DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT STUDIES IN TWO RESEARCH LABORATORIES

by
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İZMİR

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT STUDIES IN TWO RESEARCH LABORATORIES

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT STUDIES IN TWO RESEARCH LABORATORIES"** completed by **GÖKÇE GÜNEY** under supervision of **PROF. DR. BAYRAM KAHRAMAN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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I dedicate this thesis to my father, who has devoted himself to his profession, has carried out studies on occupational health and safety management, environmental management and also quality management systems in his successfully performed electrical engineering career and crowned his career with managerial duties.

Gökçe GÜNEY

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT STUDIES IN TWO RESEARCH LABORATORIES

ABSTRACT

Two of the research laboratories in Dokuz Eylül University Environmental Engineering Department were selected and occupational health and safety assessment studies were carried out within the scope of this thesis study. Mathematical models were used in occupational health and safety assessment studies. The studies were first started by utilizing the Analytical Hierarchy Process (AHP). Before starting modeling with AHP, on-site observations were made in the studied laboratories, besides, occupational accident risks and safety precautions taken or not taken were determined in the studied laboratories. Survey questions were prepared in the light of the identified risks and precautions, and these questions were asked to full-time employees and students working in the studied laboratories. The answers received from the surveys and the matrices created in the AHP were integrated into each other and some coefficients were calculated for both occupational accidents and safety precautions. The calculated accident coefficients and safety coefficients were correlated and they were found to be related to each other with a high rate of 94 percentage. Thus, it could be expressed numerically via using AHP that it is necessary to increase safety precautions in order to reduce occupational accidents. The risks determined in the AHP were also examined using the Fine-Kinney Method (FKM), and the necessary safety precautions taken for each laboratory were specifically determined for the studied laboratories within the scope of this thesis. A cost analysis had also been made for these safety precautions. The total cost of safety precautions to be taken in the studied laboratories to prevent occupational accidents was calculated as ten thousand Euro in the light of the used mathematical models.

Keywords: Analytical Hierarchy Process (AHP), Fine-Kinney Method (FKM), occupational health and safety, cost analysis

İKİ ARAŞTIRMA LABORATUVARINDA İŞ SAĞLIĞI VE GÜVENLİĞİ DEĞERLENDİRME ÇALIŞMALARI

ÖZ

Bu tez çalışmaları kapsamında Dokuz Eylül Üniversitesi Çevre Mühendisliği Bölümü'ndeki araştırma laboratuvarlarından iki tanesi seçilerek iş sağlığı ve güvenliği değerlendirme çalışmaları yapılmıştır. İş sağlığı ve güvenliği değerlendirme çalışmaları yapılırken matematiksel modellerden faydalanılmıştır. Çalışmalara öncelikle Analitik Hiyerarşi Prosesi'nden (AHP) faydalanılarak başlanmıştır. AHP'de modellemeye başlamadan önce laboratuvarlarda yerinde gözlem yapılmış ve iş kazası riskleri ile alınan-alınmayan güvenlik önlemleri belirlenmiştir. Belirlenen riskler ve önlemler ışığında anket soruları hazırlanmış ve bu sorular laboratuvarlardaki tüm tam zamanlı çalışanlara ve öğrencilere sorulmuştur. Alınan cevaplar ile AHP'de oluşturulan matrisler entegre edilmiş ve hem iş kazaları hem de güvenlik önlemleri için bazı katsayılar hesaplanmıştır. Hesaplanan kaza katsayıları ile güvenlik katsayılarının korelasyonları yapılmış ve yüzde 94 gibi yüksek bir oranla birbirleriyle ilişkili bulunmuştur. Böylelikle AHP kullanılarak iş kazalarını azaltmak için güvenlik önlemlerini arttırmanın gerekli olduğu sayısal olarak ifade edilebilmiştir. Bu tez kapsamında çalışılan laboratuvarlar için AHP'de belirlenen riskler ayrıca Fine-Kinney Metodu (FKM) kullanılarak incelenmiş ve her bir laboratuvar için alınması gerekli görülen güvenlik önlemleri spesifik olarak belirlenmiştir. Ortaya konan bu güvenlik önlemleri için bir maliyet analizi de yapılmıştır. Kullanılan matematiksel modeller ışığında, tespit edilen iş kazalarını önlemek için laboratuvarlarda alınması gereken güvenlik önlemlerinin toplam maliyeti on bin Euro olarak hesaplanmıştır.

Anahtar kelimeler: Analitik Hiyerarşi Prosesi (AHP), Fine-Kinney Metodu (FKM), iş sağlığı ve güvenliği, maliyet analizi

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CHAPTER ONE
INTRODUCTION

Occupational health and safety precautions should be implemented in terms of employee health and reliability of analysis results for laboratory studies. Furthermore, an appropriate risk management should be made for the risks that may arise from laboratory studies. Risks should not only be revealed, but should be brought to a level that can be observed and measured for laboratory studies. It will be possible to define the risks that may be encountered to laboratory and to determine the precautions that can be taken for the laboratory study with the methods used in risk analysis. Leggett (2012) reported that risk reduction efforts in academic laboratories were less successful than those practised by the industrial laboratories because of the previously reported accident rates from the literature. Investigation findings of accidents in academic laboratories often point to the absence of a risk analysis of the situation that led to the accident (Leggett, 2012). Academic and research laboratory activities expose laboratory employees to potential hazards and increase the risk of incidents, besides, an academic laboratory is eleven times more dangerous than a laboratory in the industrial sector (Lestari, Bowolaksono, Yuniautami, Wulandari, & Andani, 2019).

1.1 Aim of the Study

Occupational health and safety studies were carried out for two different research laboratories, namely biology (B) and chemistry (C), in the Tınaztepe Campus of Dokuz Eylül University within the scope of this thesis work. In order to take precautions regarding the risks that may be encountered in the studied laboratories, assessment studies using Analytical Hierarchy Process (AHP) and Fine-Kinney Risk Assessment Method (FKM) with cost analysis were made in the aforementioned laboratories.

1.2 Novelty of the Study

While determining the situation in occupational health and safety assessment studies in both chemistry (C) and biology (B) laboratories, observations were made on the basis of four different parameters: personnel health, safety of employees, environmental quality and the quality of the analysis. For each parameter, 30 to 50 survey questions were asked and the results were mathematically modeled according to Analytic Hierarchy Process (AHP) and Fine-Kinney Method (FKM). The data that ensure the health of the employees, the quality of the environment, the analysis and the reliability of the results were examined. Potential risks, accident rates and damages that may arise in the aforementioned laboratories were minimized with the occupational health and safety precautions decided to be taken in the light of this modeling study. The cost of the precautions to be taken on the basis of each risk were calculated according to the used models (AHP and FKM) in two research laboratories (chemistry and biology). There is no study using mathematical models in risk management and calculating cost analysis for research laboratories both in Turkey and abroad.

1.3 Fine-Kinney Risk Assessment Method (FKM)

The Fine risk assessment method was developed by Fine (1971) for the California Naval Weapons Center in 1971 under the name of "Mathematical Evaluation for Controlling Hazards". After then, Kinney Method was first used in a technical document prepared by G.F. Kinney and A.D. Wiruth at the Naval Weapons Center of California (NWC) in the USA in 1976 (Kinney & Wiruth, 1976). In the first document prepared by Fine, the risk factor evaluation criterias of the method and how the mathematical model will be applied were included in detail (Fine, 1971). Kinney transformed the application of the method from a mathematical approach to a graphical approach. It has also been published as the NWC-TP-5865 standard under the name of "Practical Risk Analysis for Security Management" (Kinney & Wiruth, 1976). The method is mentioned as Fine-Kinney method in the literature.

1.4 Analytic Hierarchy Process (AHP)

AHP is a multiple criteria decision-making tool that combines quantative and qualitive factors and classifies into hierarchies to solve complex decision-making problems. It is possible to express a complex decision-making problem as an ordered hierarachical structure and sort the order of alternatives via a subjective and a scientific calculation. The criteria weights based on relative importance in pair-wise comparisons are identified by AHP method, however, incomplete or inconsistent inputs to generate criteria weights are not prevented the AHP method from working because the consistency of the decision matrix is calculated at the end of the overall calculations and if the consistency is lower than 10%, the comparisons are determined from the start (Ding et al., 2020). The stages of AHP are consisted of five steps. These are; firstly structuring the decision hierarchy, secondly establishing a comparison matrix of the factors, thirdly determining percentages for the importance distribution of the factors, fourthly finding the percentage importance distribution in decision points for every factor and finally the fifth one is reaching the result distribution in the decision points (Yaralioglu & Koksal, 2003).

1.5 Literature Review

AHP had never been used for occupational health and safety assessment studies in research laboratories. Omurbek & Simsek (2014) used Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) methods for the selection of an online shopping site and furthermore, they determined the distributions of studied alternatives as percentages and obtained similar results both for AHP and ANP. Yilmaz & Surat (2015) determined the most convenient ecotourism activity by using Analytic Hierarchy Process (AHP) and a participatory approach, in which decision makers, experts and interest groups, as well as public and interest-pressure groups could be participated directly in the decision-making process. Sutrisno, Gunawan, & Tangkuman (2015) attempted to develop a modified Failure Mode and Effect Analysis (FMEA) utilizing Analytic Hierarchy Process (AHP) to minimize the waste of maintenance activities for providing a sustainable manufacturing in an electricitygenerating company. The use of AHP enabled the manager to consider many qualitative and quantitative criterias regarding the impact of maintenance waste occurrence.

Another methods were used for occupational health and safety assessment studies in research laboratories but AHP or FKM are not available in the literature. A risk management was made for the assessment of occupational hazards linked to the use of carcinogenic, mutagenic and reprotoxic chemicals using three different methods (nominal group, Delphi and direct observation) in a research laboratory in France (Bourrée et al., 2014). Bourrée et al. (2014) chosen for the nominal group method from these three methods to raise awareness and get people involved in the risk management. Taylor & Snyder (2017) examined safety behaviors of employees without supervisor commitment to safety in a laboratory study in which they performed two seemingly dangerous tasks and they concluded that the supervisor commitment to safety appears to have a very strong influence on safety behavior in risk perception for the employees. Lestari et al. (2019) evaluated an implementation of Occupational Health, Safety, and Environment Management System (OHSEMS) for laboratory researchers and students whose expose to hazardous and toxic chemicals in higher education laboratories. Their research was a semiquantitative descriptive study which determined the percentages of OHSEMS compliance in higher education laboratories with five aspects namely commitment, planning, implementation, evaluation and management.

In the studies carried out so far, researchers had used different following risk assessment methods in the business lines related to the environmental engineering (environmental sector). Ercan (2016) intended to make risk assessment applications using Scanning Level Risk Assessment method (SLRA) in three selected hazardous waste disposal plants on occupational health and safety and suggested solutions to inhibit or minimize risks caused by the hazard factors. The quantative results of the risk assessments showed that the occupational accidents causing deaths, permanent injuries or serious health complications had very high risk factors and SLRA method could be implemented successfully in this sector. Adar, Ince, Karatop, & Bilgili

(2017) examined failure mode and effect analysis (FMEA) and fuzzy-FMEA for a supercritical water gasification system (SCWG) used in the sewage sludge treatment. They determined the operation problems, their reasons with effects and the most important risks and furthermore, they concluded that conducting a risk analysis of the SCWG system is important for occupational safety. Moreno & Cozzani (2018) integrated a checklist and a tailored Hazard and Operability method to develop a risk management for in an anaerobic digestion process for biogas production. They determined the most dangerous equipments and which processes composing the danger in the anaerobic digestor and thus, they could prioritized the measures, provided a guidance to the team and supported recommendations for follow-up activities in design modification aimed at safety improvement. Demirel & Sert (2018) carried out a study in the plastic recycling sector using Pre-Hazard Analysis (PHA) method in order to determine occupational health and safety risks. By using the PHA method, implementing periodic trainings and periodic controls in the facility could be reduced, removed or took control of the risks as a result of the study. In another study the risk assessment of a river basin was carried out using Fault Tree Analysis (FTA) to determine the unfavorable events such as undesirable ecological status, low quality and scarcity of water resources and economic and social anomalies by taking advantage of the information available for the area and using experts' opinions. The results of the study showed that the index derived from the FTA could be provided comprehensive measures to water resources managers and decision makers for improving and comparing the status of internal and external effective factors in river basins (Gachlou, Roozbahani, & Banihabib, 2019). Zhu, Tang, Li, & Fang (2020) used the combination of fault tree analysis (FTA) and binary decision diagram (BDD) in their research about critical factors of explosion accident in a research laboratory and their study revealed that the main sources of explosion accidents could be sorted as gas cylinder, pressure device and hazardous chemicals. They detected that human, machine, environment and management were affected from the aforementioned accident sources. However, they achieved the goal of maintaining safety state of the laboratory in real time by using their aforementioned risk assessment methods in their study.

Although different risk assessment methodologies have been used for different study areas, there is no study that models the occupational health and safety assessment studies of environmental research laboratories like in this study using AHP and FKM and furthermore, calculates the cost of the results obtained both in Turkey and abroad.

CHAPTER TWO
MATERIALS AND METHODS

2.1 Used Models

Analytic Hierarchy Process (AHP) and Fine-Kinney Method (FKM) were selected for the occupational health and safety assessment studies in two research laboratories. Possible risks in the studied laboratories and the safety precautions to be taken against to the possible risks were determined with the help of the aforementioned risk assessment methods.

2.1.1 Analytic Hierarchy Process (AHP)

Describing the decision making problem is constituted of two stages. At the first stage, the decision points are determined. The decision is evaluated depending on the consequences. In this study, the decision points were determined as accident severities. A previous study from the literature was taken as an example to create the definitions of the accident severities (Ersoy, 2013). The definitions of the accidents severities were shown in Table 2.1. The accident severities were classified by asking some questions to the laboratory employees and the students about occupational accidents as mentioned in Table 2.2 working in two research (chemistry and biology) laboratories.

Table 2.1 The definitions of the accidents severities (Ersoy, 2013)

Impact of accidents	**Definitions**
Extreme Dangerous (ED)	The accident causes to death or permanent disability.
Very Dangerous (VD)	The accident causes to requiring hospital treatment or leaving temporary disability.
Dangerous (D)	The accident causes to treat outpatient.
Less Dangerous (LD)	The accident causes to no disability or needs first-aid on the employees.

Table 2.2 The questions asked to laboratory employees and the students

No	Occupational Accidents	**Extreme Dangerous** *(Death or permanent disability)*	**Very Dangerous** (*Hospital treatment or temporary disability)*	**Dangerous** (*Outpatient)*	**Less Dangerous** *(No disability or first-aid)*	**Accident did not happen**
1	Stumble and fall					
2	Sharp object injuries					
3	Musculoskeletal injuries					
4	Chemical contamination					
5	Falling of the objects					
6	Contamination of the studying sample					
7	Poisoning due to gases releasing from the analysis					
8	Electric shock					
9	Explosion-burning					
10	Flooding					
11	Allergy					
12	Infections originating from laboratory activities					

Then at the second stage, the factors affecting the decision points were determined as safety precautions. A previous study from the literature was taken as an example to create the definitions of the safety precautions (Ersoy, 2013). These safety precautions were shown in Table 2.3.

Table 2.3 The definitions of the safety precautions (Ersoy, 2013)

The degree of the precaution	**Definitions**	**Extension**
Completely (C)	Laboratory involves all the suggested precautions.	100%
Mostly (M)	Laboratory involves most of the suggested precautions.	Much more than 50%
Partially (P)	Laboratory involves only a part of the suggested precautions.	Less than 50%
Never (N)	Laboratory does not involves any suggested precautions.	0%

In order to specifiy the occupational accidents in the studied laboratories and the precautions for decreasing the occupational accidents, applied and ignored safety precautions at the studied laboratories determined via observations at place. Therefore, the occupational risks and safety precautions were classified under 13 groups and they were asked to all laboratory employees and students if they think any occupational risk exist in their laboratories does any of the suggested precaution applied for it (Table 2.4).

