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Occupational Health Risk Analysis and Assessment in Cement Production Processes

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Abstract

The purpose of this study is to determine safety risk scores by carrying out risk analysis within plant site according to the occupational health and safety risk management in the cement production processes. To determine occupational and safety risks scores, the plant site studies have been performed by using 5x5 L type risk matrix methodology in the Elazığ-Altınova Cement Plant. The plant site visit covers the sections of raw material processing, storage and transportation, raw material milling, clinker production and cement milling. All possible risks were listed, likelihood and severity of the risks were determined and by using these values and risk scores were calculated. After determining the risks for the workers, the safety risk tables were prepared, and the possible risks were classified as high, moderate and low-risk degrees concerning occupational and safety risk management system. The results of risk assessment revealed that the most dangerous risks were came out in the raw material milling. On the other hand, the highest risk scores were also observed in the raw material milling section. It was found that the crusher, raw material and cement mills and rotary kiln are the most dust, noise, and vibration producing units.

Keywords: Cement Process, Occupational Health and Safety, Risk Definition, Risk Analysis and Assessment, L type risk matrix methodology

Çimento Üretim Proseslerinde İş Sağlığı Risk Analizi ve Değerlendirmesi

Özet

Bu çalışmanın amacı, çimento üretim proseslerinde, iş sağlığı ve güvenliği risk yönetimine göre risk analizi yapılarak güvenlik riski skorlarını belirlemektir. Bu amaçla Elazığ-Altınova Çimento Fabrikasında 5x5 L tipi risk matris metodolojisi kullanılarak saha çalışmaları yapılmıştır. Fabrika ziyareti, hammadde işleme, depolama ve nakliye, hammadde öğütme, klinker üretimi ve çimento öğütme bölümlerini kapsamaktadır. Fabrikada öncelikle olası tüm riskler listelenerek risklerin olasılığı ve şiddeti belirlendi ve bu değerler kullanılarak risk puanları hesaplandı. Risklerin belirlenmesinden sonra güvenlik riski tabloları hazırlanmış ve olası riskler iş ve güvenlik risk yönetimi sistemi açısından yüksek, orta ve düşük risk derecelerine göre sınıflandırılmıştır. Risk değerlendirmesi sonuçlarına göre en tehlikeli risk bölgesi olarak hammadde öğütme kısmı belirlenmiştir. Öte yandan, en yüksek risk puanı da hammadde öğütme bölümünde elde edilmiştir. Kırıcı, hammadde, çimento öğütme ve döner fırının en toz, gürültü ve titreşim üreten üniteler olduğu görülmüştür.

Anahtar Kelimeler: Çimento Prosesleri, İş Sağlığı ve Güvenliği, Risk Tanımlaması, Risk Analizi ve Değerlendirilmesi, L Tipi Risk Matris Metodolojisi

1. Introduction

The cement sector is one of the important branches of the main industries for the economic development of countries. The supply and treatment of raw materials to produce cement require much energy and labor power. The labors who work for cement plants have exposed some risks such as dust, noise, and vibrations, and they have to be protected against to this kind of health risks.

Cement is a hydraulic powder material which is created at high temperatures of around 1400 °C. The cement production processes mainly include two steps: (1) the crushing, mixing and roasting of raw materials (silica, calcium carbonate, oxides of alumina and iron), (2) milling of clinker. The

production of cement is undergone a series ofprocesses such as crushing, handling of raw material, grinding clinker, blending, packing and shipping of the final product of cement clinker [1,2]. During all this processes accidents and health problems of the workers cannot be avoided, and workers are exposed to dust, noise and high-temperature effects [3,4].

The workers in a cement factory are exposed to many occupational hazards which contribute to work injuries, dies and allergic problems to cement components [5-9]. Cement can cause ill health in workers through skin and eye contact or inhalation. The risk of injuries and occupational health problems for cement factory workers depends on the duration and level of exposure and individual sensitivity [5]. Noise is also major hazard encounter during the production of cement; especially milling plants used in grind the cement product causes high tension of noise which can simply damage someone hearing levels, maintenance, and cleaning personnel worker are mostly at risk [10,11].

