actual working situations. The activity in these workshops consisted summarily of fusion (put in the oven), molding (making molds according to the customer’s model...
and casting in the molds), demolding (removing the finished product from the molds), finishing (cutting the weight weights, scraping the roughness, filing, and polishing the finished product).

3.3. Application of Decision Matrix (DMRA) Risk Assessment Technique

In the context of the risk matrix, the value of risk is a discrete value corresponding to the consequence categories (Table 1). It is logical that the categories are placed in order along the (ordered) sides of the risk matrix, i.e., the consequence categories should be classified from the least serious to the most serious, and that the probability categories should be classified from the lowest to the highest [24, 25]. The accidents are recorded in the company during the year 2018 are distributed as follow (Table 2):

<table>
<thead>
<tr>
<th>Source of risk</th>
<th>C1: Insignificant consequences</th>
<th>C2: Significant consequences</th>
<th>C3: Serious accident</th>
<th>C4: Major accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Machine</td>
<td>9</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Risk Human</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Risk Environment</td>
<td>2</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Risk Management</td>
<td>8</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

This table shows the accidents at work classified by severity that occurred at the ALFET foundry during 2018. There were 68 accidents distributed as follow: 15 accidents at work for environmental risk including 13 accidents with significant consequences and 20 accidents for risk management including 12 with significant consequences.

3.4. Development of risk matrix:

Before implementing the preventive measures, it is essential to identify the occupational risks incurred by the employees [26, 27]. At present, however, different types of hazards exist, and it is very difficult to establish them as long as the situations are different; the same applies to the prevention or control of the related hazards. However, a general overview of frequently encountered risk situations can be drawn, and then the level of risk can be determined and the priority actions identified.

Risks related to Machine (Table 2):

<table>
<thead>
<tr>
<th>Likelihood Classes</th>
<th>Consequence Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Risks related to operators (Table 3):

<table>
<thead>
<tr>
<th>Likelihood Classes</th>
<th>Consequence Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Risks related to work environment (Table 4):
Table 4. Risk environment matrix.

<table>
<thead>
<tr>
<th>Likelihood classes</th>
<th>Consequence classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Risks related to management (Table 5):

Table 5: Risk management matrix.

<table>
<thead>
<tr>
<th>Likelihood classes</th>
<th>Consequence classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

3.5. Results of DMRA

According to the four sources of risk assessed by the Decision Matrix Risk Assessment (DMRA), the following results can be seen with the corresponding analysis. For risks related to machine (Table 6):

Table 6. Likelihood classes and consequence classes of machine risk

<table>
<thead>
<tr>
<th>Risk Machine</th>
<th>C1: Insignificant consequences</th>
<th>C2: Significant consequences</th>
<th>C3: Serious accident</th>
<th>C4: Major accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>9</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probability to happen with its consequence</td>
<td>F4: Frequent</td>
<td>F4: Frequent</td>
<td>Very improbable</td>
<td>Very improbable</td>
</tr>
<tr>
<td>R</td>
<td>R4 Recoverable injuries</td>
<td>R8 Single fatality and several injuries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the statistics, the use of machines led to 29 accidents, classified as 9 non-significant consequences and 20 significant consequences. It was determined that the injuries were recoverable; only one death and several injuries may be presented. Therefore, it appears that the risks associated with machines are classified in the yellow zone (intermediate risks). Actions must therefore be taken to reduce and minimize the risks identified. Where appropriate, the intermediate risk requires actions to be prioritized immediately to reduce this risk to an acceptable level.

Risks related to the operators (Table 7):

Table 7. Likelihood classes and consequence classes of human risk.

<table>
<thead>
<tr>
<th>Risk Human</th>
<th>C1: Insignificant consequences</th>
<th>C2: Significant consequences</th>
<th>C3: Serious accident</th>
<th>C4: Major accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probability to happen with its consequence</td>
<td>F1: Very improbable</td>
<td>F2: Improbable</td>
<td>F1 : Very improbable</td>
<td>F1 : Very improbable</td>
</tr>
<tr>
<td>R</td>
<td>R1 No personal harm</td>
<td>R4</td>
<td>R3 Single fatality and several injuries</td>
<td>R4</td>
</tr>
</tbody>
</table>