Table 2.4 The risks and the precautions asked to the laboratory personnel

No	**Occupati-onal Risks**	**Safety Precautions**	**Biology Research Laboratory**									**Chemistry Research Laboratory**		
			B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**
1	Vibration - Dust - Heat - Moisture	There is no risk												
2	Noise	Training, Selection of less noisy devices, Periodic maintenance for laminar air flow cabinets and ventilation system for every year, Health surveillance												
3	Ergonomics	Training, Providing break times, Exercising, Health surveillance, Standard bench heights, Standard table heights for the studies with pc												
4	Biological samples	Training, Providing laminar air flow cabinets, Disinfection, PPE, Emergency kits												
5	Biological wastes	Training, PPE, Emergency kits, Autoclaving, Collection vehicle and container, Proper storage												
6	Chemicals	Training, PPE, Fume hoods, Eye-body wash, Emergency kits, SDSs of the chemicals												
7	Chemical wastes	Training, PPE, Emergency kits, Collection vehicle and container, Proper storage												
8	Radioactive materials	There is no risk												
9	Radioactive wastes	There is no risk												
10	Electricity	Training, Periodic control of the system, Accessible height for the electrical fuses, Objects must be removed in front of the electrical fuses, Nonconducting mat in front of the electrical panels, Using residual current device												
11	Fire - Explosion	Training, Proper storage for chemicals, Cylinders must be fixed on the wall, Fire-extinguishers and fire detectors, Emergency exits, Warning signs, Conducting fire drills												
12	Natural disaster	Training, Proper storage for chemicals, Cylinders must be fixed on the wall, Fire-extinguishers and fire detectors, Emergency exits, Warning signs, Conducting drills												
13	Flooding	Periodic maintenance of the water system												

The comparison matrix between the factors is a square matrix and the evaluation factors consist from the rows and the from the columns of the comparison matrix. The comparisons are made by using the relative importance scale of the AHP method, as shown in Table 2.5 (Saaty, 1994).

Table 2.5 Scale of the relative importance (Saaty, 1994)

Intensity of the Relative Importance	Definition	Explanation
1	**Equal Importance:** Both factors have the equal importance.	Two activities contribute equally to the objective.
3	**Moderate Importance:** The factor 1 is more important than the factor 2.	Experience and judgement another slightly favour one activity over.
5	**Essential or Strong:** The factor 1 is much more important than the factor 2.	Experience or judgement strongly favours one activity over another.
7	**Importance Demonstrated:** The factor 1 is significantly important compared to the factor 2.	An activity is strongly favoured and its dominance is demonstrated in practice.
9	**Extreme (Absolute):** The factor 1 has absolutely prevailing importance compared to the factor 2.	The evidence favouring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values	When compromise is needed.

The comparison matrix of the accident severities was composed using the priority values shown in Table 2.6 and it was determined by the relative importance scale of the AHP method.

Table 2.6 Priority values of the accident severities

Definitions	Priority value
The accident causes to death or permanent disability is more important than the accident causes to requiring hospital treatment or temporary disability.	2
The accident causes to death or permanent disability is much more or significantly important than the accident causes to treat outpatient.	6
The accident causes to death or permanent disability is absolutely prevailing important than the accident causes to no disability or first-aid.	9
The accident causes to requiring hospital treatment or temporary disability is much more important than the accident causes to treat outpatient.	4
The accident causes to requiring hospital treatment or temporary disability is significantly important compared to the accident causes no disability or first-aid.	7
The accident causes to treat outpatient is more important than the accident causes to no disability or first-aid.	3
All criterions are equal with itself.	1

For the comparison of the safety precautions in the matrix the relative importance scale of the AHP method was used and the priority values were determined as shown in Table 2.7.

Table 2.7 Priority values of the safety precautions

Definitions	Priority value
The completely applying of the safety precautions is more important than the mostly applying.	4
The completely applying of the safety precautions is absolutely prevailing important than the partially applying.	9
The mostly applying of the safety precautions is much more important than the partially applying .	5
All criterions are equal with itself.	1

Simple mathematical operations (addition, subtraction, multiplication and division), decision criterias (precautions and accidents) based on chemical, physical and biological factors in AHP (Table 2.8) and the relative importance scale were used in AHP. According to the AHP method, each alternatives are compered by using the relative importance scale suggested by Saaty (Saaty, 1994).

Table 2.8 Chemical, physical and biological factors in AHP

Factors	Occupational Risks
Chemical	Chemicals, Chemical wastes, Radioactive materials, Radioactive wastes
Physical	Vibration - Dust - Heat – Moisture, Noise, Ergonomics, Electricity, Fire – Explosion, Natural disaster, Flooding
Biological	Biological samples, Biological wastes

In this study, AHP consists of four stages. They are described below:

2.1.1.1 Structuring the Decision Hierarchy

Describing the decision making problem is constituted of two stages. In the first stage, the decision points are determined. Then, the decision is evaluated depending on the consequences. In this study, the decision points were determined as accident severities. The accident severities were classified as extreme dangerous (ED), very dangerous (VD), dangerous (D) and less dangerous (LD). The definitions of the accidents severities were shown in Table 2.1.

In the second stage, the factors affecting a decision are described. By determining the factors affecting the decision points accurately and describing the each factors in detail is very important. Because this is the best possible way to make doubled comparisons consistent and feasible (Yaralioglu, 2016). In this study, the factors affecting the decision points were determined as safety precautions. The safety precautions were classified as completely (C), mostly (M), partially (P) and never (N). The definitions of the safety precautions were shown in Table 2.3.

2.1.1.2 Composing a Comparison Matrix Between the Factors

The comparison matrix between the factors is a square matrix with $n \times n$ dimensions (Ding et al., 2020). The comparison matrix is shown in Equation 2.1.

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{2.1}$$

The evaluation factors consist from the rows and the from the columns of the matrix. The comparisons are made by using the relative importance scale of the AHP method, as shown in Table 2.5 (Saaty, 1994). In this study, the comparison matrix of the accident severities was composed using the relative importance scale of the AHP method. The priority values were determined as shown in Table 2.6 and they were put into the comparison matrix. Since the values on the diagonal represent the same factor, they become 1. If the preference is used in favour of the factor in the row when the factor in any row is compared with the factor in the column, fraction (1/importance value) is preferred (Yaralioglu & Koksal, 2003).

For the comparison matrix of the safety precautions it was composed using the relative importance scale of the AHP method. The priority values were determined as shown in Table 2.7 and the values were put into the comparison matrix.

2.1.1.3 Determination of Percent Importance Distribution of the Factors

The B row vector with $n \times 1$ dimensions is consisted by using the row vectors composing the comparison matrix for importance distribution (Yaralioglu & Koksal, 2003). The B row vector is shown in Equation 2.2.

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix} \tag{2.2}$$

The components of this vector are calculated by using Equation 2.3, with the utilisation of the elements of the comparison matrix (a_{ij}). In other words, the elements of the B row vector are calculated by dividing the elements in the lines of the comparison matrix with the row sums (Yaralioglu & Koksal, 2003).

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{2.3}$$

Then, the obtained n times B row vector is structured in a matrix format and this matrix represents the C matrix (Yaralioglu, 2016). C matrix is shown in Equation 2.4.

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ . & . & \cdots & . \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{bmatrix} = [B_1 \quad B_2 \quad . \quad . \quad . \quad B_n] \tag{2.4}$$

A priority vector namely W vector is calculated using the matrix C. W vector shows us the importance distribution of the factors to each other (Yaralioglu, 2016). The W vector is shown in Equation 2.5.

$$W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} \quad (2.5)$$

The priority vector, W is formed by adding the columns and dividing each value by this total sum of columns and then calculating the average of the rows from the C matrix, thus, a single-column vector is obtained (Ersoy, 2013). The calculation of the W vector is shown in Equation 2.6.

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \quad (2.6)$$

2.1.1.4 Evaluation of the Consistency for Comparison of the Factors

According to the AHP method, the consistency ratio (CR) should be calculated to check the decisions and the truth of priority vectors (W). CR is a comparison of the number of factors with the λ coefficient which is called the basic value. In order to calculate the value of λ, the column vector D is calculated from the matrix multiplication of the comparison matrix (A) by the priority vector (W) (Ersoy, 2013). The column vector D is shown Equation 2.7.

$$D = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} \quad (2.7)$$

Then, the basic value E for each evaluation factor is calculated from the reciprocal members of the column vectors D and W, and the basic value λ and consistency indicator (CI) are calculated from the arithmetic mean of those values (Ersoy, 2013). Calculations of the E, λ and CI are shown in Equations 2.8, 2.9 and 2.10, respectively.

$$E_i = \frac{d_i}{w_i} \; (i = 1, 2, \ldots\ldots, n) \tag{2.8}$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} \tag{2.9}$$

$$CI = \frac{\lambda - n}{n - 1} \tag{2.10}$$

In order to calculate the consistency ratio (CR), CI is divided by the random consistency index number (RI). The random consistency index (RI) number is selected from the Table 2.9 according to the size of the matrix (Ersoy, 2013). Calculation of the consistency ratio (CR) is shown in Equation 2.11.

Table 2.9 Random consistency index numbers (Ersoy, 2013)

Number of the factors	RI value	Number of the factors	RI value
1	0.00	8	1.41
2	0.00	9	1.45
3	0.58	10	1.49
4	0.90	11	1.51
5	1.12	12	1.48
6	1.24	13	1.56

$$CR = \frac{CI}{RI} \tag{2.11}$$

2.1.2 Fine-Kinney Method (FKM)

Possible risks caused from occupational accidents in the laborotories were assessed with Fine-Kinney Method (FKM) based on chemical, physical and biological factors (Table 2.10).

Table 2.10 Chemical, physical and biological factors in FKM

Factors	**Occupational Risks**
Chemical	Chemical Contamination, Poisoning due to Gases Releasing from the Analysis
Physical	Electric Shock, Explosion-Burning, Falling of the Objects, Musculoskeletal Injuries, Sharp Object Injuries, Stumble and Fall, Flooding
Biological	Infections Originating from Laboratory Activities, Contamination of the Studying Sample, Allergy due to Latex Gloves or Some Chemicals

The risk was calculated by multiplying the possibility, frequency and effect parameters to each other. Then the calculated risks were arranged from worse to better and evaluated with Fine-Kinney Method (FKM). The calculation of possibility, frequency and effect parameters are described below:

2.1.2.1 Calculation of the Possibility Parameter

Possibility means the possibility of the actualization of a damage. For the calculation of the possibilities it should be thought always the worst scenario for a possibility. Safety precautions against to the occupational accidents should not be considered. Corrective actions affect only the possibility not the frequency or effect parameters. According to the range of the possibility, the possibility parameter gets a quantitative value in the calculation of Fine-Kinney Method (FKM) (Kinney & Wiruth, 1976). The possibility values according to the range of the possibility are shown in Table 2.11.

Table 2.11 The possibility values (Kinney & Wiruth, 1976)

Possibility (possibility of actualization of the damage)	**Value**	**Range**
The actualization of the damage is expected or certain.	10.0	$p > 10^{-1}$
The actualization of the damage is dominant or quite possible.	6.0	$10^{-1} \geq p > 10^{-2}$
The actualization of the damage is possible.	3.0	$10^{-2} \geq p > 10^{-3}$
The actualization of the damage is possible but is low.	1.0	$10^{-3} \geq p > 10^{-4}$
The actualization of the damage is not expected but is possible.	0.5	$10^{-4} \geq p > 10^{-5}$
The actualization of the damage is not expected.	0.2	$10^{-5} \geq p > 10^{-6}$

2.1.2.2 Calculation of the Frequency Parameter

Frequency does not represent the frequency of the work further to that it means the repetition of the exposure to a danger in time when you are working. For the calculation of the frequencies the working time is not important but the repetition to the danger is important. According to the range of the frequency, the frequency parameter gets a quantitative value in the calculation of Fine-Kinney Method (FKM) (Kinney & Wiruth, 1976). The frequency values according to the range of the frequency are shown in Table 2.12.

Table 2.12 The frequency values (Kinney & Wiruth, 1976)

Frequency (repetition of exposure to danger in time)	Value	Range
The repetition of the exposure to the danger is almost continuous or happens a few times in one hour.	10.0	≥ 100/100
The repetition of the exposure to the danger is frequent or happens once or a few times in a day.	6.0	10 - 99/100
The repetition of the exposure to the danger happens sometimes or once or a few times in a week.	3.0	1.0 – 9.9/100
The repetition of the exposure to the danger is not frequent or happens once or a few times in a month.	2.0	0.1 – 0.99/100
The repetition of the exposure to the danger is rare or happens a few times in a year.	1.0	0.01 – 0.099/100
The repetition of the exposure to the danger is very rare or happens once in a year or happens less frequently.	0.5	≤ 0.01/100

2.1.2.3 Calculation of the Effect Parameter

Effect means the estimated damage on human and or environment. For the calculation of the effects if you have a suspicion about the effect of the accident, you should choose the higher value. According to the type of the effect, the effect parameter gets a quantitative value in the calculation of Fine-Kinney Method (FKM) (Kinney & Wiruth, 1976). The effect values according to the range of the effect are shown in Table 2.13.

Table 2.13 The effect values (Kinney & Wiruth, 1976)

Effect (estimated damage on human and/or environment)	Value
The estimated damage on human is more than one accident involving death and/or the estimated damage is an environmental disaster.	100
The estimated damage on human is a fatal accident and/or the estimated damage is a serious environmental damage.	40
The estimated damage on human is a permanent damage or injury even a working day loss and/or the estimated damage causes complaint from immediate environment.	15
The estimated damage on human is a transient damage or injury even requires hospital treatment and/or the estimated damage causes environmental damage inside of the bounds.	7
The estimated damage on human is a minor loss or injury or first aid need and/or the estimated damage causes less environmental damage inside of the bounds.	3
The estimated damage on human escapes with little or no harm and/or the estimated damage causes no environmental damage.	1

2.1.2.4 Calculations and Classifications of the Risk Values

The risk values for some potentially dangerous situations are calculated as quantitative by multiplying the three parameters: possibility, frequency and effect

(Risk value = Possibility × Frequency × Effect). The calculated risk values could be associated with the risks observed for actual situations. A risk value as low as 20 represents a situation of low risk and it is considered acceptable for the laboratory work. The precaution is not primary for the risk. A risk value between 20 to 70 indicates that it is a possible risk and it should bring under control. A situation with a risk value in a range of 70 to 200 is considered an important risk and correction is needed. Also, there can be higher risk situations; a risk value of 200 to 400 indicates that correction is urgently needed. A very high risk value of more than 400 indicates that the risk is not tolerated and necessary precautions must be taken immediately. If the work cannot be made safe a permanent shutdown becomes necessary for the laboratory, building or the environment (Kinney & Wiruth, 1976). The classifications of the risk values according to the Fine-Kinney Method (FKM) are shown in Table 2.14. Njoroge & Nichols (2014) also concluded that there is a spectrum of risk from very low to very high risk and one can never achieve zero risk. They also stated that the events occur more frequently pose greater risk and events cause greater harm are higher risk.

Table 2.14 The classifications of the risk values according to the FKM (Kinney & Wiruth, 1976)

Risk value	**Decision**	**Situation**
R > 400	Not tolerated risk	Necessary precautions must be taken immediately or facility, building, environment must be shut down.
200 < R < 400	Strong risk	The situation should enhanced in a short period (in a few months).
70 < R < 200	Important risk	The situation should enhanced in a long period (in a year).
20 < R < 70	Possible risk	The risk should bring under control.
R < 20	Insignificant risk	The precaution is not primary.

