ISSN-L 2664-9969; E-ISSN 2706-5448

UDC 658.382:005.334:666.94
DOI: 10.15587/2706-5448.2026.344218

Razika Aouad,
Samira Belhour,
Rachid Chaib,
Djamel Nettour

THE IDENTIFICATION OF CRITICAL OCCUPATIONAL RISKS AND THE DETERMINATION OF PRIORITY PREVENTIVE MEASURES IN THE ROTARY KILN AREA OF CEMENT

The objects of this research are occupational risks and priority preventive measures in the zone of the rotary kiln used in cement production. The identification of these objects is essential for housing development and infrastructure, but cement production is involving serious professional risks. Consequently, an evaluation of these is necessary; it is a critical stage in prevention process, aiming to prioritize actions in order to implement preventive measures. Therefore, an evaluation was triggered following a noticeable increase of five (05) accidents compared with 2021, with 16 accidents in 2022, to which workers in the rotary kiln zone were exposed. The adopted methodology, namely risk mapping, constitutes a strategic management tool that enables the identification, assessment, prioritization, and visualization of potential threats affecting the study area. Widely applied in industrial contexts, it offers a comprehensive representation and a systematic inventory of existing and potential hazards in both temporal and spatial dimensions. This facilitates risk management in a more informed and effective way. Furthermore, this offers decision-makers a clear overview to develop proactive action plans and allows them to monitor the effectiveness of implemented strategies. To obtain good results, qualitative and quantitative methods were applied, including the Ishikawa diagram, FMEA, and root cause analysis. These tools enabled the identification of the root causes of accidents in the studied zone. The survey results prove that gas leaks constitute the most critical hazards because of their potential to initiate fires. The findings offer a clear and comprehensive overview of occupational hazard distribution in the study zone, supporting the development of a planned prevention strategy to safeguard workers' health, enhance operational safety, and foster a sustainable safety culture.

***Keywords:** risk mapping, management, cement plant, safety, decision support tools and prevention.*

Received: 21.11.2025
Received in revised form: 21.01.2026
Accepted: 11.02.2026
Published: 28.02.2026

How to cite
Aouad, R., Belhour, S., Chaib, R., Nettour, D. (2026). The identification of critical occupational risks and the determination of priority preventive measures in the rotary kiln area of cement. Technology Audit and Production Reserves, 1 (2 (87)), 66–74. https://doi.org/10.15587/2706-5448.2026.344218

1. Introduction

The assessment of occupational risks (EvRP) is a crucial step in the prevention process. It is the starting point to ensure the sustainability of any company, and even to avoid any kind of physical, material, or environmental damage [1]. Generally, the existence of uncontrolled hazards generates occupational risks causing accidents, illnesses and, in some situations, can lead to disasters (material, bodily and environmental damage). Thus, ensuring the safety and health of employees and developing a safety culture is a priority for any enterprise [2]. The health of the enterprise is the health within the enterprise. Therefore, occupational health and safety (OHS) has become a public health priority and a major concern in human resource management, particularly in high-risk sectors [3, 4]. Additionally, employers should ensure that prevention is an integral part of all activities. Unfortunately, with the permanent intervention of man, the lack of training and information, and the negligence of certain, the risk is constantly present [5, 6]. It is important to remember that these shortcomings create risks. These risks are events that prevent a company from achieving its strategic objectives [7, 8]. Therefore, the essence of the occupational hazard identification process lies in the detailed characterization of factors that influence the consequences and likelihood of an event occurring. The more precisely it is possible to define and examine the existing hazards, the more accurately it is possible to assess the associated risk. In every activity, decision-makers strive to avoid the consequences of identified risks or reduce the likelihood of their occurrence. Dues, the more precisely it is possible to define and examine existing hazards, the more accurately it is possible to assess the associated risk. In any activity, decision-makers strive to avoid the consequences of identified risks or to reduce the likelihood of their occurrence. Consequently, occupational risk assessment is a crucial step in any prevention approach [9, 10]. Implementing a prevention approach will help to improve the company's step-by-step human and economic performance, objective of this work. To this end, occupational risk assessment (ORA) is the starting point for guaranteeing the sustainability of any business, and above all for avoiding any physical, material or environmental damage type [11]. It is an essential element in the development of a company's risk prevention and management policy [1, 12]. Henceforth, establishing a safety culture in enterprise plays a key role to health for employees [13, 14].

As a case study, the Hamma Bouziane Cement Plant, located in Constantine, Algeria, was selected due to its significance across multiple economic sectors. Cement plays an essential role in the development of housing and infrastructure; however, its production poses serious health, social, and environmental risks [15, 16]. Due to the nature of its production processes, this industry is considered among the most hazardous industries [17]. Therefore, to ensure safety in cement manufacturing, management is required to proactively identify and control common operational risks [18] and workers should prioritize practical risk assessment to reduce incidents [17].

Workforce diversity across (gender, age, tenure, and background) increases risky behaviors and complicates the enforcement of occupational health and safety rules [19, 20]. This diversity elevates process risks and weakens compliance with safety protocols in critical situations [21, 22].

In the cement manufacturing process, workers are exposed to numerous life-threatening risks, including heat-related occupational hazards. The use of rotary kilns in this process exposes workers to numerous risks, particularly occupational hazards. Ultimately, everything rests on the principle that every worker has the right to safe working conditions, free from risks to its health, safety and physical and moral integrity [23]. In this context, a thorough analysis of occupational accidents in the rotary kiln area of the Hamma Bouziane Cement Plant (SCHB) was conducted, based on accident records for the consecutive years 2021 and 2022. Despite the recognized importance of occupational health and safety (OHS) in this sector, existing studies rarely focus on the rotary kiln area in Algerian cement plants. Furthermore, few studies provide a systematic prioritization of critical hazards or propose preventive measures based on rigorous root cause and failure analyses. This represents a scientific gap that this study seeks to address. Recent accident statistics highlight a practical necessity for this research.

At the Hamma Bouziane cement plant (Algeria), the number of accidents in the rotary kiln area increased from eleven in 2021 to sixteen in 2022, underscoring the urgent need for effective risk management strategies. Applying the results of this research can help reduce workplace accidents, improving safety management, minimizing production losses, and promoting a sustainable safety culture.

This research aims to identify critical occupational risks in the rotary kiln production area of the Hamma Bouziane cement plant (Algeria) and to determine priority preventive measures. This will make it possible to enhance safety levels and risk prevention management, thereby provides a safe and healthy work environment. It also provides decision-makers with an overview to monitor the effectiveness of implemented strategies and offers an opportunity to implement preventive measures aimed at preserving health, improving worker safety, and fostering a culture of safety. Thus, ensuring a safe and healthy work environment.