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For the risks related to operators (human), 4 accidents occurred, which were classified as having insignificant consequences and significant consequences. It can be determined that recoverable injuries, one death and several injuries, can be presented. Therefore, it appears that the operator (human) risks are classified in the yellow zone (intermediate risks) and the green zone (acceptable risk). Actions must therefore be taken to reduce the risks identified. Where appropriate, the intermediate risk requires actions to be prioritized to reduce this risk and without neglecting the daily preventive and corrective actions for the acceptable risk. Risks related to work environment (Table 8):

<table>
<thead>
<tr>
<th>Risk Environment</th>
<th>C1: Insignificant consequences</th>
<th>C2: Significant consequences</th>
<th>C3: Serious accident</th>
<th>C4: Major accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>2</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probability to happen with its consequence</td>
<td>R1 (Very improbable)</td>
<td>R8 (Frequent)</td>
<td>R3 (F1: Very improbable)</td>
<td>R4 (F1: Very improbable)</td>
</tr>
</tbody>
</table>

For environmental hazards, 15 accidents occurred, which were classified as 2 with insignificant consequences and 13 with significant consequences. It can be determined that recoverable injuries, one death and several injuries, can be presented. As a result, it appears that the environmental risks are classified in the yellow zone (intermediate risks) and the green zone (acceptable risk). Thus actions must therefore be taken to reduce the risks identified. Where appropriate, the intermediate risk requires actions to be prioritized to reduce this risk and without neglecting the daily preventive and corrective actions for the acceptable risk. Risks related to management (Table 9):

<table>
<thead>
<tr>
<th>Risk Management</th>
<th>C1: Insignificant consequences</th>
<th>C2: Significant consequences</th>
<th>C3: Serious accident</th>
<th>C4: Major accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>8</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probability to happen with its consequence</td>
<td>R4 (F4: Frequent)</td>
<td>R8 (F4: Frequent)</td>
<td>R3 (F1: Very improbable)</td>
<td>R4 (F1: Very improbable)</td>
</tr>
</tbody>
</table>

For management risks (company OSH policy), there were 20 accidents, classified as 8 non-significant consequences and 12 significant consequences. It was determined that recoverable injuries, one death and several injuries, could be presented. Therefore, the following actions must be taken to reduce and minimize the identified risks, where appropriate for the intermediate risk requires actions to be prioritized immediately to reduce that risk to an acceptable level. Following this evaluation, it can be noted that the breakdown is as follows (Table 10):

<table>
<thead>
<tr>
<th>Source of risk</th>
<th>Accident number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Machine</td>
<td>29</td>
<td>43%</td>
</tr>
<tr>
<td>Risk Homme</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>Risk Environment</td>
<td>15</td>
<td>22%</td>
</tr>
<tr>
<td>Risk Management</td>
<td>20</td>
<td>29%</td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>100%</td>
</tr>
</tbody>
</table>
This table shows us that the highest risk is the 43% machine risk, and then the 29% management risk, the 22% environmental risk, and finally, the lowest is the 6% human risk. The following figure illustrates the percentage of each source of risk present in the ALFET foundry.

![Risk levels and their distribution in ALFET company](image)

**Figure 5. Risk levels and their distribution in ALFET foundry.**

### 3.6. Calculation of overall risk rate

Based on this result, the overall risk rate is determined by the following equation:

\[
\text{Overall Risk Rate} = R_{\text{machine}} \times R_{\text{human}} \times R_{\text{environment}} \times R_{\text{management}} \\
= 0.43 \times 0.06 \times 0.22 \times 0.29 \\
= 1.3 \times 10^{-3} \text{ mort/an}
\]

### 4. Discussions and recommendations

Generally, to determine the acceptability of the risk, a comparison must be made with the ALARP principle [28], and thus it can be found that \(1.3 \times 10^{-3}\), and therefore, the risk level is tolerable at the ALFET company. In addition, the four sources of risk are in the green and yellow zones so the overall risk is **Tolerable** (ALARP Region). Thus we arrive through this work to assess the professional environment at the Algerian foundry to establish the necessary preventive measures, ensure the health and safety of the employees and well-being, and the improvement of the working conditions (Figure 3).

Finally, we end this work with the following practical recommendations:

**1) For risk machine**, the health and safety managers must:
- Strictly apply the general principles of prevention;
- Report machinery hazards; all machinery must carry warnings, signs, and warning devices essential for the safety of workers (crash sign, high voltage electrical hazard, etc.);
- Minimize noise and vibration from machinery (80 dB(A) vibration exposure alert threshold for 8 hours of work);
- Take into account the state of technology evolution (managers must be up to date with the technology market of their industrial domain, the latest products, new methods, scientific articles, etc.).