2.1.2.5 Assessment of the Results

In this study, classified risk values were fitted into a sequence from not tolerated risk to insignificant risk. Corrective actions against to the risks were wrote into the risk assessment report. The format of the risk assessment report according to the Fine-Kinney Method (FKM) is shown in Figure 2.1.

RISK ASSESSMENT REPORT FOR FINE-KINNEY METHOD										
					Risk Rating					
NO	Risk	Source of Danger	Possible situation if danger turns into accident	Affected People	Possibility	Frequency	Effect	Risk Value	Decision	Corrective Action
1									Not tolerated risk	
2									Strong risk	
3									Important risk	
4									Possible risk	
5									Insignificant risk	

Figure 2.1 The format of the risk assessment report according to the FKM

2.2 Used Laboratories

The studies were performed in a chemistry (C) and a biology (B) research laboratories in Environmental Engineering Department at Dokuz Eylul University in Izmir/Turkey. Both chemistry (C) and biology (B) research laboratories are accredited laboratories from Ministry of Environment and Urbanization of Turkey and Turkish Accreditation Agency (TURKAK). They serve analysis services to government agencies and to business firms in a wide range. Some advanced research and educational studies are carried out in these laboratories. The chemistry (C) laboratory has 8 full-time employees while the biology (B) laboratory has 3 full-time employees. Also, some under graduate and post graduate students are carried out their educational and research studies at part times in these laboratories. The biology (B) and chemistry (C) research laboratories increased the numbers of their analyis in time, therefore extra area requirements are needed. The biology (B) research laboratory consists of 9 sub-laboratories and the chemistry (C) research laboratory consists of 3 sub-laboratories. The sub-laboratory names were coded as from B-1 to B-9 for the biology (B) and from C-1 to C-3 for the chemistry (C) research laboratory. B-1 is biology (B) main research laboratory and B-2 is biology (B) instrumental research laboratory. B-3 and B-4 are biology (B) toxicity research laboratories. B-5 and B-6 are biology (B) post graduate student research laboratories while B-7 is biology (B) under graduate student research laboratory. B-8 and B-9 serve to the biology (B) research laboratory as chemical depots. C-1 is chemistry (C) main research laboratory and C-2 is chemistry (C) instrumental research laboratory. C-3 serves to the chemistry (C) research laboratory as chemical depot.

2.3 Cost Analysis

Cost analysis were performed for suggested precautions and corrective actions arranged in AHP and Fine-Kinney Method in order to determine the cost benefit of the biology (B) and chemistry (C) laboratories using Microsoft Excel 2010.

CHAPTER THREE
RESULTS AND DISCUSSIONS

3.1 Analytic Hierarchy Process (AHP)

3.1.1 The Comparison Matrix Between the Factors

The comparison matrix between the accident severities is a square matrix with 4 × 4 dimensions and it was shown in Equation 3.1.

$$A_{\text{(accident severities)}} = \begin{bmatrix} 1 & 2 & 6 & 9 \\ 1/2 & 1 & 4 & 7 \\ 1/6 & 1/4 & 1 & 3 \\ 1/9 & 1/7 & 1/3 & 1 \end{bmatrix} \tag{3.1}$$

The comparison matrix between the safety precautions was shown in Equation 3.2. We have four safety precautions as the factors but the comparison matrix is 3 × 3 dimensions. Because taking no safety precaution (Never, N) is out of the calculation because it hasn't got any positive effect.

$$A_{\text{(safety precautions)}} = \begin{bmatrix} 1 & 4 & 9 \\ 1/4 & 1 & 5 \\ 1/9 & 1/5 & 1 \end{bmatrix} \tag{3.2}$$

3.1.2 The Percentages for the Importance Distribution of the Factors

B row vectors with a number of four were calculated for the comparison matrix of accident severities having a dimension of 4 × 4 by dividing the elements in the lines of the comparison matrix with the row sums. The calculated B row vectors for the comparison matrix of accident severities were shown in Equation 3.3, 3.4, 3.5 and 3.6.

$$B_{1\text{ (accident severities)}} = \begin{bmatrix} 0.5625 \\ 0.2812 \\ 0.0937 \\ 0.0625 \end{bmatrix} \tag{3.3}$$

$$B_{2\text{ (accident severities)}} = \begin{bmatrix} 0.5895 \\ 0.2947 \\ 0.0737 \\ 0.0421 \end{bmatrix} \tag{3.4}$$

$$B_{3\text{ (accident severities)}} = \begin{bmatrix} 0.5294 \\ 0.3529 \\ 0.0882 \\ 0.0294 \end{bmatrix} \tag{3.5}$$

$$B_{4\text{ (accident severities)}} = \begin{bmatrix} 0.4500 \\ 0.3500 \\ 0.1500 \\ 0.0500 \end{bmatrix} \tag{3.6}$$

The C matrix structured from the B row vectors of the accident severities was shown in Equation 3.7.

$$C_{\text{(accident severities)}} = \begin{bmatrix} 0.5625 & 0.5895 & 0.5294 & 0.4500 \\ 0.2812 & 0.2947 & 0.3529 & 0.3500 \\ 0.0937 & 0.0737 & 0.0882 & 0.1500 \\ 0.0625 & 0.0421 & 0.0294 & 0.0500 \end{bmatrix} \tag{3.7}$$

The priority vector (W) of the accident severities was calculated using the C matrix of the accident severities. The W vector representing the importance distribution of the accident severities to each other was shown in Equation 3.8.

$$W_{\text{(accident severities)}} = \begin{bmatrix} 0.5329 \\ 0.3197 \\ 0.1014 \\ 0.0460 \end{bmatrix} \approx \begin{bmatrix} 0.53 \\ 0.32 \\ 0.10 \\ 0.05 \end{bmatrix} \tag{3.8}$$

In this study, an accident index in the studied laboratories was calculated for each extreme dangerous accident as 0.53, for each very dangerous accident as 0.32, for each dangerous accident as 0.10 and for each less dangerous accident as 0.05 points.

Moreover, it could be said that extreme dangerous, very dangerous, dangerous and less dangerous accidents in the studied laboratories have a significance value of 53%, 32%, 10% and 5%, respectively.

B row vectors with a number of three were calculated for the comparison matrix of safety precautions having a dimension of 3 × 3 by dividing the elements in the lines of the comparison matrix with the row sums. The calculated B row vectors for the comparison matrix of safety precautions were shown in Equation 3.9, 3.10, and 3.11.

$$B_{1\ (\text{safety precautions})} = \begin{bmatrix} 0.7347 \\ 0.1837 \\ 0.0816 \end{bmatrix} \tag{3.9}$$

$$B_{2\ (\text{safety precautions})} = \begin{bmatrix} 0.7692 \\ 0.1923 \\ 0.0385 \end{bmatrix} \tag{3.10}$$

$$B_{3\ (\text{safety precautions})} = \begin{bmatrix} 0.6000 \\ 0.3333 \\ 0.0667 \end{bmatrix} \tag{3.11}$$

The C matrix structured from the B row vectors of the safety precautions was shown in Equation 3.12.

$$C_{(\text{safety precautions})} = \begin{bmatrix} 0.7347 & 0.7692 & 0.6000 \\ 0.1837 & 0.1923 & 0.3333 \\ 0.0816 & 0.0385 & 0.0667 \end{bmatrix} \tag{3.12}$$

The priority vector (W) of the safety precautions was calculated using the C matrix of the safety precautions. The W vector representing the importance distribution of the safety precautions to each other was shown in Equation 3.13.

$$W_{(\text{safety precautions})} = \begin{bmatrix} 0.7013 \\ 0.2364 \\ 0.0623 \end{bmatrix} \approx \begin{bmatrix} 0.70 \\ 0.24 \\ 0.06 \end{bmatrix} \tag{3.13}$$

In this study, a safety index was calculated for the precautions taken in the studied laboratories for completely applied as 0.70, for mostly applied as 0.24 and for partially applied as 0.06 points. In addition to this, it could be said that completely, mostly and partially applied precautions in the studied laboratories have a significance value of 70%, 24% and 6%, respectively.

3.1.3 The Consistency for Comparison of the Factors

D column vector with a dimension of 4 × 1 was calculated from the matrix multiplication of the comparison matrix of the accident severities having a dimension of 4 × 4 by the priority vector of the accident severities having a dimension of 4 × 1. The calculated D column vector for the accident severities was shown in Equation 3.14.

$$D_{\text{(accident severities)}} = \begin{bmatrix} 1 & 2 & 6 & 9 \\ 1/2 & 1 & 4 & 7 \\ 1/6 & 1/4 & 1 & 3 \\ 1/9 & 1/7 & 1/3 & 1 \end{bmatrix} \times \begin{bmatrix} 0.5329 \\ 0.3197 \\ 0.1014 \\ 0.0460 \end{bmatrix} = \begin{bmatrix} 2.1947 \\ 1.3138 \\ 0.4081 \\ 0.1847 \end{bmatrix} \quad (3.14)$$

The basic value E for the accident severities was calculated from the reciprocal members of the column vectors D and W, and the basic value λ and consistency indicator (CI) were calculated from the arithmetic mean of those values. Calculations of the E, λ and CI for the accident severities were shown in Equations 3.15, 3.16 and 3.17, respectively.

$$E_{\text{(accident severities)}} = \begin{bmatrix} 2.1947 \\ 1.3138 \\ 0.4081 \\ 0.1847 \end{bmatrix} \div \begin{bmatrix} 0.5329 \\ 0.3197 \\ 0.1014 \\ 0.0460 \end{bmatrix} = \begin{bmatrix} 4.1184 \\ 4.1095 \\ 4.0247 \\ 4.0152 \end{bmatrix} \quad (3.15)$$

$$\lambda_{\text{(accident severities)}} = (4.1184 + 4.1095 + 4.0247 + 4.0152) / 4 = 4.0670 \quad (3.16)$$

$$CI_{\text{(accident severities)}} = \frac{\lambda - n}{n-1} = \frac{4.0670 - 4}{4-1} = 0.0223 \quad (3.17)$$

The random consistency index (RI) number was selected as 0.90 from the Table 2.9 and the calculated consistency ratio (CR) of the accident severities was shown in Equation 3.18.

$$\text{CR}_{\text{(accident severities)}} = \frac{CI}{RI} = \frac{0.0223}{0.90} = 0.0248 \tag{3.18}$$

A consistency ratio (CR) smaller than 10% means that the matrices are consistent. Otherwise, the one-to-one comparisons made by the decision maker between the factors should be reviewed (Ersoy, 2013). The consistency ratio (CR) of the accident severities was found as approximately 2.5% (0.0248) and this value is smaller than 10% (0.10). The calculated comparison matrix of the accident severities having a dimension of 4 × 4 was found consistent according to those calculations.

D column vector with a dimension of 3 × 1 was calculated from the matrix multiplication of the comparison matrix of the safety precautions having a dimension of 3 × 3 by the priority vector of the safety precautions having a dimension of 3 × 1. The calculated D column vector for the safety precautions was shown in Equation 3.19.

$$\text{D}_{\text{(safety precautions)}} = \begin{bmatrix} 1 & 4 & 9 \\ 1/4 & 1 & 5 \\ 1/9 & 1/5 & 1 \end{bmatrix} \times \begin{bmatrix} 0.7013 \\ 0.2364 \\ 0.0623 \end{bmatrix} = \begin{bmatrix} 2.2076 \\ 0.7232 \\ 0.1875 \end{bmatrix} \tag{3.19}$$

The basic value E for the safety precautions was calculated from the reciprocal members of the column vectors D and W, and the basic value λ and consistency indicator (CI) were calculated from the arithmetic mean of those values. Calculations of the E, λ and CI for the safety precautions were shown in Equations 3.20, 3.21 and 3.22, respectively.

$$\text{E}_{\text{(safety precautions)}} = \begin{bmatrix} 2.2076 \\ 0.7232 \\ 0.1875 \end{bmatrix} \div \begin{bmatrix} 0.7013 \\ 0.2364 \\ 0.0623 \end{bmatrix} = \begin{bmatrix} 3.1479 \\ 3.0592 \\ 3.0096 \end{bmatrix} \tag{3.20}$$

$$\lambda_{\text{(safety precautions)}} = (3.1479 + 3.0592 + 3.0096) / 3 = 3.0722 \quad (3.21)$$

$$CI_{\text{(safety precautions)}} = \frac{\lambda - n}{n-1} = \frac{3.0722-3}{3-1} = 0.0361 \quad (3.22)$$

The random consistency index (RI) number was selected as 0.58 from the Table 2.9 and the calculated consistency ratio (CR) of the safety precautions was shown in Equation 3.23.

$$CR_{\text{(safety precautions)}} = \frac{CI}{RI} = \frac{0.0361}{0.58} = 0.0622 \quad (3.23)$$

The consistency ratio (CR) of the safety precautions was found as 6.2% (0.0622) and this value is smaller than 10% (0.10). The calculated comparison matrix of the safety precautions having a dimension of 3 × 3 was found consistent according to those calculations.

3.1.4 Modelling With AHP

The occupational accidents and their damages were investigated asking 12 questions to the employees and the students (personnel) in the studied laboratories in a five year period from 2014 to 2019. Some of the occupational accidents were detected from our monitoring study for the possible accidents and some of them were prepared by taking into consideration of the previous occupational accidents in the studied laboratories. The occupational accidents were determined as “Stumble and Fall”, “Sharp Object Injuries”, “Musculoskeletal Injuries”, “Chemical Contamination”, “Falling of the Objects”, “Contamination of the Studying Sample”, “Poisoning”, “Electric Shock”, “Explosion-Burning”, “Flooding”, “Allergy” and “Infections Originating from Laboratory Activities”. The possible sources of the dangers in the biology and the chemistry laboratories were detected via observations at place. The occupational accidents and the possible sources of the dangers were shown in Table 3.1.

Table 3.1 The accidents and the possible sources of the dangers

The occupational accidents	**The possible sources**
Stumble and Fall	Electric cables, doorsills and waterpipes on the floor, untidy lab., floor cleaning
Sharp Object Injuries	Analysis
Musculoskeletal Injuries	Standing during analysis, lifting heavy things
Chemical Contamination	Analysis
Falling of the Objects	Materials on the open shelves, cabinets, fume hoods
Contamination of the Studying Sample	Wastewater, biological sludge, microorganisms, soil, solid waste
Poisoning	Gases releasing from the analysis, chemicals using in the analysis
Electric Shock	Electrical equipment
Explosion-Burning	Gas cylinders, chemicals, fire-extinguishers
Flooding	Valve breakdown, rain water leakage
Allergy	Latex gloves, chemicals
Infections Originating from Laboratory Activities	Analysis

We asked to the laboratory personnel that “If you had an occupational accident at your laboratory in a five year period (2014-2019) which danger category fits to you, please tick up the check box”. The collected answers about the accident severities from the laboratory personnel between 2014 and 2019 were shown in Table 3.2.