To achieve the set aim, the following tasks must be completed:

1. To conduct a quantitative analysis of workplace accidents.
2. To determine the root causes of accidents in the rotary cement kiln area.
3. To determine preventive measures for the rotary cement kiln area.

2. Materials and Methods

In this research, the rotary kiln at the Hamma Bouziane Cement Plant (SCHB) was selected because it represents a critical point in the production process in terms of occupational hazards. Examining this area allows for the prioritization of safety measures and the effective protection of workers.

The rotary kiln is one of the most critical and high-risk areas of cement production. The process involves extremely very high temperatures, complex chemical reaction and the operation of large rotating machinery. The cement production unit, including the rotary kiln, was built and completed by the French company Creusot-Loire Enterprise (country of origin: France). The rotary kiln is composed of the main components shown in Fig. 1.

Table 1 shows the characteristics of the rotary kiln.

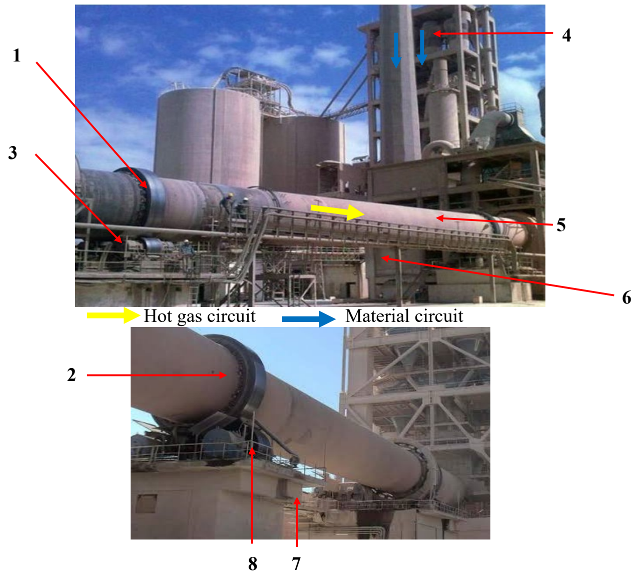

Fig. 1. Components the rotary kiln:
1 – ferrule; 2 – ring tyre; 3 – roller; 4 – multi-cyclone preheater; 5 – inclined cylinder; 6 – gas pipe; 7 – motor; 8 – cooler

Table 1

Characteristics of the rotary kiln

Cylinder length: 70 to 120 m	Diameter: 5 m	Permanent rotation of the cylinder: 2 to 3 rpm
Works: 24h/24 et 7d/7	Capacity: 3000 T/h	Maximum temperature reached: approximately 1500

These characteristics illustrate the large scale and continuous operation of the rotary kiln used in cement production. The inside of a rotary kiln is lined with refractory bricks to protect the shell from extreme temperatures. A burner heats the material, and the resulting hot gases circulate counter-current to the material's flow, which helps increase heat transfer efficiency.

During the field visit to the rotary kiln, the following was obtained the accident statistics for 2021 and 2022 were obtained from the official records of the Hamma Bouziane Cement Plant. These records provide a reliable and accurate source of information on occupational injuries and lost-time incidents. These statistics were used in the quantitative analysis of accidents to identify, assess, and map risks to facilitate their management.

Following the quantitative analysis, the research proceeded to qualitative analysis to obtain more reliable results, as follows:

1. The potential causes of burns was determined by Ishikawa diagram or the cause/effect. Applying the Ishikawa diagram among the most effective tools to seek the causes of a problem. It provides the visual representation of all the possible causes of a problem to analyze and find out the root cause. Inspections and interviews with operators have made it possible to identify the potential causes of burns in the rotary kiln.

2. Failure modes, effects, and criticality analysis (FMECA) was applied to identify hazardous phenomena affecting the rotary kiln and to determine the most critical components at risk. Based on the criticality assessment (C), three indicators were used: frequency of occurrence (F), severity of failure (G), and probability of non-detection (N), all obtained from the official factory accident records.

3. The potential causes of fire in the gas pipelines supplying the rotary kiln were identified using fault tree analysis (FTA). FTA is a deductive and systematic risk analysis method that begins with a predefined undesired event, in this case fire ignition, and traces back-

ward to identify all possible technical, human, and organizational causes that may lead to its occurrence. The analysis involved identifying primary and secondary failure events related to gas leakage, equipment malfunction, operational errors, and inadequate safety barriers. Logical relationships between these events were established using AND/OR gates to construct the fault tree. This approach enabled a structured evaluation of the contribution of each basic event to the top event, facilitating the identification of critical failure paths and the prioritization of preventive and corrective measures to reduce the likelihood of fire incidents in the rotary kiln gas supply system.

During work, any employee may be the victim of industrial accident or occupational injury (professional risks) resulting:

– temporary incapacity for work (TIW);
– permanent partial disability (PPD);
– death putting an end to its activity.

Based on workplace accident statistics for 2021 and 2022, the following results were observed.

3. Results and Discussions

3.1. Quantitative analysis of workplace accidents

3.1.1. Distribution of work accidents with lost time of the 2 years

Fig. 2, *a*, *b* illustrate the number of work-related incidents resulting in lost time for the years 2021 and 2022.

In 2021, 11 accidents were recorded, whereas in 2022, the number increased to approximately 16 accidents, representing an increase of five (05) accidents compared to the year 2021. This is due to the low effectiveness of safety barriers and the negligence of some workers.

Notably, in 2021, no accidents were recorded during the first three months, with all incidents occurring sequentially between April and November. In contrast, in 2022, accidents were distributed more sporadically throughout the year, indicating persistent but irregular safety challenges.