Because of inevitable work-related diseases and accidents, occupational safety regulations are compulsive to prevent such risks through recognition, evaluation, and control of the hazards in an ideal world. Safety management not only saves lives but also is a profit maker for the countries. Therefore, the cement industry is supposed to take correct measurements, evaluation, and control of such risks. Diverse studies for assessing the risks in cement plants have been previously investigated in various studies. Some of these studies concern the reduction of carbon dioxide [12,13], noise pollution risk assessment [11], dust hazard assessment [14], the evaluation of life quality of workers [15,16], occupational health assessment in cement factories [17,18]. Although the main purpose of these studies is to reduce the risks relevant to the workers in cement processes, there is lack of comprehensive determination, analysis, and assessment of occupational health risks for the processes in cement factories. Therefore, preventative and protective measures may need to be implemented to control any risks in the cement factories.

The occupational health and safety cover the determination of risk which is associated with the frequency of failure and consequence effects. Predicting and evaluation of risk are essential to take appropriate control measures. Evaluation of risk can be performed with qualitative and quantitative methods. Centers and factors of existing danger can be identified by quantitative methods of evaluation and elimination or control of them are provided by taking preventing and control solutions.

This work aims to identify risks and to assess them may occur during cement production. For this reason, a case study is carried out in Elazığ-Altınova Cement Plant.

2. Materials and Methods

In this study, the risk analysis and assessment in cement production have been performed in Elazığ-Altınova according to occupational health and safety management system. The factory under study was first established in Elazığ in 1954, and it started to produce cement by the dry system with a capacity of 85,000 tones/year. In this research, the cement factory has been divided into 5 main sections which are

1. Raw material processing
2. Storage and transportation
3. Raw material milling
4. Clinker production
5. Cement milling

2.1. Description of cement plant under study

Production of cement covers the crushing of raw materials, grinding and mixing of crushed and other raw materials, roasting of the raw material mixture to produce clinker, grinding of clinker along with the additive materials, and packaging.

The first step in cement production processes is the primary crushing of raw materials such as limestone, clay, sand, gypsum, and oxides of alumina and iron. In the crushing section, the crushing of raw materials is made with the help of crusher to reduce size approximately to three inches or smaller [19]. The raw material processing facility includes the crusher, conveyor belts, and the work vehicles. After crushing, the raw materials are transported to storage site by transport vehicles and stored in bunkers and silos.

The raw materials are then first mixed in the appropriate amounts and grounded by using raw material mills in the raw material milling section. The prepared raw material mixture is then fed into the rotary kiln system to produce clinker. The clinker is an intermediate product for manufacturing of cement. The first process is pre-heating in the rotary kiln, and as the temperature increases, physical and chemical changes occur in the pre-calcined materials, and then they melt and merge to form sintered products. Meanwhile, the fuels such as coal and petroleum coke are used to reach temperatures as high as 1450 °C in the rotary kiln [2,20]. The clinker production facility includes the rotating furnace, the preheating cyclones, the clinker cooler, the clinker filters and the work vehicles.

The finishing process for the production of cement is the clinker grinding with gypsum and other constituents. The cement mill is used to crush the clinker into a very fine powder. This fine powder is considered as cement. To control the setting of cement, small aomunt of gypsum is also added to the cement. Slag and fly ash can also be added to control other properties of the final product. The grinded cement is stored in silos from which it is marketed either in container load or bags. The dry cement production process is very energy intensive.