Table 3.2 The collected answers about accident severities

Accidents	**Impact of accident**	**Biology Research Laboratory**									**Chemistry Research Laboratory**			**Total and percen-tage (%)**
		B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	
Stumble and Fall	ED	1												15 15.79%
	VD					1								
	D													
	LD	3	1	3	2	1		1				1	1	
Sharp Object Injuries	ED													17 17.89%
	VD													
	D	1		2										
	LD	2	1	3	3	1		2			2			
Musculoskeletal Injuries	ED					2								21 22.11%
	VD			2						1				
	D	2	2		4		2		2				2	
	LD								1		1			
Chemical Contamination	ED													11 11.58%
	VD						1							
	D							1			2			
	LD	1	2	1	1	1						1		
Falling of the Objects	ED													10 10.53%
	VD								1				1	
	D									1				
	LD		1		1	2			2			1		
Contamination of the Studying Sample	ED													4 4.21%
	VD					1								
	D													
	LD						2	1						

Table 3.2 continues

Accidents	**Impact of accidents**	**Biology Research Laboratory**									**Chemistry Research Laboratory**			**Total and percen-tage (%)**
		B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	
Poisoning	ED													8 8.42%
	VD	2			1		2							
	D					1								
	LD											2		
Electric Shock	ED													1 1.05%
	VD													
	D		1											
	LD													
Explosion-Burning	ED													0 0.00%
	VD													
	D													
	LD													
Flooding	ED													1 1.05%
	VD										1			
	D													
	LD													
Allergy	ED													3 3.16%
	VD													
	D													
	LD	1				1	1							
Infections Originating from Lab. Activities	ED													4 4.21%
	VD										1			
	D	1				1								
	LD						1							

Table 3.2 continues

Accidents	**Impact of accidents**	**Biology Research Laboratory**									**Chemistry Research Laboratory**			**Total and percen-tage (%)**
		B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	
Sub-totals	ED	1	0	0	0	2	0	0	0	0	0	0	0	3 3.16%
	VD	2	0	2	1	2	3	0	1	1	2	0	1	15 15.79%
	D	4	3	2	4	2	2	1	2	1	2	0	2	25 26.31%
	LD	7	5	7	7	6	4	4	3	0	3	5	1	52 54.74%
Total and percentage (%)	Total	14	8	11	12	12	9	5	6	2	7	5	4	95
	percent (%)	14.74%	8.42%	11.58%	12.63%	12.63%	9.47%	5.26%	6.32%	2.11%	7.37%	5.26%	4.21%	100.00%

A laboratory may include complex activities related to various research and student activities searching humans, microorganisms, plants, animals or nanoparticles. Chemical, biological, physical and ergonomic hazards could be found in laboratories and these hazards have a potential to increase the risk of incidents (Lestari et al., 2019). It was aimed to specifiy the occupational risks in the studied laboratories and the precautions for decreasing the occupational accidents. For this reason, applied and ignored safety precautions at the studied laboratories determined via observations at place. Occupational risks were classified under 13 groups such as; vibration – dust – heat – moisture, noise, ergonomics, biological samples, biological wastes, chemicals, chemical wastes, radioactive materials, radioactive wastes, electricity, fire – explosion, natural disaster and flooding. We asked to the laboratory personnel that “If you think an occupational risk exist in your laboratory does any of the suggested precautions applied for it? Please write the safety precaution answer which fits to you”. The collected answers about the safety precautions from the laboratory personnel between 2014 and 2019 were shown in Table 3.3.

Table 3.3 The collected answers about safety precautions

No	Occupational Risks	Safety Precautions	Biology Research Laboratory									Chemistry Research Laboratory			Total and percentage (%)
			B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	C-1	C-2	C-3	
1	Vibration - Dust - Heat - Moisture	There is no risk	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	0 0.00%
2	Noise	Training, Selection of less noisy devices, Periodic maintenance for laminar air flow cabinets and ventilation system for every year, Health surveillance	M	P	--	--	M	M	--	--	--	M	P	--	6 5.88%
3	Ergonomics	Training, Providing break times, Exercising, Health surveillance, Standard bench heights, Standard table heights for the studies with pc	P	M	P	P	P	P	M	M	M	P	M	M	12 11.76%
4	Biological samples	Training, Providing laminar air flow cabinets, Disinfection, PPE, Emergency kits	P	M	M	M	P	P	M	--	--	P	M	--	9 8.82%
5	Biological wastes	Training, PPE, Emergency kits, Autoclaving, Collection vehicle and container, Proper storage	P	M	M	M	P	P	M	--	--	P	M	--	9 8.82%
6	Chemicals	Training, PPE, Fume hoods, Eye-body wash, Emergency kits, SDSs of the chemicals	M	M	M	M	M	M	M	P	P	M	M	M	12 11.76%
7	Chemical wastes	Training, PPE, Emergency kits, Collection vehicle and container, Proper storage	M	M	--	M	M	M	M	--	--	M	M	--	8 7.84%
8	Radioactive materials	There is no risk	--	--	--	--	--	--	--	--	--	--	--	--	0 0.00%
9	Radioactive wastes	There is no risk	--	--	--	--	--	--	--	--	--	--	--	--	0 0.00%
10	Electricity	Training, Periodic control of the system, Accessible height for the electrical fuses, Objects must be removed in front of the electrical fuses, Nonconducting mat in front of the electrical panels, Using residual current device	P	P	M	M	P	P	P	M	M	P	P	P	12 11.76%
11	Fire - Explosion	Training, Proper storage for chemicals, Cylinders must be fixed on the wall, Fire-extinguishers and fire detectors, Emergency exits, Warning signs, Conducting fire drills	P	M	M	M	P	P	M	M	M	P	M	M	12 11.76%
12	Natural disaster	Training, Proper storage for chemicals, Cylinders must be fixed on the wall, Fire-extinguishers and fire detectors, Emergency exits, Warning signs, Conducting drills	P	M	P	P	P	P	M	M	M	M	M	M	12 11.76%
13	Flooding	Periodic maintenance of the water system	M	--	M	--	M	M	M	C	C	M	M	C	10 9.80%
Sub-totals		C	0	0	0	0	0	0	0	1	1	0	0	1	3 2.94%
		M	4	7	6	6	4	4	8	4	4	5	8	4	64 62.75%
		P	6	2	2	2	6	6	1	1	1	5	2	1	35 34.31%
		N	0	0	0	0	0	0	0	0	0	0	0	0	0
Total and percentage (%)		Total	10	9	8	8	10	10	9	6	6	10	10	6	102
		percentage (%)	9.80%	8.82%	7.84%	7.84%	9.80%	9.80%	8.82%	5.88%	5.88%	9.80%	9.80%	5.88%	100.00%

After the answers were collected from the laboratory personnel, the accident and safety indexes were obtained by using AHP method to measure the weight of the safety precautions and the accidents impacts. Consequently, the safety indexes were estimated by the sum of multiplication of the priority vector (W) of the safety precautions and the applied or ignored safety precautions taken. The calculation formula was shown in Equation 3.24.

$$\mathrm{SI} = 0.7013 \times \sum \mathrm{Completely} + 0.2364 \times \sum \mathrm{Mostly} + 0.0623 \times \sum \mathrm{Partially} \qquad (3.24)$$

The safety indexes (SI) were found as 1.3817, 1.7794, 1.6053, 1.6053, 1.3817, 1.3817, 2.1899, 1.7092, 1.7092, 1.5558, 2.2522 and 1.7092 for B-1, B-2, B-3, B-4, B-5, B-6, B-7, B-8, B-9, C-1, C-2 and C-3, respectively (Table 3.4).

Table 3.4 The results of the safety and the accident indexes calculations

		Biology Research Laboratory									Chemistry Research Laboratory		
	Weight of the precautions taken	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**
Completely (C)	0.7013	0	0	0	0	0	0	0	1	1	0	0	1
Mostly (M)	0.2364	4	7	6	6	4	4	8	4	4	5	8	4
Partially (P)	0.0623	6	2	2	2	6	6	1	1	1	5	2	1
Never (N)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Safety index (SI):	1.3194	1.7794	1.5430	1.5430	1.3194	1.3194	1.9535	1.7092	1.7092	1.4935	2.0158	1.7092
	Weight of the accidents impact	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**
Extreme Dangerous (ED)	0.5329	1	0	0	0	2	0	0	0	0	0	0	0
Very Dangerous (VD)	0.3197	2	0	2	1	2	3	0	1	1	2	0	1
Dangerous (D)	0.1014	4	3	2	4	2	2	1	2	1	2	0	2
Less Dangerous (LD)	0.0460	7	5	7	7	6	4	4	3	0	3	5	1
	Accident index (AI):	1.8999	0.5342	1.1642	1.0473	2.1840	1.3459	0.2854	0.6605	0.4211	0.9802	0.2300	0.5685

In the same way, the accident indexes were calculated by the sum of multiplication of the priority vector (W) of the accident severities and the number of accidents. The calculation formula was shown in Equation 3.25.

$$AI = 0.5329 \times \sum \text{Extreme Dangerous} + 0.3197 \times \sum \text{Very Dangerous} + 0.1014 \times \sum \text{Dangerous} + 0.0460 \times \sum \text{Less Dangerous} \quad (3.25)$$

The accident indexes (AI) were determined as 2.0117, 0.8999, 1.1642, 1.0933, 2.1840, 2.1548, 0.2854, 0.6605, 0.5591, 1.5131, 0.2300 and 0.5685 for B-1, B-2, B-3, B-4, B-5, B-6, B-7, B-8, B-9, C-1, C-2 and C-3, respectively (Table 3.4).

In the last stage, the safety precautions and the accident severities were compared as regarding. The safety and accidents indexes were correlated with the help of the Excel 2010. A negative exponential relationship ($y = 86.11e^{-2.92x}$) was detected between the safety index and the accident index in the studied laboratories (Figure 3.1). The regression coefficient between safety and accident indexes was calculated as $R^2 = 0.941$ (Figure 3.1). Higher R^2 value as 0.941 means that the safety precautions are effective in the protection and hazard reduction of the occupational accidents.

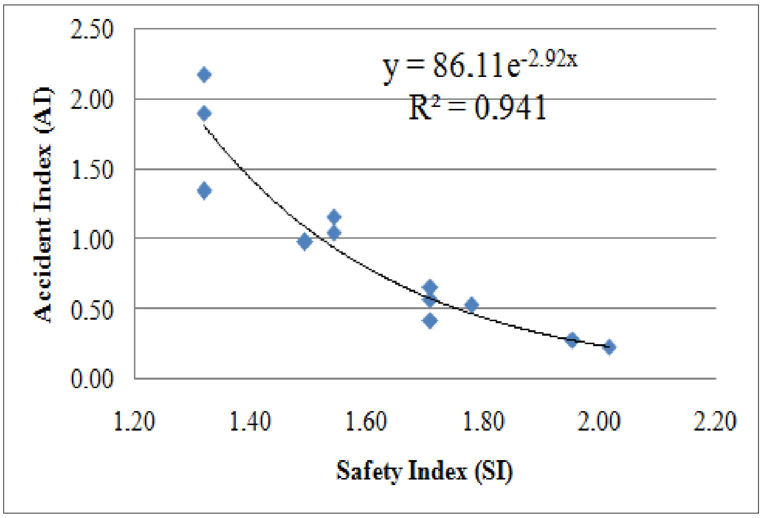


Figure 3.1 The relationship between safety and accident indexes

3.2 Fine-Kinney Method (FKM)

Fine-Kinney Method (FKM) was used to monitor the possible risks and to determine the precautions based on chemical, physical and biological factors by multiplying the possibility, frequency and effect parameters to each other.

3.2.1 Risk of Electric Shock in FKM

Possibility of accident due to the electric shock was considered as "expected/certain" and the possibility value was determined as 10 according to the possibility range of FKM (Figure 3.2). Frequency of this type of accident was accepted as "very rare (once in a year or less frequently)" and the frequency value was measured as 0.5 according to the frequency range of FKM (Figure 3.2). The effect value of an electric shock accident was considered as "more than one accident involving death/environmental disaster" and the effect value was obtained as 100 according to the effect range of FKM (Figure 3.2). The risk of electric shock was calculated by multiplying the possibility (10), frequency (0.5) and effect (100) values to each other and calculated as 500 in FKM (Figure 3.2). According to the FKM, if a risk value was found higher than 400, the risk couldn't be tolerated and "necessary precautions must be taken immediately or facility, building, environment must be shut down" (Figure 3.2). The result of the electrick shock risk (500) showed that if an electrick shock accident takes place in the studied laboratories, this type of accident cannot be tolerated and this risk may lead to multiple fatal accidents according to the FKM (Figure 3.2). The origin of the electrick shock is the electrical equipment and all personnel and building are effected from this type of an accident. The applied and ignored safety precautions at the studied laboratories determined via observations at place. Corrective actions that can be taken against electric shock can be listed as follows: Occupational health and safety training should be provided to all laboratory personnel for all studied laboratories. Periodic maintenance of the electrical system should be practiced in every year for all studied laboratories. The electrical fuses must be available at accessible height in B5 and B6 laboratories. Objects must be removed in front of the electrical fuses in B1. Furthermore, five of the studied laboratories (B3, B4, B7, B8 and B9) have not any nonconducting mats in front of the electrical panels. Three of the studied laboratories (B8, B9 and C3) have not residual current devices in their electric systems. Despite the risk of an electric shock, nonconducting mats and residual current devices must be supplied immediately.