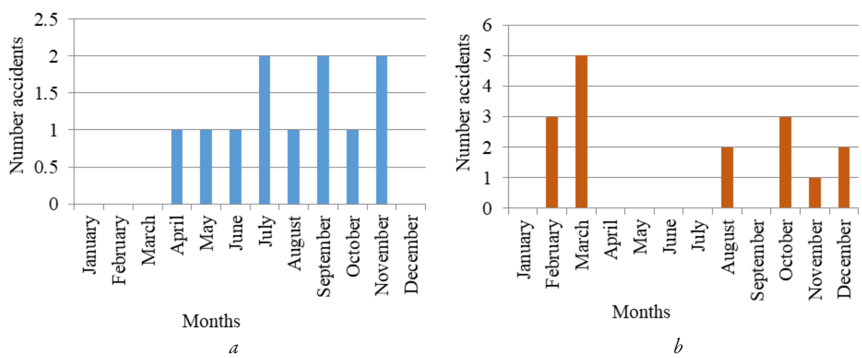

Fig. 2. Number of lost-time accidents: *a* – Year 2021; *b* – Year 2022

3.1.2. Distribution of accidents according to the material elements

Fig. 3 shows that 16 accidents occurred in 2022, with an estimated increase of 5 accidents compared to the year 2021. In 2022, a large number of accidents resulting from hot materials, totaling 6 accidents over two consecutive months (February and March). In addition to 4 accidents of falling on one level (slips, trips, missteps, loss of balance...). In contrast, in 2021, the majority of accidents were associated with working positions, highlighting differences in the sources of occupational hazards between the two years.

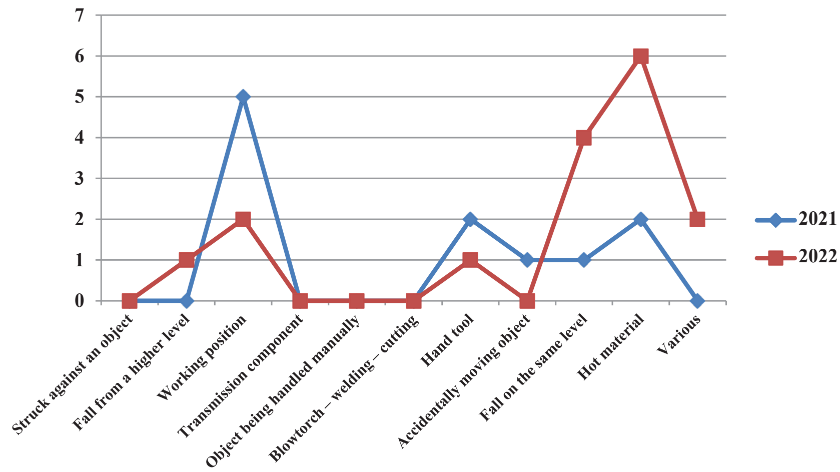

Fig. 3. Analysis of accidents by material element

3.1.3. Distribution of accidents according to the seat of lesions

As illustrated in Fig. 4, in 2022, the majority of work-related injuries were concentrated on the feet, with 08 accidents. In 2021, the injuries were mainly concentrated in the knees, accounting for 4 accidents. Additionally, there were two injuries affecting the eyes, arms, and face. Additionally, there were two injuries affecting the eyes, arms, and face. Most of these incidents are due to non-compliance with the use of personal protective equipment (PPE), including failure to use gloves, and protective masks. These findings underscore the urgent need to implement preventive measures to protect and preserve human capital.

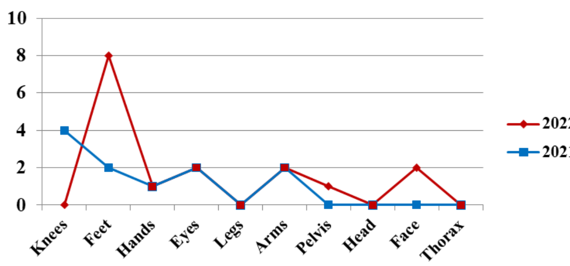

Fig. 4. Analysis of accidents by seat of lesions

3.1.4. Distribution of accidents according to the nature of lesions

As shown in Fig. 5, the physical consequences of work-related accidents in 2022 included 5 cases of burns and 3 cases of fractures, with the remaining injuries accounting for lower percentages. In 2021, the physical consequences consisted of 3 cases of trauma and dysphasia (T.S.L.O). These trends suggest that workplace safety efforts should now focus on preventing burns, multiple injuries, and heat-related incidents by providing personal protective equipment, appropriate training, and conducting periodic risk assessments.

3.1.5. Frequency rate and severity rate during the months of the 2 years

Over the two years, these two indicators (the accident frequency rate and the accident severity rate) provide an indication of the effectiveness of the implemented safety measures. Thus, their values are high; more accidents occur and have consequences in terms of work stoppages [24]. As such, it is interesting to locate the frequency rate and severity rate under the principle of "Continuous improvement".

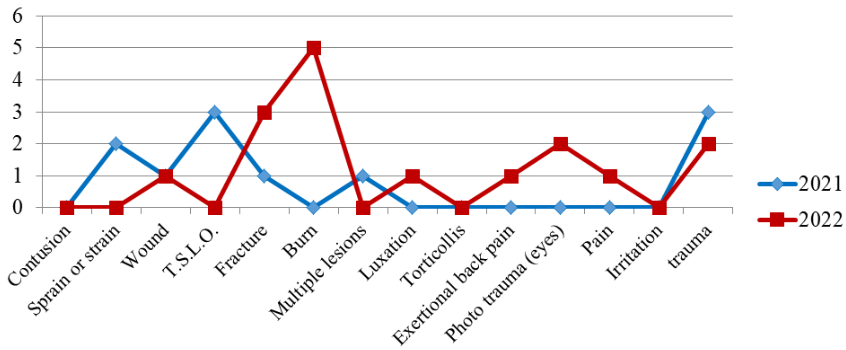

Fig. 5. Analysis of accidents by nature of lesions

3.1.5.1. Accident frequency rate (TF)

Fig. 6 illustrated the accident frequency rate (*TF*) which is calculated by formula

TF = (Number of work accidents with lost time/Number of hours worked) × 10^6.

In 2021, the highest accident frequency rate was recorded in September, reaching 30.77, while in the other months the frequency rate varies from 14 and 29. In 2022, a significant increase in the frequency rate was observed in March (77) and October (46.42); during the remaining months, the frequency rate varied from 15 and 45.

This variation in accident frequency rates over the two years (2021 and 2022) indicates a shortfall in the company's occupational safety and health management system.

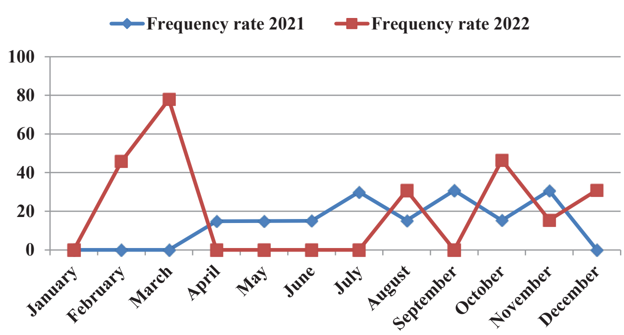

Fig. 6. Accident frequency rate (TF)

3.1.5.2. Accidenti rate (TG)

Fig. 7 illustrated the accident severity rate (*TG*) which is calculated by formula

TG = (Number of days lost/Number of hours worked) × 10^3.