2) For **risk human**, health and safety managers must:
- Enforce the use of personal protective equipment by operators; health and safety managers must be rigorous, stop the operator; and give him warnings);
- Motivate, sensitize, and give appropriate instructions to the workers to ensure their safety and protect their health (increase in wages and a no-accidents bonus);
- Conduct periodic operator training; for example, every 6 months, the health and safety manager must explain to their workers the dangers that exist and raise awareness of how to protect them;
- Medical surveillance: a medical sheet for each operator contains last name, first name, age, state of health, nature of workplace, hazards to be exposed.

3) For **risk environment**, health and safety managers must:
- Have an adequate ventilation of workplaces to avoid any alteration of the workers' health;
• Respect hygiene rules; a good floor holding by suction or by a wet process (water jet or water vapor system) is essential to avoid the accumulation of spills and dust under or around machinery.

• Have good lighting in workshops to eliminate the health and minimize accidents. Finally, good lighting is a factor of both physical and moral comforts (the average illumination to be maintained must not be less than 200 lux).

• Identify, remove/control hazardous agents and factors related to the workplace. As a result, the workplace will be continuously monitored to detect, prevent and control the risks associated with the occupational activities. As a result, the workplace should be continuously monitored to detect, remove or control hazardous agents and factors before they have negative effects. This work enables the decision-makers to classify the work-related hazards according to their severity and likelihood of occurrence, even manage to draw up an action plan based on the priority actions to be undertaken and thus engage in a process of continuous improvement based on the feedback. This approach can be generalized for other sectors.

References


• Finally, the employer is required to determine the preventive measures to be implemented (human, organizational, technical) by giving priority to the collective over the individual, while engaging in a process of continuous improvement based on the feedback, the assessment of risks and the opinions of the employees of actual knowledge acquired in the field.

5. Conclusions

The analysis shows that the Algerian foundry in Tiaret is in a tolerable position from the viewpoint of health and safety at work. Therefore, an action plan is required for continuous improvement in OSH to promote a safe and sustainable development in the workplace. One of the goals of occupational health is to protect and promote the health of workers, to protect the environment, and to promote a safe and sustainable development. Thus the role of occupational hygiene is precisely to prevent and control the risks associated with the occupational activities. As a result, the workplace should be continuously monitored to detect, remove or control hazardous agents and factors before they have negative effects. This work enables the decision-makers to classify the work-related hazards according to their severity and likelihood of occurrence, even manage to draw up an action plan based on the priority actions to be undertaken and thus engage in a process of continuous improvement based on the field work and the feedback. This approach can be generalized for other sectors.

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چکیده:

این پژوهش به هدف شوهمی‌سازی فرآیند مدیریت ریسک در کارخانه دوب آهن شرکت ALEFT در الجزایر شرح می‌دهد. روش پیشنهادی مبتکر بر روش ماتریس ALARP در جامعه در شرایط حساس و حساسیت‌های مختلف اعمال شده است. این پژوهش به هدف ایجاد یک روش جدید و قابل قبول در مدیریت ریسک در کارخانه دوب آهن شرکت ALEFT در الجزایر می‌رود. کارگران و مدیران کار با نگرش و مدیریت ریسک که مطرح کار از نظر بهداشتی و امنی در محل کار مناسب است، به نحو منظور ارزیابی نیازمندی‌های پیش‌فرض مداوم و پایدار در شرکت و اطمینان از حفظ جوی مناسب در محیط کار است، این هدف برای حمات و ارتقای سلامت و ایمنی کارگران و مدیران کار با نگرش و مدیریت ریسک که مطرح کار از نظر بهداشتی و امنی در محل کار مناسب است، با این وجود به منظور ارتقای توسعه پایدار و ایمنی شرکت، یک برنامه عملی بر اساس ارزیابی زیست و بازخورد آن از طرق اقدامات اولویت‌دار برای بهبود مستمر در توصیه می‌شود. به این منظور ماتریس کار پایه بطور مداوم برای پایان عوامل خطر در سری‌ترین زمان ممکن قبلاً الگوگذاری می‌شود که نیاز مورد بررسی قرار گیرد.

کلمات کلیدی: میزان خطر کلی، بهداشت و ایمنی شغلی، محیط زیست، توسعه پایدار، ارزیابی، پیشگیری