2.2. Risk analysis and assessment

To determine occupational health risks scores, the plant site studies have been performed by using 5x5 L type risk matrix methodology in the Cement Plant. This method is simple, so it is ideal for analysts who have to do risk analysis alone. However, this method is not sufficient for all processes involving different processes or with very different current schemes, and the success rate of the method changes according to the knowledge of the analyst. This method should be used in such enterprises in order to determine the hazards that require special priority and which require special precautions. A 5x5 L-Type Matrix is especially used in the evaluation of cause-effect relationships. With this method, the result is graded and measured if it is realized with the possibility of realizing an event first.

The plant site visit covers the sections of the raw material process, storage and transportation, raw material milling, clinker production and cement milling. In these sections, all possible risks were listed, likelihood and severity of the risks were determined and by using these values and risk scores were calculated. After determining the risks for the workers, the safety risk tables were prepared, and the possible risks were classified as high, moderate and low-risk degrees concerning occupational and safety risk management system.

Risk analysis examines risks in detail to determine the extent of the risks and the relationships among them. Risk analysis also classifies risks into sets of related risks and ranks them according to importance. Risk analysis evaluates all identified risks to estimate the likelihood of occurrence, consequence of occurrence, and timeframe for necessary mitigation actions. Risk assessment is the qualitative and/or quantitative evaluation of the likelihood and consequence of a risk occurring [21-26].

A Risk Matrix is a graphical representation of the likelihood and consequence scores of a risk (Fig. 1). It is sometimes called a “5x5 Matrix” because it contains five rows and five columns. The rows of a Risk Matrix show likelihood scores, while the columns show the consequence scores.

In the cement factory under study, risk analysis studies have been performed by using 5x5 L type risk assessment decision matrix. Due to its simplicity of this method, the analysists can use this method by themselves. This method is commonly used for the assessment of cause and effect relation. The risk score values of the hazards observed during factory visiting are calculated by the multiplying of likelihood and severity as

$$\text{Risk Score} = \text{Likelihood} \times \text{Severity} \quad (1)$$

The likelihood and severity of risk can be estimated by using Table 1. and Table 2. After estimating of possible risk scores, the assessment of risk is made by taking the Table 3 as a reference. The risk assessment tables are then prepared, and the risks can be classified as high, moderate and low-risk degrees concerning occupational and safety risk management system.

		SEVERITY				
		Critical (5)	Very Serious (4)	Serious (3)	Minor (2)	Negligible (1)
LIKELIHOOD	Frequent (5)	25 Not tolerated	20 High	15 High	10 Moderate	5 Low
	Moderate (4)	20 High	16 High	12 Moderate	8 Moderate	4 Low
	Occasional (3)	15 High	12 Moderate	9 Moderate	6 Low	3 Low
	Remote (2)	10 Moderate	8 Moderate	6 Low	4 Low	2 Low
	Unlikely (1)	5 Low	4 Low	3 Low	2 Low	1 unimportant

Figure 1. 5x5 L type risk decision matrix

Table 1. The probability of a risk

Score	Likelihood	Likelihood of occurrence
1	Unlikely	So unlikely
2	Remote	Unlikely, but possible to occur
3	Occasional	Likely to occur sometime in the life of an item
4	Moderate	Will occur several times in the life of an item
5	Frequent	Likely to occur frequently

Table 2. The severity of a risk for occupational health

Score	Likelihood	Potential Consequence
1	Negligible	İnjuries and diseases that do not require medical treatment
2	Minor	Minor injuries that require first-aid only
3	Serious	Severe injuries that require hospitalization or multiple medical treatment
4	Very Serious	Life-threating injuries or multiple injuries that require hospitalization
5	Critical	Death or multiple injuries that pose threat to life

Table 3. The risk assessment table for occupational health

Risk Score	Risk degree	Actions should be taken to prevent against to risk
25	Not tolerated	The process must not be operated until the risk is reduced to acceptable level. it is necessary to stop single being studied action. The activities must be cancelled if the risk cannot be prevented.
15, 16, 20	Critical	Situation is emergency or required actions must be taken in nearest time. The action can be continue under supervision and control if the risk has not dangerous potential
8, 9, 10, 12	Moderate	The required protective actions must be taken to reduce risk level.
2, 3, 4, 5, 6	Minor (may be tolerated)	Emergency measure is not needed but the ruling measures must continue.
1	Negligible	Taking precaution is not priority