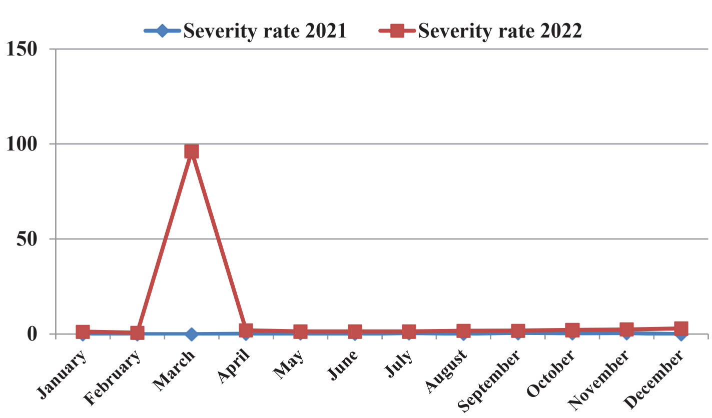

Fig. 7. Accident severity rate (TG)

It can be noticed the severity rate is stationary in 2021. While it was found in 2022, a very large increase in the severity rate on March (96.16), and for the other months the risk rate ranges from 0.73 to 2.95. This really requires attention to the consequences in terms of human loss, or even of work stoppages, for this reason, the company must work to improve safety and health at work within the company.

3.1.6. Distribution of the number of days lost of the 2 years

Fig. 8 *a*, *b* represent the number of days lost in 2021 and 2022.

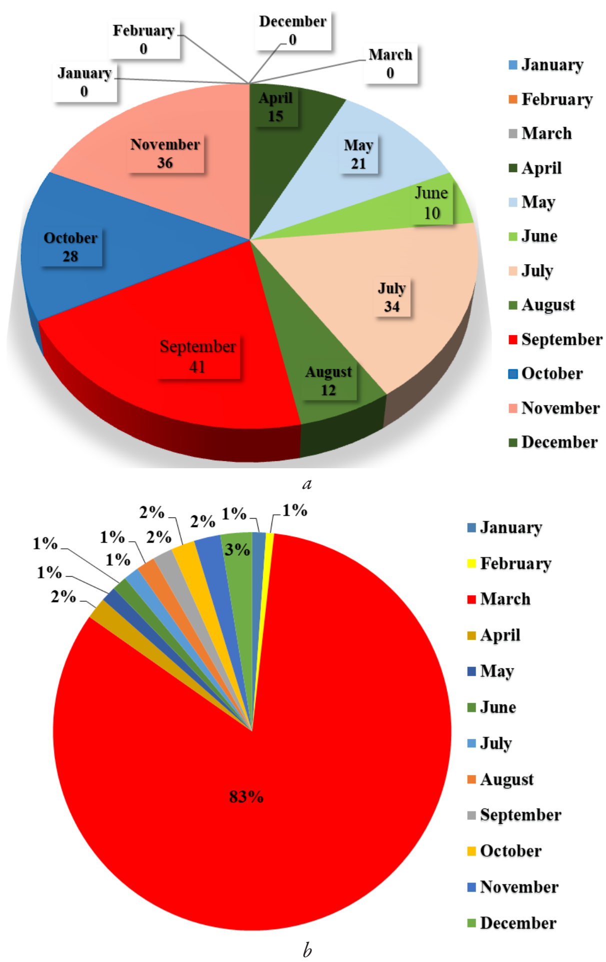

Fig. 8. Distribution of the number of days lost of the 2 years: *a* – Year 2021; *b* – Year 2022

This period was characterized by the spread of Covid-19, which led to a significant increase in the number of lost days. In 2021, the highest number of lost days was recorded in September, with 41 days lost due to two (02) lost-time work accidents. In contrast, in 2022, the peak occurred in March, with 6175 days lost due to the recording of five (05) work accidents with lost time.

3.1.7. Synthesis of accidents at work

According to Fig. 9, *a* the highest values of severity rate, frequency rate, number of lost workdays, and number of occupational accidents were recorded in September, November, and July. Due to falls, resulting in one (01) sprain and one (01) trauma to the knees and arms in September and July.

ISSN-L 2664-9969; E-ISSN 2706-5448

In addition, one (01) case of dysphasia and one (01) hand injury were reported in November, as well as two (02) knee fractures in September.

According to Fig. 9, *b* the month of March is the month with the highest share of severity rate, frequency, number of days lost and number of lost time accidents. These incidents were primarily, caused by the handling of hot materials, resulting in two (02) feet burns and one (01) fractured foot. In addition, two (02) cases of depression, this affected the eyes and the face.

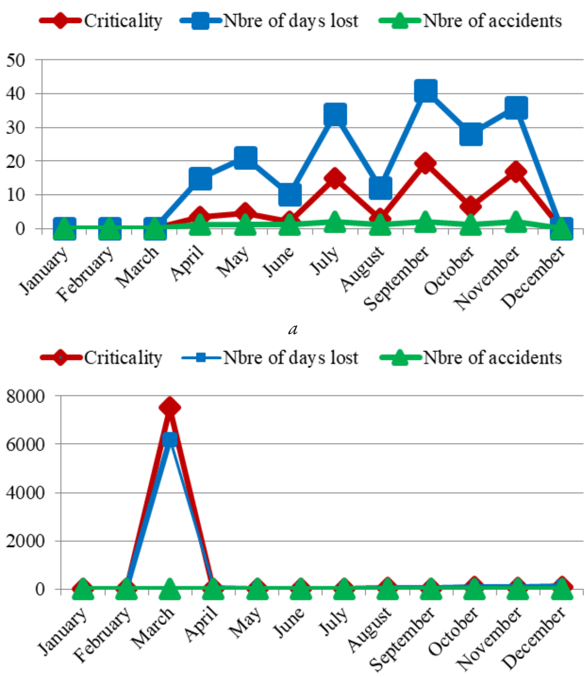

Fig. 9. Summary of accidents at work: *a* – Year 2021; *b* – Year 2022

Through quantitative analysis based on a risk mapping approach, it was found that accidents involving hot substances or materials, leading to burns, accounted for a high percentage of incidents, particularly in 2022. In addition, burns to the eyes, arms and face were recorded. Based on these findings, the rotary kiln in the HAMMA BOUZIANE cement plant is considered the most hazardous area due to its extremely high temperature.