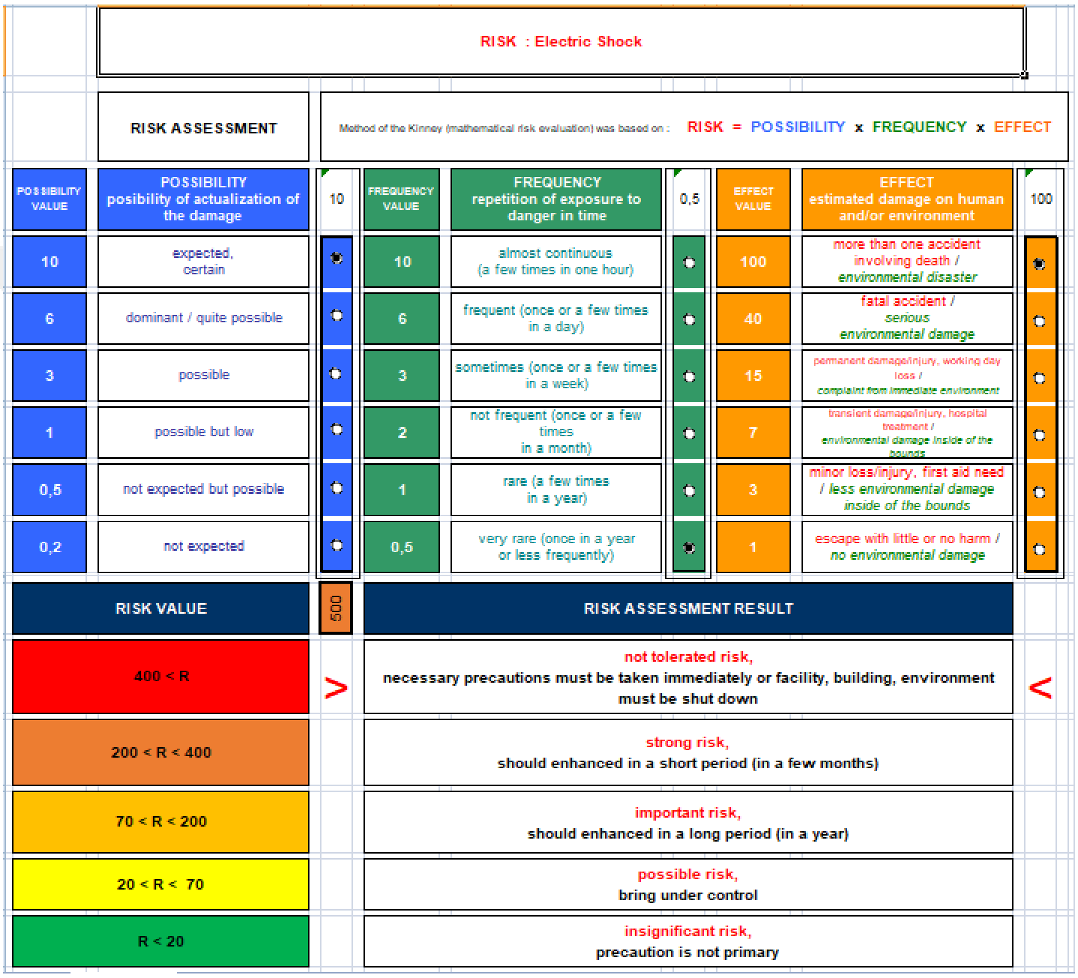


Figure 3.2 Calculation of electric shock risk in FKM

3.2.2 Risk of Explosion-Burning in FKM

Possibility of explosion-burning because of the stored chemicals was accepted as "dominant/quite possible" and the possibility value was found as 6 according to the possibility range of FKM (Figure 3.3). Frequency of the accident was considered as "very rare (once in a year or less frequently)" and the frequency value was determined as 0.5 according to the frequency range of FKM (Figure 3.3). The effect value of the accident was assumed as “more than one accident involving death/environmental disaster” and the effect value was detected as 100 according to the effect range of FKM (Figure 3.3). The risk of explosion-burning was measured by multiplying the possibility (6), frequency (0.5) and effect (100) values to each other and calculated as 300 in FKM (Figure 3.3). According to the FKM, if a risk value was calculated between 200 and 400, the risk accepted as a strong risk and “should be enhanced in a short period (in a few months)” (Figure 3.3). The quantitative result of the explosion-burning (300) indicated that this type of accident has a strong risk in the studied laboratories which use chemicals in their working areas and chemical depots (Figure 3.3). Lestari et al. (2019) indicated that fire and explosion incidents caused by the use of chemicals are among the incidents that may occur in academic laboratories. According to another literature, when an accident occurs in academic research laboratory, involving chemical exposure, explosion or fire, people are often seriously and sometimes fatally injured (Leggett, 2012). The gas cylinders, chemicals and fire-extinguishers can cause explosion-burning and all personnel and building are effected from the risk of explosion-burning. An accident related to the explosion-burning can lead to death. Occupational health and safety training and conducting fire drills have a great importance against to the risk of explosion-burning in the studied laboratories. The gas cylinders used in the studied laboratories must be fixed on the wall in a case of vibration, falling or hitting. Unfortunately, two chemical depots (B8 and B9) have not got any fire-extinguishers. Moreover, these laboratories do not have any fire detectors. Since the explosion-burning risk is found to be strong in these laboratories where chemicals are stored, the necessary equipment should be purchased and installed immediately. The fire-extinguishers should be maintained periodically for every year. Also, some of the laboratories (B1, B8, B9 and C1) do not store chemicals in suitable chemical cabinets. Suitable chemical cabinets for the studied chemicals should be purchased for these four research laboratories.

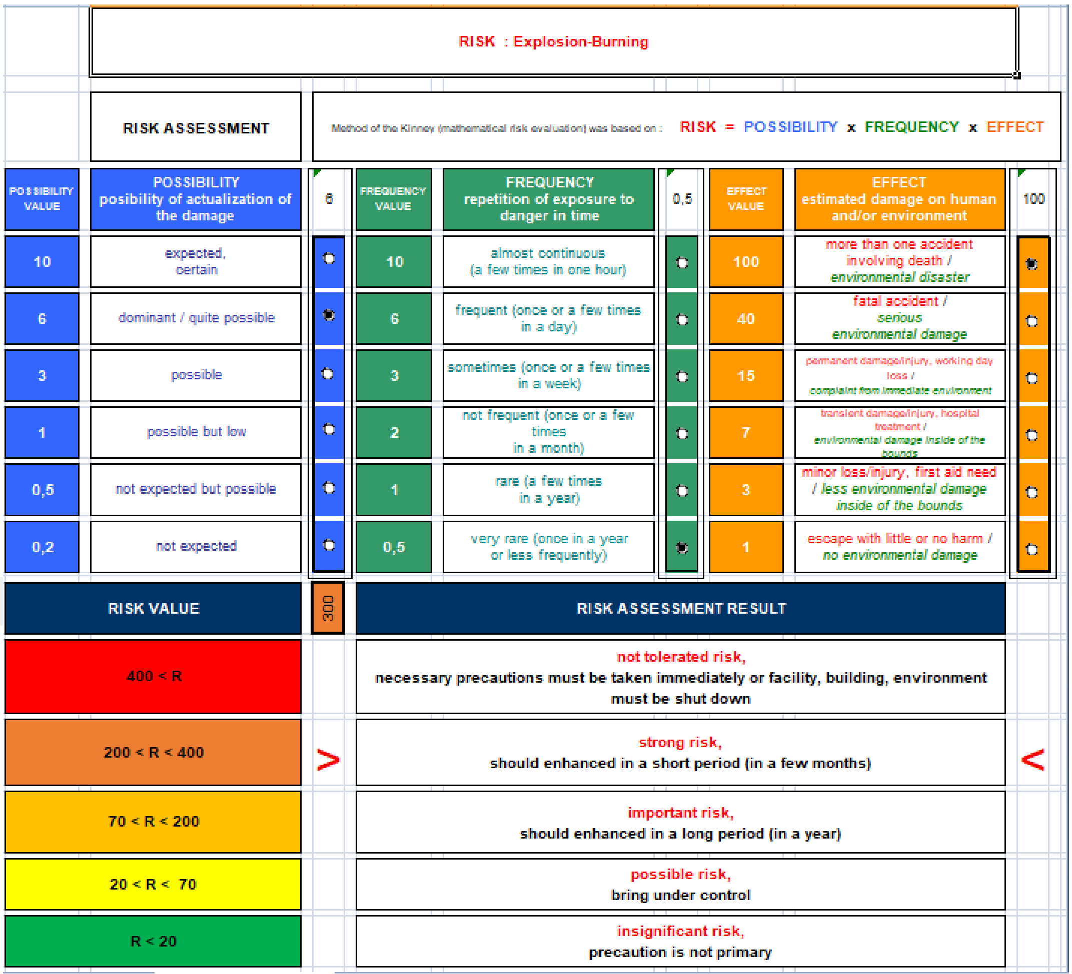


Figure 3.3 Calculation of explosion-burning risk in FKM

3.2.3 Risk of Infections Originating from Laboratory Activities in FKM

Possibility of infections originating from laboratory activities was assumed as “dominant/quite possible” and the possibility value was detected as 6 according to the possibility range of FKM (Figure 3.4). Frequency of the accident was accepted as “rare (a few times in a year)” and the frequency value was obtained as 1 according to the frequency range of FKM (Figure 3.4). The effect value of the accident was considered as “fatal accident/serious environmental damage” and the effect value was measured as 40 according to the effect range of FKM (Figure 3.4). The risk of infections was determined by multiplying the possibility (6), frequency (1) and effect (40) values to each other and found as 240 in FKM (Figure 3.4). According to the FKM, if a risk value was obtained between 200 and 400, the risk accepted as a strong risk and “should be enhanced in a short period (in a few months)” (Figure 3.4). The calculation for infections originating from laboratory activities (240) proved that infections have strong risk on laboratory personnel because if a personnel catches an infection from the studied sample in the laboratory, this situation could be turns into working day loss or even death (Figure 3.4). Some researchers also stated that infection occurred from the studying sample is a biological hazard observed in academic research laboratories (Lestari et al., 2019). The wastewater, solid waste and sludge/sediment are the studied samples analysed in the studied laboratories and the risk of infection effects the laboratory personnel. Occupational health and safety training and health surveillance of laboratory personnel have a great importance against to prevent infection risk. The laminar air flow cabinets must have a periodic maintenance in B1, B7, C1 and C2 laboratories. Also, laboratory personnel should disinfect their working area. The laboratory supervisors must ensure that personnel have and use personal protective equipment (PPE). The appropriate PPE can be listed as lab coat, lab glasses, masks and nitrile gloves, depending on the samples studied in the laboratories. In the aforementioned laboratories, necessary PPE is supplied to all personnel.

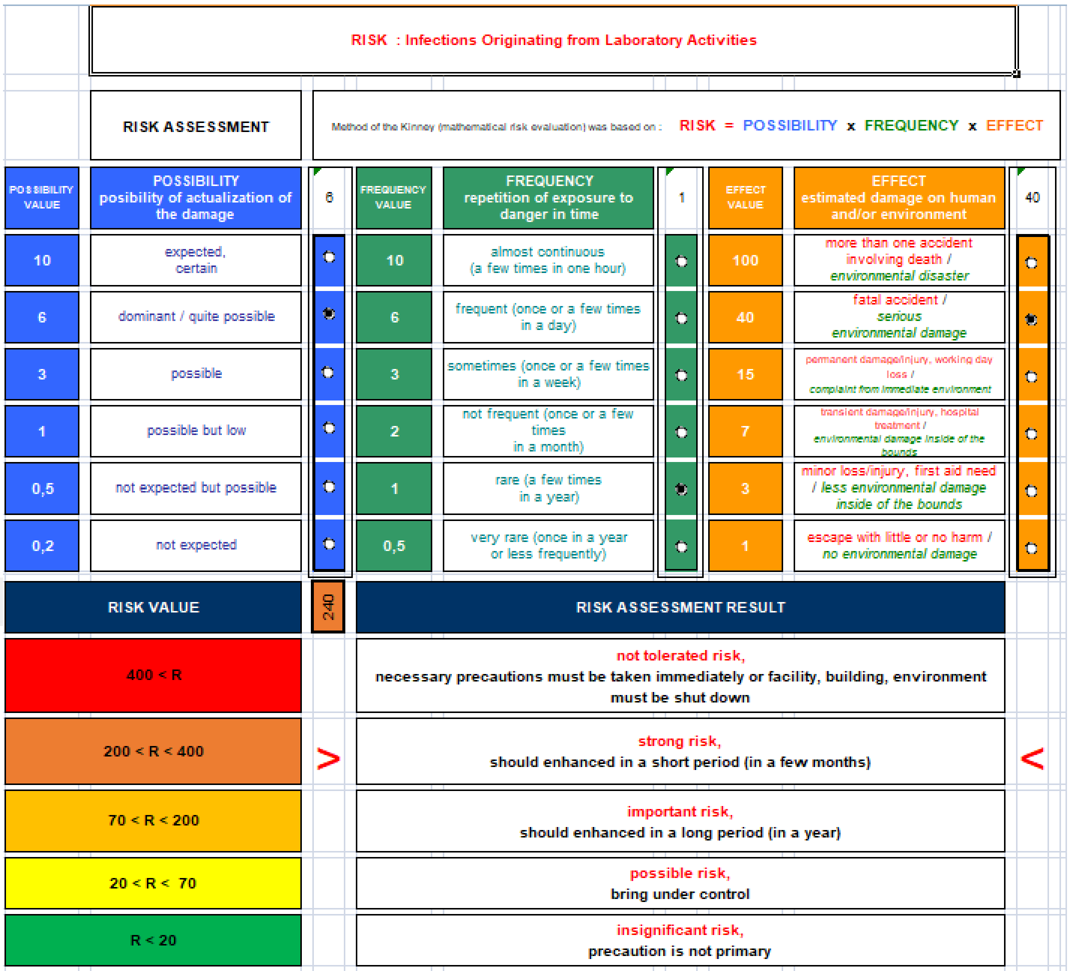


Figure 3.4 Calculation of infections risk in FKM

3.2.4 Risk of Chemical Contamination in FKM

Possibility of chemical contamination was supposed as "dominant/quite possible" and the possibility value was obtained as 6 according to the possibility range of FKM (Figure 3.5). Frequency of the accident was hypothesized as "sometimes (once or a few times in a week)" and the frequency value was found as 3 according to the frequency range of FKM (Figure 3.5). The effect value of the accident was pretended as "transient damage/injury, hospital treatment/environmental damage inside of the bounds" and the effect value was determined as 7 according to the effect range of FKM (Figure 3.5). The risk of chemical contamination was detected by multiplying the possibility (6), frequency (3) and effect (7) values to each other and measured as 126 in FKM (Figure 3.5). The quantification of the risk between 70 and 200 showed that the risk is an important risk and "should be enhanced in a long period (in a year)” in FKM (Figure 3.5). Chemical contamination effects laboratory personnel during analysis process and having a risk value of 126 in FKM indicated that the risk is important, besides, transient damage/injury, hospital treatment could be necessary if this important risk occurs in the studied laborotories (Figure 3.5). Occupational health and safety training of laboratory personnel is necessary to prevent chemical contamination risk. All laboratory personnel must be use PPE such as ab coat, lab glasses, masks and nitrile gloves to minimize the chemical contamination risk in all studied laborotories. All laboratory supervisors supply aforementioned PPEs to all laboratory personnel in all studied laborotories.

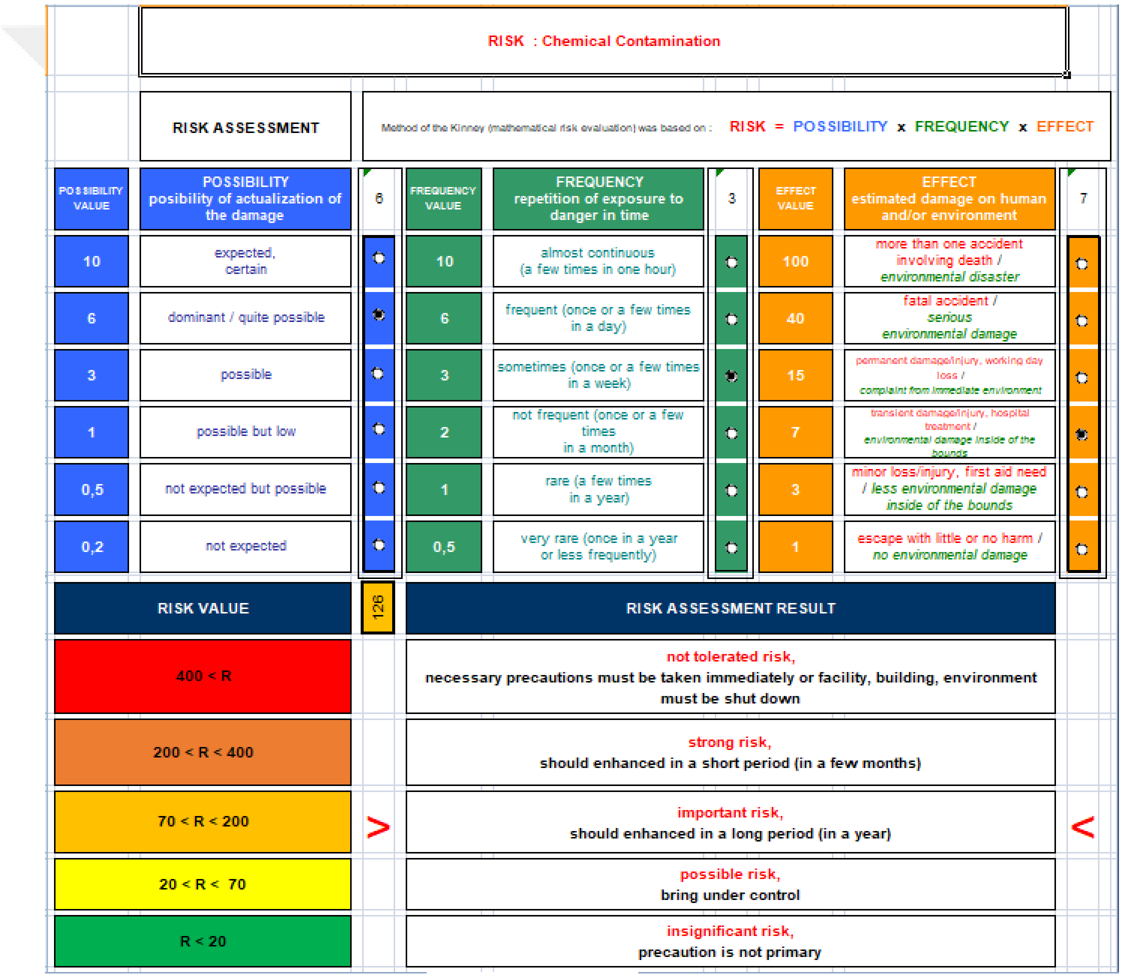


Figure 3.5 Calculation of chemical contamination risk in FKM

3.2.5 Risk of Falling of the Objects in FKM

Possibility of falling of the objects was hypothesized as “possible” and the possibility value was measured as 3 according to the possibility range of FKM (Figure 3.6). Frequency of the accident was postulated as “not frequent (once or a few times in a month)” and the frequency value was detected as 2 according to the frequency range of FKM (Figure 3.6). The effect value of the accident was accepted as “permanent damage/injury, working day loss/complaint from immediate environment” and the effect value was found as 15 according to the effect range of FKM (Figure 3.6). The risk of falling of the objects was estimated by multiplying the possibility (3), frequency (2) and effect (15) values to each other and determined as 90 in FKM (Figure 3.6). Having a risk value between 70 and 200 indicated that the risk of falling of the objects is an important risk and “should be enhanced in a long period (in a year)” in FKM (Figure 3.6). Materials on the open shelves (B1), cabinets (B3, B5, B6, B8, B9) and fume hoods (B1, B4, B5, B7 and C1) are the source of danger in the studied laboratories. The risk of falling of the objects effects laboratory personnel and may be cause permanent damage/injury or working day loss. The cabinets and fume hoods must be fixed on the walls in a case of vibration, falling or an earthquake. Open shelves of the cabinets must be closed, besides, no materials put on the cabinets. Any of the chemicals used in the aforementioned laboratories should not be placed on the open shelves. The laboratory supervisors must supply proper chemical cabinets and the laboratory personnel put chemicals into the chemical cabinets.