2.3. Definition of risks in the cement plant under study

To achieve comprehensible assessment of risk concerns occupational health, all sources resulting in risks during the cement production process must be defined. Therefore, in all processes in the cement production plant, the possible risks can be encountered as

1. General and routine risk sources for the entire cement production processes
   - Safety
   - Work environment
   - Work and passage areas
   - Work equipment
   - Labelling for safety
   - Protection equipment
   - Manual and automatic load handling
2. Special risks during the cement production processes in plant
   - Raw material processing (crushing)
   - Clinker production (sintering)
   - Grinding and milling processes (raw material, cement, and coal milling)
   - Ladders and scaffolding
   - Forklifts
   - Work vehicles
   - Welding and cutting activities
   - Fuel storage activities
   - Use of hazardous materials
   - Power generating units
3. Environmental risks
   - Dust
   - Noise
   - Heat effects due to high temperatures
   - Fire

3. Results and Discussion

All possible risks in all sections of Cement Plant were listed, likelihood and severity of the risks were identified and by using these values, the risk scores were calculated. The assessment of possible risks was then done by using the risk assessment tables together with risk decision matrix (Table.1). The total risks of 413 were determined for the Cement Plant, and the classification of these risk scores are given in Table 4. Table 5 reveals that the risk scores were cumulated between "20 and 6" risk scores, and there are no risks both at "25" risk score and under "6" risk score for the entire cement plant. From the Table 5, it was also seen that among these risks, 76 of them were high risks (18.4 %), 333 of them moderate risks (80.6 %), and 4 of them were low risk (1 %). As a result of risk assessment, 128 risk scores of the total risk scores (31.0 %) are determined in the raw material milling section, and these risks are encountered as the most dangerous risks. On the other hand, the highest risk score of "20" (only 1) was also seen in raw material milling section.

Fig. 2 indicates the relative frequency of risk scores in each section of the cement plant. It can be seen from Fig. 2, in the raw material milling section, the highest relative frequency of risk score (the score of "12") was determined as 0.75, while the lowest relative frequency of risk scores is obtained at "15 and 20 risk" scores. The high and moderate risk sources and their results for all section of Cement Plant are given Table 5 and 6, respectively. From Table 5, It was observed that the workers are exposed to various hazards that result in most serious injuries, death, and breathing problems in the cement factory. The hazards are physical, chemical or accidental due to mechanical and other working conditions.

Table 4. The risk scores estimated at the cement plant

Risk score / Process	25	20	16	15	12	10	9	8	6	5	4	3	2	1	Total
Raw material processing	-	-	13	1	54	-	33	-	-	-	-	-	-	-	101
Storage and transportation	-	-	13	-	29	-	3	-	-	-	-	-	-	-	42
Raw material milling	-	1	27	-	78	-	18	-	4	-	-	-	-		128
Clinker Production	-	-	20	-	63	-	29	-	-	-	-	-	-	-	112
Cement milling and packaging	-	-	2	1	26	-	5	-	1	-	-	-	-	-	35

Among the hazards listed in Table 5, the most observed hazard is the falling of workers from height in the cement factory, this was followed by contact with hot surfaces and materials, exposure to dust, exposure to noise and backfiring of the furnace. The hurling of materials, unauthorized loading, poor ventilation are the other main hazards that cause serious health problems.

The moderate risk score table (Table 6) also reveals that the workers are exposed to similar hazards in high score table that results in most serious injuries, death, breathing problems, gradual hearing impairment, eye problems, and muscular and skeletal disorders in the cement factory. The hazards are physical, chemical or accidental due to mechanical and other working conditions. Among the physical hazards, the most observed hazard is the falling of workers from height in the cement factory, this was followed by contact with hot surfaces and materials, exposure to dust, exposure to noise and backfiring of the furnace. The hurling of materials, unauthorized loading, poor ventilation are the other main hazards that cause serious health problems.