3.2. Determination of the main causes of workplace accidents in the rotary cement kiln area

3.2.1. Analysis of workplace accident causes using the Ishikawa diagram

The Ishikawa diagram is a modern quality management tool that explains the cause and effect relationship for any quality issue that has arisen or that may arise [25]. The diagram Fig. 10 includes possible causes according to the rule of "5M":

– *Manpower,* the most common causes are: failure to wear personal protective equipment (PPE) such as heat-resistant gloves, face shields, or flame-retardant clothing, lack of worker training. In addition, stress, fatigue, distraction or rushing during kiln inspection or maintenance.
– *Machines,* the most common causes are: the proximity from a heat source (oven wall), malfunctioning burners causing flame impingement outside the intended zone and leakage of hot gases or materials from kiln seals or inspection doors. In addition, poorly insulated kiln shell allowing radiant heat exposure.
– *Methods,* the most common causes are: Improper handling of hot materials and poor enforcement of safety rules. In addition, maintenance interventions in confined/enclosed spaces.
– *Materials,* the most common cause is: Hot clinker spillage during transfer and use of volatile or contaminated fuel causing unstable combustion and flame escape. In addition, poor quality of personal protective equipment (EPI).
– *Medium,* the most common cause is: poor ventilation in kiln area leading to heat buildup with the high ambient heat. In addition, power failure.

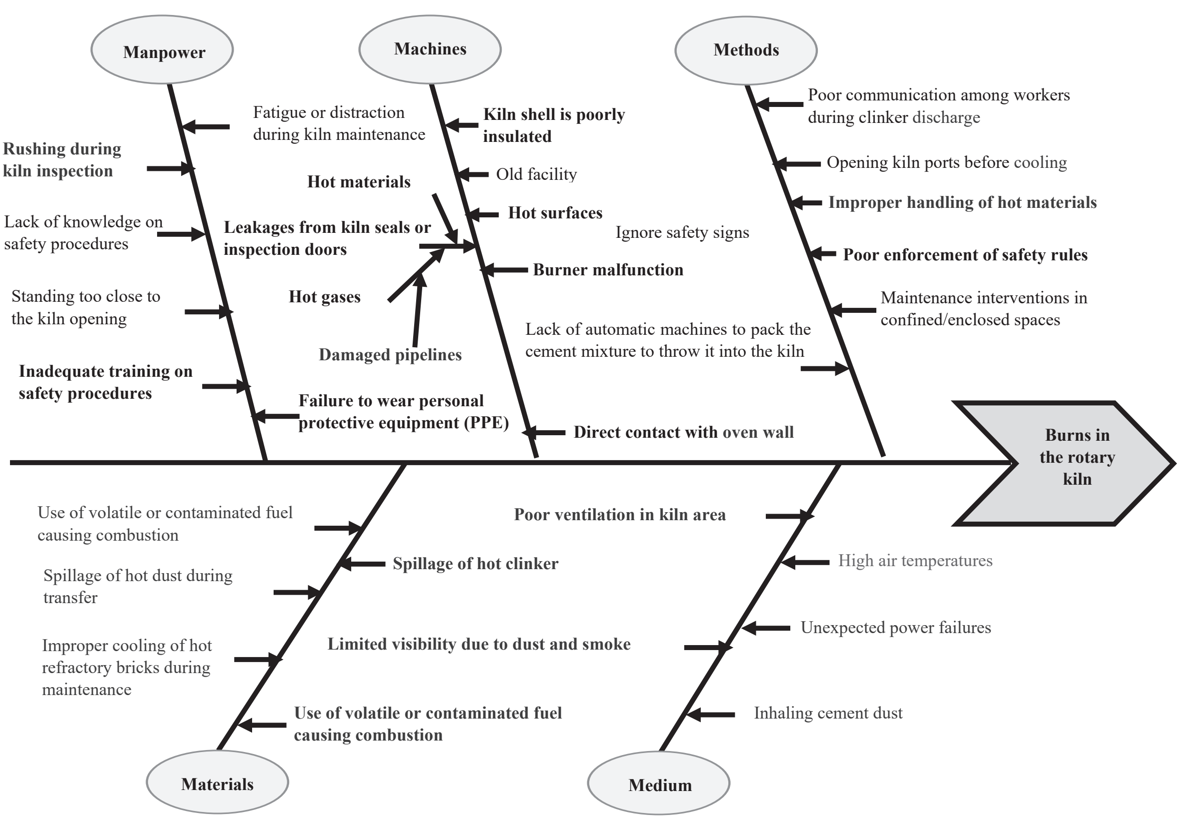

Fig. 10. Possible causes of burns in the rotary kiln to the rule of 5M: Manpower, Machines, Methods, Materials, Medium

The accidental release of hot materials is one of the most widely experienced and potentially fatal problems; it often results in catastrophic consequences for health, safety, and the environment. In addition, gas leaks: is a gas leak due to damaged pipelines, faulty gas appliances, or improperly sealed fittings.

3.2.2. Application of the failure mode effects and criticality analysis (FMECA) on the rotary kiln

In order to ensure effective quality management and functional safety, with the aim of implementing preventive measures and identifying potential defects or failures before their occurrence or manifestation, a failure modes, effects, and criticality analysis (FMECA) was conducted (Table 2).

This method is based on the analysis of three key concepts: failure mode, failure effect, and failure criticality. Each of these notions plays a crucial role in understanding and preventing potential risks [26]. Criticality helps to prioritize risks and guide the implementation of appropriate corrective actions. The criticality of a risk is determined based on the value c, as shown in Table 3.

In Table 2, colors are highly important in failure modes, effects, and criticality analysis (FMECA) for rapid risk assessment. A gradient from green to dark red – for example, green (low), yellow (below average), orange (average), and dark red (major) – enables users to quickly prioritize attention and implement corrective actions.

Table 2

Criticality score

Low	$1 \le C \le 5$
Below average	$5 < C \le 10$
Average	$10 < C \le 15$
Major	$C > 15$

The analysis of the failure mode, effects and criticality analysis (FMECA) results applied to rotary kiln allowed to identify the following dangerous phenomena:

– gas leak results in fire, explosion inside the kiln, death and suffocation;
– collapse of refractory bricks resulting in burns, fractures of varying severity and exposure to trauma (which can lead to specific oral language disorder (TSLO));
– high temperature in the ferrule results to burns.