	RISK : Falling of the Objects							
	RISK ASSESSMENT	Method of the Kinney (mathematical risk evaluation) was based on : RISK = POSSIBILITY x FREQUENCY x EFFECT						
POSSIBILITY VALUE	POSSIBILITY posibility of actualization of the damage	3	FREQUENCY VALUE	FREQUENCY repetition of exposure to danger in time	2	EFFECT VALUE	EFFECT estimated damage on human and/or environment	15
10	expected, certain	○	10	almost continuous (a few times in one hour)	○	100	more than one accident involving death / *environmental disaster*	○
6	dominant / quite possible	○	6	frequent (once or a few times in a day)	○	40	fatal accident / *serious environmental damage*	○
3	possible	●	3	sometimes (once or a few times in a week)	○	15	permanent damage/injury, working day loss / *complaint from immediate environment*	●
1	possible but low	○	2	not frequent (once or a few times in a month)	●	7	transient damage/injury, hospital treatment / *environmental damage inside of the bounds*	○
0,5	not expected but possible	○	1	rare (a few times in a year)	○	3	minor loss/injury, first aid need / *less environmental damage inside of the bounds*	○
0,2	not expected	○	0,5	very rare (once in a year or less frequently)	○	1	escape with little or no harm / *no environmental damage*	○

RISK VALUE	90	RISK ASSESSMENT RESULT	
400 < R		not tolerated risk, necessary precautions must be taken immediately or facility, building, environment must be shut down	
200 < R < 400		strong risk, should enhanced in a short period (in a few months)	
70 < R < 200	>	important risk, should enhanced in a long period (in a year)	<
20 < R < 70		possible risk, bring under control	
R < 20		insignificant risk, precaution is not primary	

Figure 3.6 Calculation of falling of the objects risk in FKM

3.2.6 Risk of Musculoskeletal Injuries in FKM

Possibility of musculoskeletal injuries was assessed as “possible” and the possibility value was accepted as 3 according to the possibility range of FKM (Figure 3.7). Frequency of the accident was figured out as “not frequent (once or a few times in a month)” and the frequency value was calculated as 2 according to the frequency range of FKM (Figure 3.7). The effect value of the accident was supposed as “permanent damage/injury, working day loss/complaint from immediate environment” and the effect value was obtained as 15 according to the effect range of FKM (Figure 3.7). The risk of musculoskeletal injuries was found by multiplying the possibility (3), frequency (2) and effect (15) values to each other and detected as 90 in FKM (Figure 3.7). The accident of musculoskeletal injuries has a risk value of 90 and accepted as an important risk (should be enhanced in a long period (in a year)) due to ranking between 70 and 200 in FKM (Figure 3.7). According to the literature hand, arm and shoulder problems have been associated with awkward static postures, forceful movements and highly repetitive work with insufficient recovery time. The selection of appropriate laboratory equipment, providing breaks for the laboratory personnel, organising the design of workstation to prevent awkward body posture were listed against to the development of pain, discomfort and restricted use of the hand and arm for the musculoskeletal injuries (HSE, 2003). The musculoskeletal injuries can be caused by standing during analysis or lifting heavy things in the studied laboratories. The laboratory personnel may suffer from permanent damage/injury or may exposed working day loss. Occupational health and safety training should be provided to all laboratory personnel for all studied laboratories. It is necessary to ensure that the health surveillance of laboratory personnel is done regularly. It must be ensure that all laboratory personnel take a break. The laboratory personnel should be told about the importance of exercising. Standard bench heights for B2, B5 and B6 laboratories and standard table heights for the studies with pc for B1 laboratory must be provided for the corrective actions.

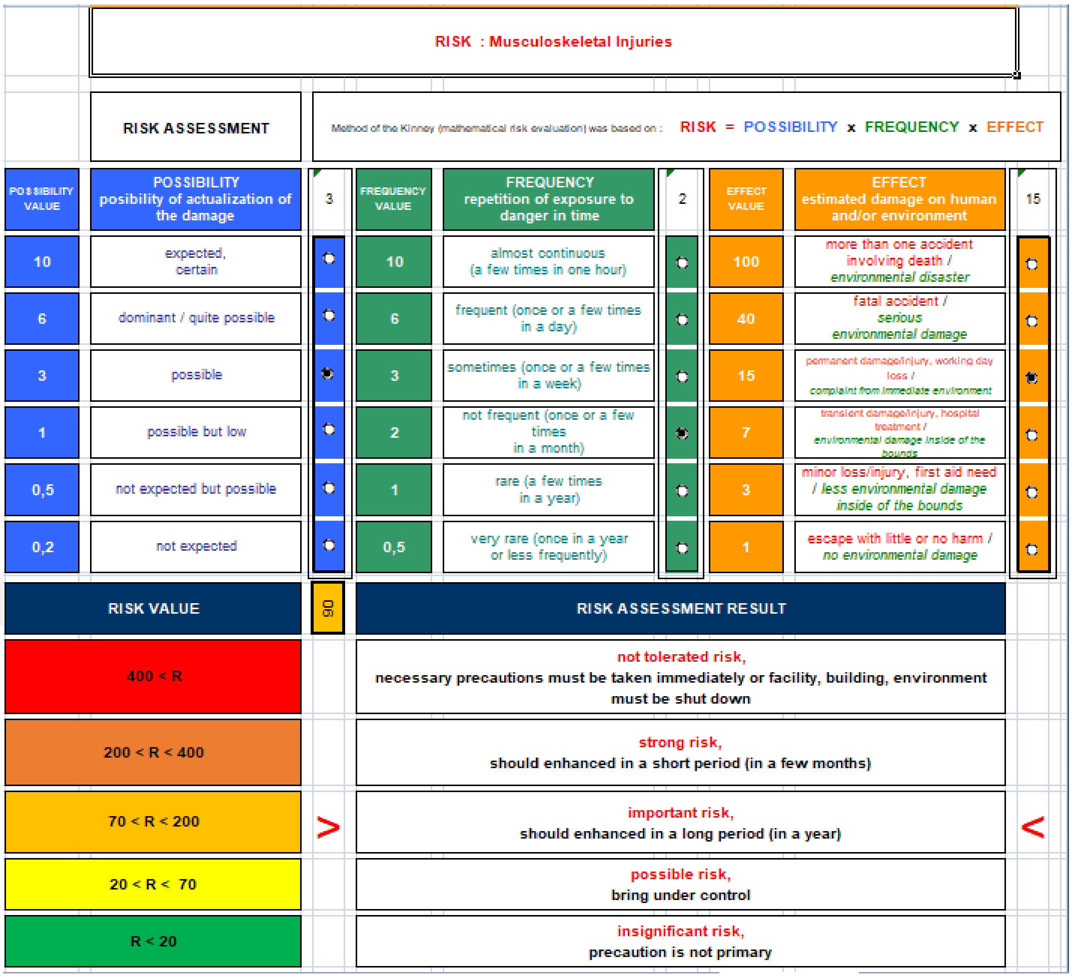


Figure 3.7 Calculation of musculoskeletal injuries risk in FKM

3.2.7 Risk of Poisoning due to Gases Releasing from the Analysis in FKM

Possibility of poisoning was considered as “dominant/quite possible” and the possibility value was determined as 6 according to the possibility range of FKM (Figure 3.8). Frequency of the accident was accepted as “not frequent (once or a few times in a month)” and the frequency value was measured as 2 according to the frequency range of FKM (Figure 3.8). The effect value of the accident was assessed as “transient damage/injury, hospital treatment/environmental damage inside of the bounds” and the effect value was obtained as 7 according to the effect range of FKM (Figure 3.8). The risk of poisoning due to gases releasing from the analysis was calculated by multiplying the possibility (6), frequency (2) and effect (7) values to each other and found as 84 in FKM (Figure 3.8). The numerical result of the poisoning risk (84) was found between 70 and 200 and according to the FKM, poisoning due to gases releasing from the analysis is an important risk and "should be enhanced in a long period (in a year)" (Figure 3.8). Gases releasing from the analysis and chemicals using in the analysis can poison laboratory personnel. They may exposed transient damage/injury or hospital treatment in a case of poisoning. Occupational health and safety training should be provided to all laboratory personnel for all studied laboratories. If the analysis requires, fume hoods usage must be provided for all laboratory personnel. Although B5 and B6 laboratories have fume hoods, they are defective and should be repaired immediately. Periodic maintenance for ventilation system should be done for every year in B1 and C1 laboratories. The appropriate PPE is the cartridge respirator instead of medical mask in case of gas releasing from the analysis and chemicals. The cartridge respirators should be supplied to all personnel if the analysis requires to wear it due to the gas releasing for all laboratories.

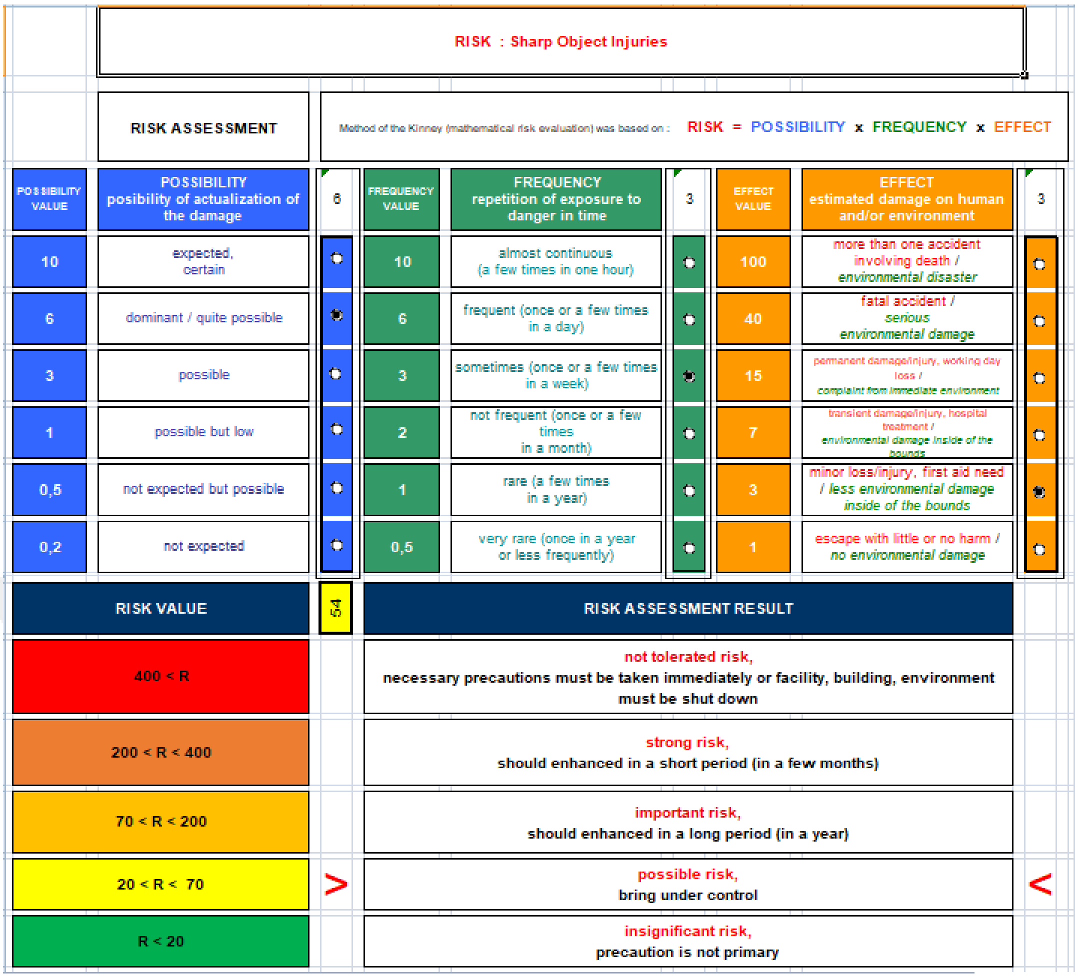
	RISK : Poisoning due to Gases Releasing from the Analysis							
	RISK ASSESSMENT	Method of the Kinney (mathematical risk evaluation) was based on : RISK = POSSIBILITY x FREQUENCY x EFFECT						
POSSIBILITY VALUE	POSSIBILITY posibility of actualization of the damage	6	FREQUENCY VALUE	FREQUENCY repetition of exposure to danger in time	2	EFFECT VALUE	EFFECT estimated damage on human and/or environment	7
10	expected, certain		10	almost continuous (a few times in one hour)		100	more than one accident involving death / environmental disaster	
6	dominant / quite possible		6	frequent (once or a few times in a day)		40	fatal accident / serious environmental damage	
3	possible		3	sometimes (once or a few times in a week)		15	permanent damage/injury, working day loss / complaint from immediate environment	
1	possible but low		2	not frequent (once or a few times in a month)		7	transient damage/injury, hospital treatment / environmental damage inside of the bounds	
0,5	not expected but possible		1	rare (a few times in a year)		3	minor loss/injury, first aid need / less environmental damage inside of the bounds	
0,2	not expected		0,5	very rare (once in a year or less frequently)		1	escape with little or no harm / no environmental damage	

RISK VALUE	84	RISK ASSESSMENT RESULT	
400 < R		not tolerated risk, necessary precautions must be taken immediately or facility, building, environment must be shut down	
200 < R < 400		strong risk, should enhanced in a short period (in a few months)	
70 < R < 200	>	important risk, should enhanced in a long period (in a year)	<
20 < R < 70		possible risk, bring under control	
R < 20		insignificant risk, precaution is not primary	

Figure 3.8 Calculation of poisoning risk in FKM

3.2.8 Risk of Sharp Object Injuries in FKM

Possibility of sharp object injuries was accepted as “dominant/quite possible” and the possibility value was found as 6 according to the possibility range of FKM (Figure 3.9). Frequency of the accident was considered as “sometimes (once or a few times in a week)” and the frequency value was determined as 3 according to the frequency range of FKM (Figure 3.9). The effect value of the accident was assumed as “minor loss/injury, first aid need/less environmental damage inside of the bounds” and the effect value was detected as 3 according to the effect range of FKM (Figure 3.9). The risk of sharp object injuries was measured by multiplying the possibility (6), frequency (3) and effect (3) values to each other and calculated as 54 in FKM (Figure 3.9). Possible risks are classified in a range between 20 and 70 in FKM and they must bring under control. The quantification of sharp object injuries was found as 54 (Figure 3.9). The sharp object injuries could be due to the sharp glass, metal, etc. objects used in analysis and minor loss/injury or first aid need may be required for laboratory personnel. Occupational health and safety training for all laboratory personnel and informative posters in all studied laboratories should be provided against sharp object injuries. Laboratory personnel must use PPEs. The first-aid chest's materials should be always checked in a case of first-aid is need. The first-aid chest of six laboratories (B1, B5, B6, B7, C1 and C2) are out of date, excluding laboratories used as chemical depots (B8, B9 and C3). Three of the laboratories (B2, B3 and B4) do not have any first-aid chests and must be supplied immediately. According to HSE (2003), after the sharp objects were used in analysis, the laboratory personnel must safely destroy them or clean/disinfect/sterilize appropriately, besides, never left them around.