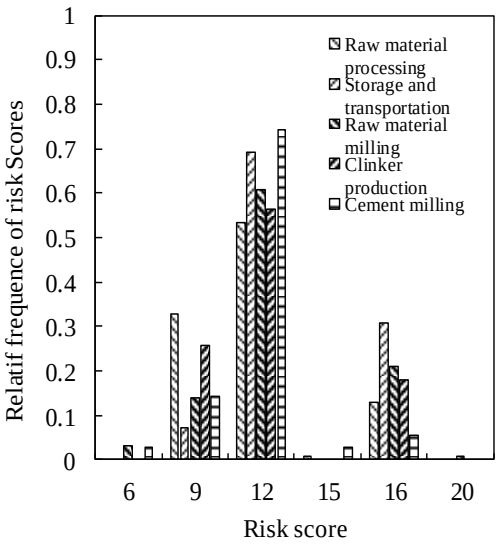

Figure 2. The relative frequency of risk scores

Table 5. Division table for high risk scores

Process	**Hazard source/hazard**	**Risk**
Crushing	-Transportation of raw material/ accident on workers, fall from height -The maintenance of the parts of the crusher/accident on workers -Cleaning of hopper and its parts/fall of workers from height, hurling of materials -Evacuation of water from the bottom of crusher/electric shock -Filtering/fall from height	Serious injury/death
Storage and transportation	-Transportation of crushed raw material/accident caused by mobile crane, fall from height -Cleaning of walking passage/ fall from height -Maintenance of the conveyor belts/ fall from height -Cleaning of hopper and its parts/accident on workers, unauthorized loading, working at height -Cleaning of storage area/collapse of roof the storage area, fall from height	Serious injury/death
Raw material milling	-Cleaning and maintenance of mill and its parts/fall of workers from height, work in confined space, unauthorized works, contact with hot surface -Cleaning of hopper and its parts/fall of workers from height, fall of materials, unauthorized loading -Cleaning and maintenance of the conveyor belts/ fall from height, accident -Filtering/fall from height, accident, electric shock, contact with hot surface, poor air conditioning -Cleaning and maintenance of compressor/accident	Serious injury/death/ breathing problems
Clinker production	-Working of rotary kiln/ fall from height, exposure to explosives, exposure to high temperature, contact with hot surface, exposure to hot gases, exposure to dust, backfiring of the furnace -Cleaning and maintenance of elevator/accident -Cleaning and maintenance of rotary kiln and its parts/fall of workers from height, contact to hot surface, face to hot gases, unauthorized works -Cleaning and maintenance of the conveyor belts/ fall from height, accident	Serious injury/death/ breathing problems
Cement milling	-Working of cement mill/face to dust, accident	Serious injury/ breathing problems