The failure mode, effects, and criticality analysis (FMECA) allowed to identify the criticality of the various elements likely to experience failures (Fig. 11).

The classification histogram (Fig. 12) shows that the most critical components are piping system connected to the burner (gas pipes).

Table 3

Application of the FMECA approach on the rotary kiln

Elements	Failure Mode	Causes	Consequences	F	G	N	C	Preventive action
Ferrule	– Deformation; – Ovalization; – Cracking	– Oven bending; – Non uniform temperature; – Falling bricks; – Crusting; – Appearance of the hot spot; – Fall of refractory bricks and crusting; – Oven axis misalignment; – High temperature; – Corrosion; – Poor welding quality	– Falling cracked bricks; – Problems of rotation; – Damage of the bricks and the ferrule; – Overload on the rollers; – Collapse and reduction in the lifespan of bricks; – Risk of rupture and erosion; – Leakage of material at very high temperature; – System shutdown	1	5	3	15	– Regular monitoring of the ferrule temperature; – Changing the ferrule
Bricks	– Wear and fall of bricks	– Ovalization; – Deformation of the ferrule; – Thermal shock	– Appearance of hot spots; – Falling bricks; – System shutdown; – Exposed to combustion; – Exposed by injuries and fractures	1	5	3	15	– Inspection of bricks during kiln shutdown; – Regular monitoring of the ferrule temperature; – Installation of high-quality bricks according to standards
Motor	– Low torque motor; – Low oven rotation speed	– Internal defects; – Excessive load; – Bad nutrition	– Decrease in production; – Risk of clogging; – System shutdown	2	2	1	4	Detect by operator
Torch	– Flame extinguishing; – Low flame; – Blocking	Accumulation of CH_4 gas due to lack of synchronization between the gas supply and its ignition by the torch	– Insufficient gas circulation; – Internal explosion; – System shutdown	1	3	2	6	– Regularly check the flame condition; – Installation of flame sensors; – Changement
Gas pipes	– Gas leak; – Pipeline ruptures; – Corrosion	– Old installation; – Poor lubrication; – Breakage of the gas injector; – Regulation fault; – Use of volatile or contaminated fuel	– Explosion; – Fire; – Suffocation; – Partial or complete damage to nearby structures; – Cessation of operations; – Injuries/Death	3	3	3	27	– Installation of gas sensors; – Changing the joints; – Tighten fittings; – Leak detector

Notes: green (low), yellow (below average), orange (average), red (major)

ISSN-L 2664-9969; E-ISSN 2706-5448

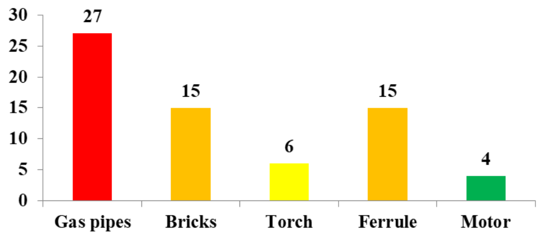

Fig. 11. The criticality levels of the rotary kiln components: 27 – major, 15 – average, 6 – below average and 4 – low

Fig. 12. Piping system (Gas pipes) [27]

3.2.3. Application of the fault tree analysis (FTA)

Applying of the fault tree analysis (Fig. 13), enables the visualization and analyze all the logical combinations of events that lead to a system failure (undesirable event), working backward from effects to causes (deductive approach).

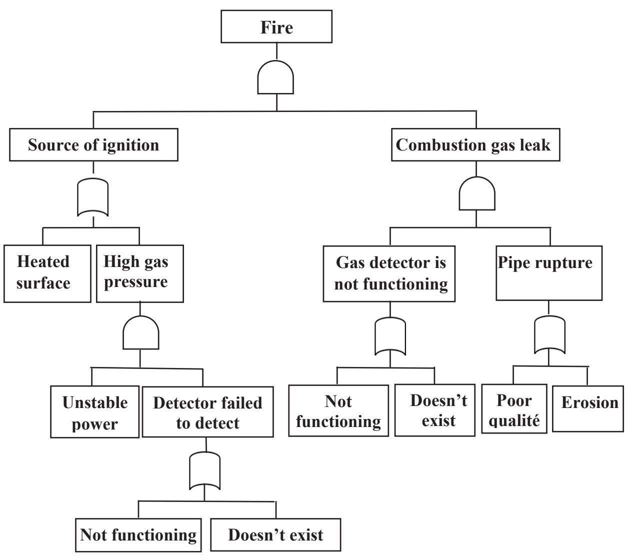

Fig. 13. Application of the fault tree analysis (FTA)

Using this deductive approach, potential root causes of a fire in the rotary kiln gas line can be identified, enabling the definition of effective preventive measures.

3.3. Proposed preventive measures for the rotary cement kiln area

To reduce workplace accidents and enhance safety in the rotary cement kiln area, the following preventive measures are recommended:

– install fire alarms, gas detectors and gas leak alarm systems;

– sanctions should be applied to any worker who ignores danger signs or fails to follow appropriate safety measures within the furnace area;

– organize training sessions and awareness campaigns on accident prevention and intervention methods (for example, the risks of explosions and burns). Continuing education in occupational health and safety (OHS) is now strongly recommended;

– improve supervision and monitoring to ensure compliance with safety procedures and the correct use of PPE.

Consequently, risk assessment and risk mapping within a company are of paramount importance. This allows for the identification of critical occupational risks in terms of time and location, as well as the determination of priority preventive measures. It also helps promote a culture of health and safety in the workplace.

3.4. Limitations of research and prospects for its further development

Despite the relevance of the results obtained, this research presents certain limitations. The analysis is primarily based on historical occupational accident data from 2021 and 2022, which may not fully reflect future operating conditions or rare accident scenarios. In addition, the application of methods such as risk mapping, Ishikawa, FMECA, and fault tree analysis (FTA) depends on the availability and accuracy of data, and any missing or incomplete information may affect the reliability of the results. Furthermore, FTA does not account for the dynamic evolution of operating conditions or the real-time influence of human and organizational factors, which may impact accident occurrence.