RISK : Sharp Object Injuries

RISK ASSESSMENT — Method of the Kinney (mathematical risk evaluation) was based on : RISK = POSSIBILITY x FREQUENCY x EFFECT

POSSIBILITY VALUE	POSSIBILITY posibility of actualization of the damage	6	FREQUENCY VALUE	FREQUENCY repetition of exposure to danger in time	3	EFFECT VALUE	EFFECT estimated damage on human and/or environment	3
10	expected, certain		10	almost continuous (a few times in one hour)		100	more than one accident involving death / environmental disaster	
6	dominant / quite possible		6	frequent (once or a few times in a day)		40	fatal accident / serious environmental damage	
3	possible		3	sometimes (once or a few times in a week)		15	permanent damage/injury, working day loss / complaint from immediate environment	
1	possible but low		2	not frequent (once or a few times in a month)		7	transient damage/injury, hospital treatment / environmental damage inside of the bounds	
0,5	not expected but possible		1	rare (a few times in a year)		3	minor loss/injury, first aid need / less environmental damage inside of the bounds	
0,2	not expected		0,5	very rare (once in a year or less frequently)		1	escape with little or no harm / no environmental damage	

RISK VALUE	54	RISK ASSESSMENT RESULT	
400 < R		not tolerated risk, necessary precautions must be taken immediately or facility, building, environment must be shut down	
200 < R < 400		strong risk, should enhanced in a short period (in a few months)	
70 < R < 200		important risk, should enhanced in a long period (in a year)	
20 < R < 70	>	possible risk, bring under control	<
R < 20		insignificant risk, precaution is not primary	

Figure 3.9 Calculation of sharp objects injuries risk in FKM

3.2.9 Risk of Contamination of the Studying Sample in FKM

Possibility of contamination of the studying sample was assumed as "possible" and the possibility value was detected as 3 according to the possibility range of FKM (Figure 3.10). Frequency of the accident was accepted as "sometimes (once or a few times in a week)" and the frequency value was obtained as 3 according to the frequency range of FKM (Figure 3.10). The effect value of the accident was considered as "minor loss/injury, first aid need/less environmental damage inside of the bounds" and the effect value was measured as 3 according to the effect range of FKM (Figure 3.10). The risk of contamination of the studying sample was determined by multiplying the possibility (3), frequency (3) and effect (3) values to each other and found as 27 in FKM (Figure 3.10). The risk value of contamination of the studying sample (27) was calculated between 20 and 70 and the quantification of the risk showed that this is a "possible risk and must bring under control" according to the FKM (Figure 3.10). The studied sample could be wastewater, biological sludge, soil/sediment and solid waste in the researched laboratories and minor loss/injury or first aid need may be required for laboratory personnel if a contamination occurs from the studied sample. Occupational health and safety training, preventive inoculation and health surveillance for all laboratory personnel should be provided to prevent the risk of contamination of the studying sample in all studied laboratories. It must be ensured that all personnel beware of disinfection and use PPEs. Unfortunately, the preventive inoculation of laboratory personnel is not performed in any of the studied laboratories.

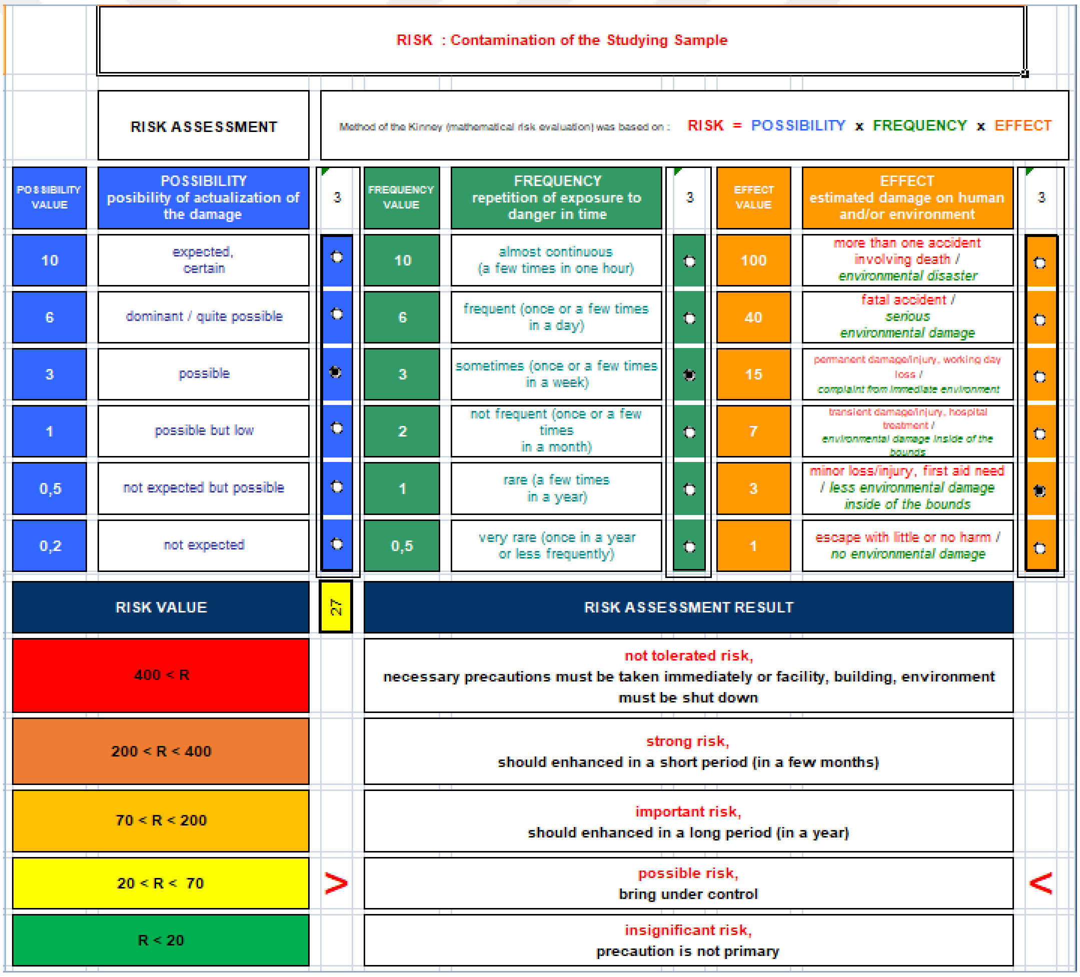
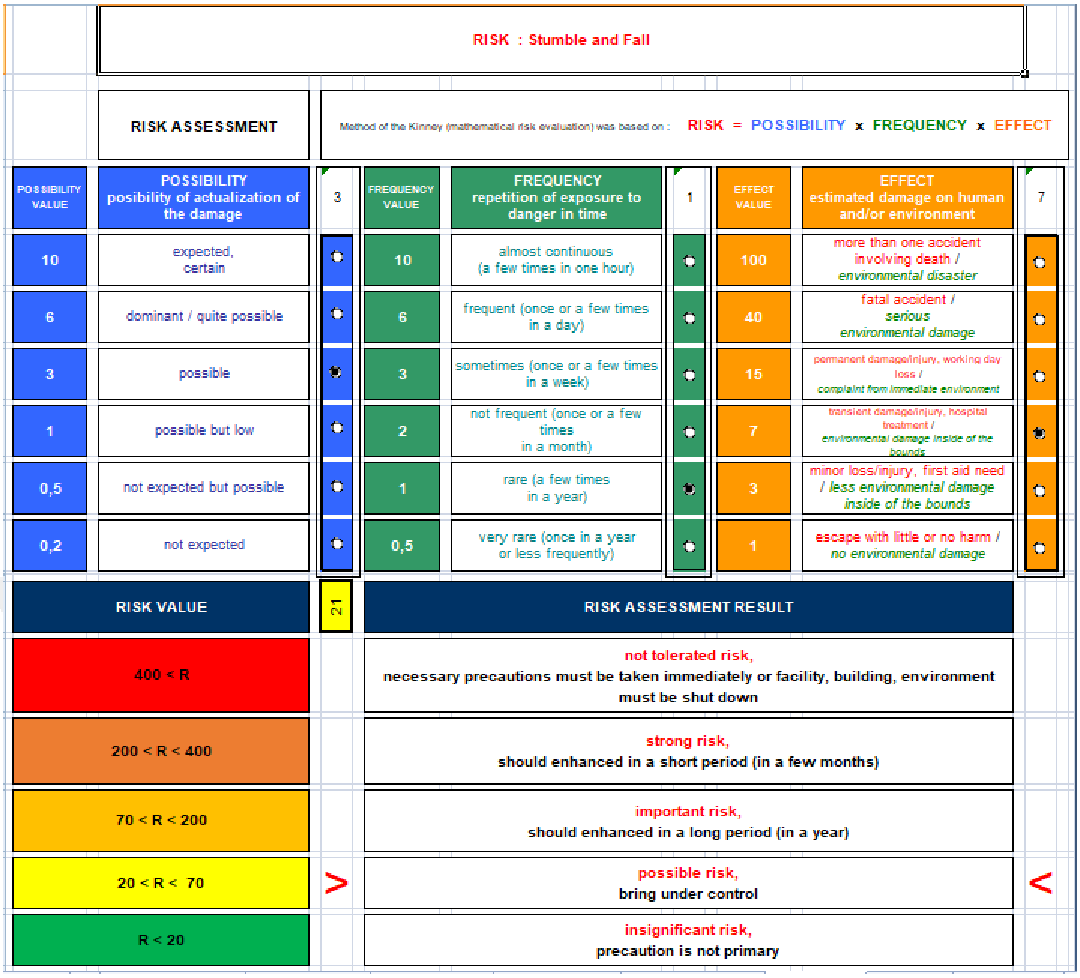


Figure 3.10 Calculation of contamination of the studying sample risk in FKM

3.2.10 Risk of Stumble and Fall in FKM

Possibility of stumble and fall was supposed as “possible” and the possibility value was obtained as 3 according to the possibility range of FKM (Figure 3.11). Frequency of the accident was hypothesized as “rare (a few times in a year)” and the frequency value was found as 1 according to the frequency range of FKM (Figure 3.11). The effect value of the accident was pretended as “transient damage/injury, hospital treatment/environmental damage inside of the bounds” and the effect value was determined as 7 according to the effect range of FKM (Figure 3.11). The risk of stumble and fall was detected by multiplying the possibility (3), frequency (1) and effect (7) values to each other and measured as 21 in FKM (Figure 3.11). The numerical risk value of stumble and fall was found as 21 and the risk values between 20 and 70 means that the risk is a “possible risk and must bring under control” according to the FKM (Figure 3.11). The laboratory personnel may be stumble and fall due to the electric cables on the ground, doorsills and waterpipes on the floor, untidy laboratory and floor cleaning in the studied laboratories. The risk of stumble and fall can lead to minor injuries or, at worst, transient damages/ hospital treatment. It is also recommended in the literature that the laboratory floor surfaces need to be durable, easy to clean, be without holes, should not present a slip hazard and be well maintained (HSE, 2003). The precautions such as; putting the electric cables, doorsills and waterpipes below ground (B1), providing proper storage for the materials against untidiness in the laboratories (B5 and B6) and placing warning signs after clean up the floor (for all studied laboratories) can be taken to eliminate the risk of stumble and fall.



RISK : Stumble and Fall

RISK ASSESSMENT	Method of the Kinney (mathematical risk evaluation) was based on : RISK = POSSIBILITY x FREQUENCY x EFFECT							
POSSIBILITY VALUE	POSSIBILITY posibility of actualization of the damage	3	FREQUENCY VALUE	FREQUENCY repetition of exposure to danger in time	1	EFFECT VALUE	EFFECT estimated damage on human and/or environment	7
10	expected, certain		10	almost continuous (a few times in one hour)		100	more than one accident involving death / environmental disaster	
6	dominant / quite possible		6	frequent (once or a few times in a day)		40	fatal accident / serious environmental damage	
3	possible		3	sometimes (once or a few times in a week)		15	permanent damage/injury, working day loss / complaint from immediate environment	
1	possible but low		2	not frequent (once or a few times in a month)		7	transient damage/injury, hospital treatment / environmental damage inside of the bounds	
0,5	not expected but possible		1	rare (a few times in a year)		3	minor loss/injury, first aid need / less environmental damage inside of the bounds	
0,2	not expected		0,5	very rare (once in a year or less frequently)		1	escape with little or no harm / no environmental damage	

RISK VALUE	21	RISK ASSESSMENT RESULT	
400 < R		not tolerated risk, necessary precautions must be taken immediately or facility, building, environment must be shut down	
200 < R < 400		strong risk, should enhanced in a short period (in a few months)	
70 < R < 200		important risk, should enhanced in a long period (in a year)	
20 < R < 70	>	possible risk, bring under control	<
R < 20		insignificant risk, precaution is not primary	

Figure 3.11 Calculation of stumble and fall risk in FKM

3.2.11 Risk of Allergy due to Latex Gloves or Some Chemicals in FKM

Possibility of allergy due to latex gloves or some chemicals was hypothesized as "possible but low" and the possibility value was measured as 1 according to the possibility range of FKM (Figure 3.12). Frequency of the accident was postulated as "rare (a few times in a year)" and the frequency value was detected as 1 according to the frequency range of FKM (Figure 3.12). The effect value of the accident was accepted as "minor loss/injury, first aid need/less environmental damage inside of the bounds" and the effect value was found as 3 according to the effect range of FKM (Figure 3.12). The risk of allergy due to latex gloves or some chemicals was estimated by multiplying the possibility (1), frequency (1) and effect (3) values to each other and determined as 3 in FKM (Figure 3.12). The quantification of the risk was calculated as 3 and the risk of allergy due to latex gloves or some chemicals is an insignificant risk according to the FKM (Figure 3.12). The risk values below 20 proved that the risk is an “insignificant risk” and the precaution is not primary in FKM (Figure 3.12). However, sensitive laboratory personnel could be affected the risk of allergy due to latex gloves, the laboratory supervisors should provide nitrile gloves instead of latex gloves in all studied laboratories. Also, the occupational health and safety training should be provided for using PPE against allergy due to some chemicals for all laboratory personnel in all studied laboratories.