Table 6. Division table for moderate risk scores

Process	**Hazard source/hazard**	**Risk**
Crushing	-Starting up of crusher/accident, exposure to noise, exposure to dust, fall of material pieces -Working with transport vehicles/uncomfortable seats and other devices, long working times, insufficient lighting, poor air conditioning -Transportation of raw material/ accident, fall from height, fall of material pieces, exposure to dust, exposure to noise -The maintenance of the parts of the crusher/accident on workers -Cleaning of hopper and its parts/accident, unplanned loading, fall of workers from height, fall of materials, accident when working with hand tools, exposure to dust, insufficient working area, uncomfortable vehicles, lifting heavy tools with hand, exposure to noise -Cleaning and maintenance of the conveyor belts/ fall from height, accident, exposure to noise, unsuitable air conditioning, slippery ground, exposure to dust -Filtering/accident, fall from height, exposure to dust, accident when working with hand tools, exposure to high pressure	Serious injury/death/ breathing problems/gradual hearing impairment /eye problems, /muscular and skeletal disorders
Storage and transportation	-Working with mobile crane/accidental startup, exposure to vibration, unsuitable working area, accident, poor air conditioning, uncomfortable facilities -Transportation of crushed raw material/accident, exposure to vibration, uncomfortable facilities, exposure to dust -Cleaning of walking passage/accident, unsuitable working area, accident when working hand tools, exposure to dust -Maintenance of the conveyor belts/ accident, absence of protective barrier -Cleaning of hopper and its parts/accident on workers, hurling of material, accident when working with hand tools, exposure to dust, insufficient working area -Cleaning of storage area/exposure to dust, accident on workers, hurling of material, accident when working with hand tools, exposure to dust, insufficient working area	Serious injury/death/ breathing problems/gradual hearing impairment /eye problems, /muscular and skeletal disorders
Raw material milling	-Starting up of mill/accident, exposure to noise, exposure to dust, fall of material pieces -Working with transport vehicles/uncomfortable seats and other devices, long working times, insufficient lighting, poor air conditioning -Cleaning and maintenance of mill and its parts/fall of workers from height, insufficient, working area, unauthorized works, contact with hot surface, slippery ground, accident when working hand tools, exposure to dust, exposure to noise -Cleaning and maintenance of the elevator/accident, unplanned loading, accident when working hand tools, exposure to dust, exposure to noise -Cleaning of hopper and its parts/accident, hurling of materials, accident when working hand tools, exposure to dust, exposure to noise, unsuitable working area --Cleaning and maintenance of the conveyor belts/ fall from height, accident, exposure to noise, unsuitable air conditioning, slippery ground, exposure to dust -Filtering/accident, exposure to dust, contact with hot surface, poor air conditioning, accident when working hand tools, exposure to noise -Cleaning and maintenance of compressor/accident, exposure to noise, poor air conditioning, accident when working hand tools	Serious injury/death/ breathing problems/gradual hearing impairment /eye problems, /muscular and skeletal disorders
Clinker production	-Starting up of rotary kiln/accident, exposure to noise, exposure to dust, fall of material pieces, unsuitable working area, slippery ground -Working with transport vehicles/uncomfortable seats and other devices, long working times, insufficient lighting, poor air conditioning -Cleaning and maintenance of the elevator/accident, unplanned loading, accident when working hand tools, exposure to dust, exposure to noise -Working of rotary kiln/ fall from height, exposure explosives, exposure to high temperature, contact with hot surface, exposure to hot gases, exposure to dust, backfiring of burner, poor ventilation -Cleaning and maintenance of rotary kiln and its parts/fall of workers from height, contact with hot surface, exposure to hot gases, unauthorized works -Filtering/accident, exposure to dust, contact with hot surface, poor air conditioning, accident when working hand tools, exposure to noise -Cleaning and maintenance of the conveyor belts/ fall from height, accident	Serious injury/death/ breathing problems/gradual hearing impairment /eye problems, /muscular and skeletal disorders
Cement milling	- The similar hazards and cause as in raw material milling	Serious injury/death/ breathing problems/gradual hearing impairment /eye problems, /muscular and skeletal disorders

4. Conclusions

In this study, the occupational health risk analysis and assessment in in the Elazığ-Altınova Cement Plant were carried out according to the occupational health and safety risk management in the cement production processes. For this reason, the plant site studies have been performed by using 5x5 L type risk matrix methodology. It was concluded that

- The most dangerous risks were determined in the raw material milling section.
- The highest risk scores were observed in the raw material milling section.
- The crusher, raw material and cement mills and rotary kiln are the most dust, noise, and vibration producing units.
- The workers are exposed to various occupational health hazards that cause various kind of illness in the cement factory workers' health. These are physical, chemical or accidental due to mechanical hazards and other health problems.

The further study can be carried out by using other risk analysis and assessment methods such as X-type matrix, and hazards and operability (HAZOP). These methods can be applied to all of the chemical ındustries and require team work.

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