Future research could address these limitations by integrating real-time monitoring systems and dynamic risk assessment tools to better capture changes in operating conditions. The incorporation of probabilistic and simulation-based approaches would allow a more accurate estimation of failure scenarios. Moreover, further studies should place greater emphasis on human and organizational factors, including operator behavior, training, and safety culture, to enhance accident prevention. Expanding the analysis to longer time periods and different industrial contexts would also improve the generalizability of the findings.

4. Conclusions

The research results highlighted the identification of critical occupational hazards and the determination of priority preventive measures in the area of the cement production rotary kiln, as follows:

1. The quantitative analysis of workplace accidents was carried out as follows:

– risk mapping was created using occupational accident statistics from 2021 and 2022;

– analysis showed that accidents involving hot substances accounted for a significant proportion of incidents, particularly in 2022 (16 accidents);

– most of the incidents resulted in burns to the eyes, arms and face, highlighting the high-risk areas of the rotary kiln system;

– the results indicate that current measures are insufficient, as staff often lack the training, information, and guidance necessary to manage risks effectively.

2. Determining the root causes of accidents in the area of the rotary cement production kiln, namely:

– using the Ishikawa diagram, the root causes of burn hazards in the rotary kiln was identified, primarily related to hot materials and gas leaks;

– failure mode, effects and criticality analysis (FMEA) identified the piping system as the most critical component, with a criticality level of 27 (major), indicating absolute priority for preventive measures;

– fault tree analysis (FTA) enabled the identification of the main events likely to cause a fire in the rotary kiln gas line. The analysis systematically revealed the potential root causes, including equipment malfunctions, operational errors, and deficiencies in safety controls, allowing for the prioritization of effective preventive measures;

– the research revealed that staff often lack training and supervision, which leads to poor involvement in the use of personal protective equipment (PPE) within the organization, a lack of experience and non-compliance with preventive measures. Implementing a health and safety culture in a company is challenging and requires the involvement of all staff, guided by the principle "Prevention is everyone's business". Except, to preserve the health and improve the safety of employees, any company should engage in a process of continuous improvement [28].

3. The determination of priority preventive measures in the area of the rotary cement production kiln, namely:

– implement safety systems and enforce strict compliance with procedures;
– provide continuous training and awareness on accident prevention and OHS;
– conduct risk assessments and mapping to identify critical hazards;
– foster a safety culture and commit to continuous improvement.

Finally, every company should commit to a continuous improvement approach to protect the health and enhance the safety of its employees, and even foster a sustainable approach to continuous improvement in occupational health and safety.

Acknowledgment

We express our sincere gratitude to the team of the HAMMA BOUZIANE Cement Company (SCHB), for their support and assistance during data collection.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship or other, which could affect the research and its results presented in this article.

Financing

The research was performed without financial support.

Data availability

The manuscript has no linked data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

Authors' contributions

Razika Aouad: Conceptualization, Investigation, Resources, Data curation, Formal analysis, Visualization, Project administration, Writing – original draft; ***Samira Belhour***: Conceptualization, Investigation, Resources, Data curation, Formal analysis, Visualization, Project administration, Writing – original draft; ***Rachid Chaib***: Methodology, Data curation, Formal analysis, Writing – review and editing, Supervision; ***Djamel Nettour***: Data curation, Formal analysis, Writing – review and editing.

References

1. Bouzerara, R., Chaib, R., Verzea, I. (2023). For better governance of harmfulness in companies: a case study. *Procedia Structural Integrity, 48,* 4–11. https://doi.org/10.1016/j.prostr.2023.07.103
2. Burtan, Z., Nowak-Senderowska, D., Szczepański, P. (2025). Methodology for Identification of Occupational Hazards Using Their Characteristic Features in Hard Coal Mining. *Applied Sciences, 15 (13),* 7079. https://doi.org/10.3390/app15137079
3. Kharzi, R., Chaib, R., Verzea, I., Akni, A. (2020). Safe and Sustainable Development in a hygiene and healthy company using decision matrix risk assessment technique: a case study. *Journal of Mining and Environment, 11 (2),* 363–373. https://doi.org/10.22044/jme.2020.9156.1807
4. Aouragh, L., Ouazraoui, N., Boubaker, L., Bourmada, N., Sekhri, A. (2025). Integrating Human Performance Factors to Improve Occupational Risk Assessment. *International Journal of Safety and Security Engineering, 15 (3),* 609–619. https://doi.org/10.18280/ijsse.150319
5. Mounia, T., Chaib, R., Samira, B., Djamel, N. (2024). The use of risk mapping for sustainable management of harmful effects in business: Case study. *XX International May Conference on Strategic Management – IMCSM24 Proceedings – Zbornik Radova,* 191–199. https://doi.org/10.5937/imcsm24070m
6. Kabiesz, P., Tutak, M. (2024). Developing a Culture of Safety for Sustainable Development and Public Health in Manufacturing Companies – A Case Study. *Sustainability, 16 (17),* 7557. https://doi.org/10.3390/su16177557
7. Abdelatif, A., Rachid, C., Smain, A., Ion, V. (2015). Promoting a sustainable organizational culture in a company: The National Railway Transport Company. *Journal of Rail Transport Planning & Management, 5 (1),* 23–30. https://doi.org/10.1016/j.jrtpm.2015.01.001
8. Revilla, A. J., Pérez-Luño, A., Nieto, M. J. (2016). Does Family Involvement in Management Reduce the Risk of Business Failure? The Moderating Role of Entrepreneurial Orientation. *Family Business Review, 29 (4),* 365–379. https://doi.org/10.1177/0894486516671075
9. Bakhuys Roozeboom, M. C., Wiezer, N. M., Boot, C. R. L., Bongers, P. M., Schelvis, R. M. C. (2021). Use of Intervention Mapping for Occupational Risk Prevention and Health Promotion: A Systematic Review of Literature. *International Journal of Environmental Research and Public Health, 18 (4),* 1775. https://doi.org/10.3390/ijerph18041775
10. Tremblay, A., Badri, A. (2018). Assessment of occupational health and safety performance evaluation tools: State of the art and challenges for small and medium-sized enterprises. *Safety Science, 101,* 260–267. https://doi.org/10.1016/j.ssci.2017.09.016
11. Figueroa-Maldonado, J., Herrera-Franco, G., Moreno-Alcívar, L., Bravo-Montero, L. (2024). Comparative Analysis of Methodologies for Occupational Safety Risk Assessment in an Artisanal Woodworking Industry. *International Journal of Safety and Security Engineering, 14 (6),* 1825–1835. https://doi.org/10.18280/ijsse.140617
12. Gamboa-Sánchez, M. C., Cotrina-Teatino, M. A., Vega-Gonzalez, J. A., Noriega-Vidal, E. M., Arango-Retamozo, S. M., Marquina-Araujo, J. J. (2024). Effective Critical Risk Management in Welding Operations for Mining: A Case Study on Incident Reduction. *International Journal of Safety and Security Engineering, 14 (4),* 1039–1047. https://doi.org/10.18280/ijsse.140403
13. Bautista-Bernal, I., Quintana-García, C., Marchante-Lara, M. (2024). Safety culture, safety performance and financial performance. A longitudinal study. *Safety Science, 172,* 106409. https://doi.org/10.1016/j.ssci.2023.106409
14. Cooper, M. D.; Gilbert, C. et al. (Eds.) (2018). The safety culture construct: theory and practice. *Safety cultures, safety models: Taking stock and moving forward.* Cham: Springer International Publishing. Safety Cultures, Safety Models, SpringerBriefs in Safety Management, 47–61. https://doi.org/10.1007/978-3-319-95129-4_5
15. Moradi, M., Malmasi, S., Babaei Pouya, A. (2020). Identification Of Health, Safety, and Environment Aspects in Cement Factory Using AHP And FMEA Techniques. *Iranian Journal of Health Sciences, 8 (1),* 1–10. https://doi.org/10.18502/jhs.v8i1.4020
16. Pandeya, P., Mishra, D. K., Khanal, S. P., Joshi, Y. P., Marahatta, S. B., Neupane, A. et al. (2021). Occupational Health Risk among Selected Cement Factory Workers in Dang District of Nepal. *International Journal of Health Sciences and Research, 11 (5),* 8–22. https://doi.org/10.52403/ijhsr.20210502
17. Mohammadfam, I., Kamalinia, M., Momeni, M., Golmohammadi, R., Hamidi, Y., Soltanian, A. (2017). Evaluation of the Quality of Occupational Health and Safety Management Systems Based on Key Performance Indicators in Certified Organizations. *Safety and Health at Work, 8 (2),* 156–161. https://doi.org/10.1016/j.shaw.2016.09.001
18. Koskela, M. (2014). Occupational health and safety in corporate social responsibility reports. *Safety Science, 68,* 294–308. https://doi.org/10.1016/j.ssci.2014.04.011
19. Kim, Y., Jeong, S. S., Yiu, D. W., Moon, J. (2020). Frequent CEO Turnover and Firm Performance: The Resilience Effect of Workforce Diversity. *Journal of Business Ethics, 173 (1),* 185–203. https://doi.org/10.1007/s10551-020-04534-0

ISSN-L 2664-9969; E-ISSN 2706-5448

20. Ssemuddu, J. B., Olupot, P. W., Kirabira, J. B., Okure, M., Kayenga, T. J. (2025). Strengthening occupational safety, health, and environment risk assessments in cement manufacturing under stochastic production pressure using hybrid predictive models. *Discover Applied Sciences, 7 (9).* https://doi.org/10.1007/s42452-025-07594-x
21. Fresenbet, D. S., Olana, A. T., Tulu, A. S., Danusa, K. T. (2022). Occupational injury and associated factors among cement factories workers in central Ethiopia. *Journal of Occupational Medicine and Toxicology, 17 (1).* https://doi.org/10.1186/s12995-022-00348-0
22. Maqsoom, A., Khan, K., Musarat, M. A., Mubasit, H., Umer, M. (2020). Influence of Internal Workforce Diversity Factors on Labor Productivity in Construction Projects: Empirical Evidence from Pakistan. *2020 Second International Sustainability and Resilience Conference: Technology and Innovation in Building Designs.* IEEE, 1–7. https://doi.org/10.1109/ieeeconf51154.2020.9319935
23. Glendon, A. I., Clarke, S., McKenna, E. (2016). *Human Safety and Risk Management.* Boca Raton: CRC Press. https://doi.org/10.1201/9781420004687
24. Rachid, C., Ion, V., Irina, C., Mohamed, B. (2015). Preserving and improving the safety and health at work: Case of Hamma Bouziane cement plant (Algeria). *Safety Science, 76,* 145–150. https://doi.org/10.1016/j.ssci.2015.01.014
25. Kanti Bose, T. (2012). Application of Fishbone Analysis for Evaluating Supply Chain and Business Process – A Case Study on the ST James Hospital. *International Journal of Managing Value and Supply Chains, 3 (2),* 17–24. https://doi.org/10.5121/ijmvsc.2012.3202
26. Taleb, M, Belhour, S, Chaib, R, Kahoul, H. (2025). Applied approach for sustainable management and operation of the Constantine tramway. *Journal of Dalian University of Technology, 32 (9),* 24–34. Available at: https://drive.google.com/file/d/15_du9HTBvMhV9fESq6izihpWMMTuPv4l/view
27. *Custom Cement Production Line Cement Rotary Kiln Burner 300tpd Cement Plant Cement Clinker Biochar Rotary Kiln Gas Burner.* Available at: https://bntet-burner.en.made-in-china.com/product/SJNpdzfVYRYL/China-Custom-Cement-Production-Line-Cement-Rotary-Kiln-Burner-300tpd-Cement-Plant-Cement-Clinker-Biochar-Rotary-Kiln-Gas-Burner.html
28. Chaib, R., Verzea, I., Benidir, M., Taleb, M. (2012). Promoting a culture of health and safety at work: safety – a permanent priority. *Risk Analysis VIII, 44 (9),* 405–413. https://doi.org/10.2495/risk120341

***Razika Aouad**, Doctor of Technical Sciences, Associate Professor, Department of Transport Engineering, Laboratory of Transports and Environment Engineering, Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0009-0004-5479-4157*

***Samira Belhour,** Doctor of Technical Sciences, Associate Professor, Department of Transport Engineering, Laboratory of Transports and Environment Engineering, Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0000-0001-9719-4646*

***Rachid Chaib,** Doctor of Technical Sciences, Professor, Department of Transport Engineering, Laboratory of Transports and Environment Engineering, Mentouri Brothers University Constantine1, Constantine, Algeria, ORCID: https://orcid.org/0000-0001-8680-1906*

✉***Djamel Nettour,** Doctor of Technical Sciences, Associate Professor, Department of Mining Engineering, Metallurgy and Materials, LAVAMINE Laboratory, Higher National School of Technology and Engineering ENSTI, Sidi Amar, Algeria, e-mail: djnettour@gmail.com, ORCID: https://orcid.org/0000-0003-0056-5389*

✉*Corresponding author*