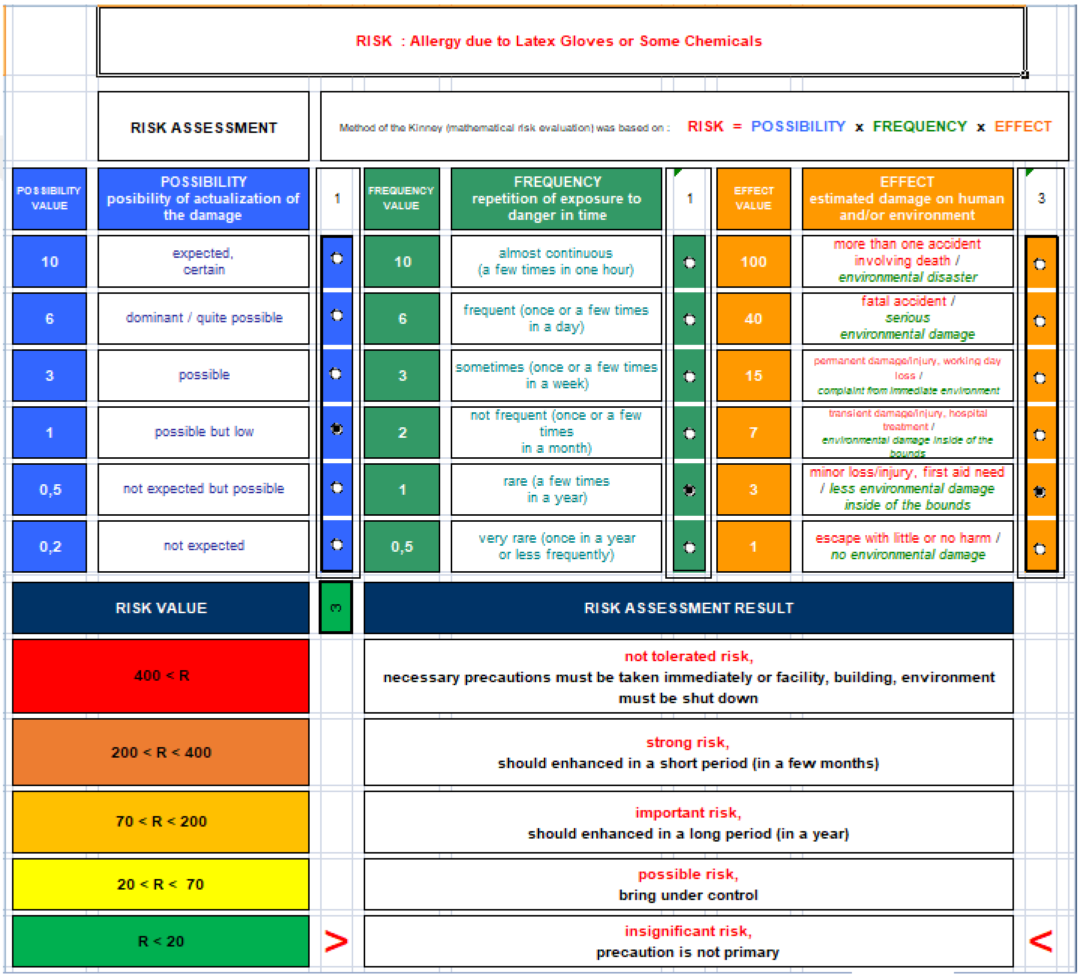
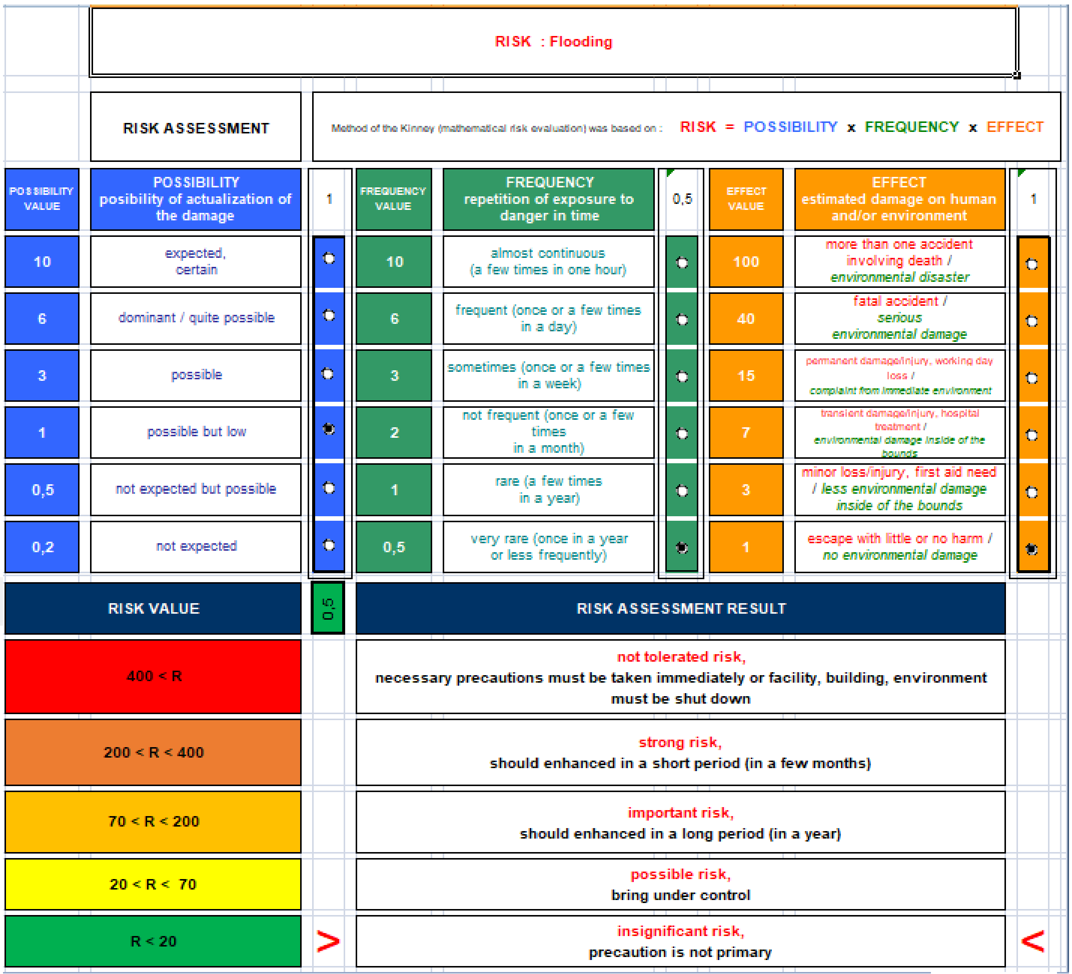


Figure 3.12 Calculation of allergy risk in FKM

3.2.12 Risk of Flooding in FKM

Possibility of flooding was assessed as “possible but low” and the possibility value was accepted as 1 according to the possibility range of FKM (Figure 3.13). Frequency of the accident was figured out as “very rare (once in a year or less frequently)" and the frequency value was calculated as 0.5 according to the frequency range of FKM (Figure 3.13). The effect value of the accident was supposed as "escape with little or no harm/no environmental damage" and the effect value was obtained as 1 according to the effect range of FKM (Figure 3.13). The risk of flooding was found by multiplying the possibility (1), frequency (0.5) and effect (1) values to each other and detected as 0.5 in FKM (Figure 3.13). The risk of flooding has a numerical value as 0.5, therefore it is accepted as an "insignificant risk" due to the risk value is below 20 and the precaution is not primary according to the FKM (Figure 3.13). All personnel and building may be affected the risk of flooding due to a valve breakdown or rain water leakage and could be escape with little or no harm. However the the risk was calculated as an insignificant risk, the periodic maintenance of the water system should be provided for all studied laboratories. Furthermore, a final control should be always performed before leaving from B1 because it has waterpipes above ground.



RISK : Flooding

RISK ASSESSMENT — Method of the Kinney (mathematical risk evaluation) was based on : RISK = POSSIBILITY x FREQUENCY x EFFECT

POSSIBILITY VALUE	POSSIBILITY posibility of actualization of the damage	1	FREQUENCY VALUE	FREQUENCY repetition of exposure to danger in time	0,5	EFFECT VALUE	EFFECT estimated damage on human and/or environment	1
10	expected, certain		10	almost continuous (a few times in one hour)		100	more than one accident involving death / environmental disaster	
6	dominant / quite possible		6	frequent (once or a few times in a day)		40	fatal accident / serious environmental damage	
3	possible		3	sometimes (once or a few times in a week)		15	permanent damage/injury, working day loss / complaint from immediate environment	
1	possible but low		2	not frequent (once or a few times in a month)		7	transient damage/injury, hospital treatment / environmental damage inside of the bounds	
0,5	not expected but possible		1	rare (a few times in a year)		3	minor loss/injury, first aid need / less environmental damage inside of the bounds	
0,2	not expected		0,5	very rare (once in a year or less frequently)		1	escape with little or no harm / no environmental damage	

RISK VALUE	0,5	RISK ASSESSMENT RESULT
400 < R		not tolerated risk, necessary precautions must be taken immediately or facility, building, environment must be shut down
200 < R < 400		strong risk, should enhanced in a short period (in a few months)
70 < R < 200		important risk, should enhanced in a long period (in a year)
20 < R < 70		possible risk, bring under control
R < 20	>	insignificant risk, precaution is not primary

Figure 3.13 Calculation of flooding risk in FKM

3.3 Cost Analysis

Training should be given to all laboratory personnel in order to create an occupational health and safety culture and to inform them about the risks they will encounter in the laboratory. This training is the duty of the deaconship within the scope of this thesis. Besides, it is the duty of the rectorship to do the health surveillance while the preventive inoculation is the duty of the deaconship for the laboratory personnel. For this reason, they have been excluded from the cost analysis.

3.3.1 Risk of Electric Shock

The five of the studied laboratories (B3, B4, B7, B8 and B9) have not any nonconducting mats in front of the electrical panels. Three of the studied laboratories (B8, B9 and C3) have not residual current devices in their electric systems. The total cost of providing nonconducting mats for the aforementioned five laboratories (unit price 6.50 Euro) and residual current devices for the aforementioned three laboratories (unit price 35.00 Euro) was found as 137.50 Euro (Table 3.5).

Table 3.5 The approximate total cost of safety precautions

The risk	**The occupational health and safety precautions**	**The approximate total cost**
Electric Shock	nonconducting mats: (6.50 Euro/unit) × (5 unit/lab)* = 32.50 Euro	137.50 Euro
	residual current devices: (35.00 Euro/unit) × (3 unit/lab)* = 105.00 Euro	
Explosion-Burning	fire-extinguishers: (18.00 Euro/unit) × (2 unit/lab)* = 36.00 Euro	7733.00 Euro
	fire detectors: (23.50 Euro/unit) × (2 unit/lab)* = 47.00 Euro	
	maintenance for fire-extinguishers in a year: (3.50 Euro/unit) × (12 unit/year)** = 42.00 Euro	
	chemical cabinets (90 min fire-resistant): (1902.00 Euro/unit) × (4 unit/lab)* = 7608.00 Euro	
Infections Originating from Laboratory Activities and Chemical Contamination	[(8.00 Euro/lab coat) + (3.00 Euro/lab glasses) + (26.50 Euro/cartridge mask)] × (11 lab personnel)** = 412.50 Euro	412.50 Euro
Falling of the Objects	close the open shelves on the benches for 1 lab	118.00 Euro
Musculoskeletal Injuries	standard bench: (176.50 Euro/m^2) × (4 m^2/for 3 labs)* = 706.00 Euro	746.00 Euro
	standard table: (40.00 Euro/unit) × (1 unit/lab)* = 40.00 Euro	
Poisoning due to Gases Releasing from the Analysis	repairing broken fume hoods: (118.00 Euro/unit) × (2 unit/lab)* = 236.00 Euro	708.00 Euro
	periodic maintenance for ventilation systems: (236.00 Euro/unit) × (2 unit/lab)* = 472.00 Euro	
Sharp Object Injuries	first-aid chests: (35.00 Euro/unit) × (3 unit/lab)* = 105.00 Euro	105.00 Euro
Stumble and Fall	warning signs: (4.00 Euro/unit) × (10 unit/lab)* = 40.00 Euro	40.00 Euro
Total cost		**10,000.00 Euro**

Note: The cost of the materials used for safety precautions were calculated according to the market prices (February 15th, 2021). Recent Euro exchange rate was used to convert the Euro currency to Turkish Liras (1 € = 8.50 TL, February 15th, 2021).

*: number or laboratories needing for it

**: total number in B and C labs

3.3.2 Risk of Explosion-Burning

The two chemical depots (B8 and B9) have not got any fire-extinguishers and fire detectors. The price of purchasing fire-extinguishers (unit price 18.00 Euro) and fire detectors (unit price 23.50 Euro) for the aforementioned two laboratories was detected as 83.00 Euro (Table 3.5). The total number of fire-extinguishers that the two main laboratories (C and B) with their sub-departments should have is twelve. The cost of maintenance for one fire-extinguisher is 3.50 Euro/year. Their annual maintenance cost was calculated as 42.00 Euro (Table 3.5).

Proper chemical cabinets must be purchased for four laboratories (B1, B8, B9 and C1). The cost of one chemical cabinet is 1902.00 Euro (ninety minutes fire resistant). The total cost was calculated as 7608.00 Euro for four chemical cabinets (Table 3.5).

3.3.3 Risk of Infections Originating from Laboratory and Activities and Chemical Contamination

The laminar air flow cabinets should have maintenance in four laboratories (B1, B7, C1 and C2). For laminar air flow cabinets, it is difficult to determine an exact cost for the maintenance fee, as the maintenance time is determined according to the hour of use.

It is difficult to calculate an exact cost for the number of disinfectants or nitrile gloves to be used against the risk of infections in the studied laboratories because the required number will vary according to the frequency of the analysis and the number of personnel. However, the cost of lab coat, lab glasses and cartridge mask to be supplied to one personnel is 8 Euro, 3 Euro and 26.50 Euro, respectively. It was calculated as 37.50 Euro for one laboratory personnel totally. The total cost was found as 412.50 Euro as there were 8 and 3 full-time personnel in chemistry and biology laboratories, respectively (Table 3.5).

3.3.4 Risk of Falling of the Objects

There are some materials on the open shelves in one laboratory (B1). Therefore, the price required to close the open shelves on the benches was found to be 118.00 Euro against the risk of falling of the objects.

3.3.5 Risk of Musculoskeletal Injuries

Within the scope of this study, it was found necessary to provide standard bench heights (B2, B5 and B6) and standard table heights (B1) for some laboratories. The price of supplying a standard bench for the aforementioned three laboratories (linear meter price 176.50 Euro and necessary for 4 m^2 totally) and purchasing a table with standard height for the aforementioned one laboratory (unit price 40.00 Euro) was detected as 746.00 Euro (Table 3.5).

3.3.6 Risk of Poisoning due to Gases Releasing from the Analysis

Two of the laboratories (B5 and B6) have broken fume hoods. The cost for repairing them was calculated as 236.00 Euro (118.00 Euro/unit). Periodic maintenance for ventilation system should be done for every year in B1 and C1 laboratories. Therefore, the total maintenance cost was determined as 472.00 Euro (236.00 Euro/unit) in these two (B1 and C1) laboratories (Table 3.5).

The appropriate PPE is the cartridge respirator instead of medical mask in case of gas releasing from the analysis and chemicals. The cost of one cartridge respirator is 26.50 Euro. It is difficult to determine an exact cost for the cartridge respirators replacing with medical masks because the required number will vary according to the frequency of the analysis and the number of personnel.

3.3.7 Risk of Sharp Object Injuries

Three of the laboratories (B2, B3 and B4) do not have any first-aid chests. The total purchase price for all (unit price 35.00 Euro) was determined as 105.00 Euro (Table 3.5).

3.3.8 Risk of Stumble and Fall

Against the risk of stumble and fall, ten warning signs (unit price 4.00 Euro) are required to be placed after cleaning in the studied laboratories and the total cost was found as 40.00 Euro (Table 3.5).

3.3.9 Risk of Allergy due to Latex Gloves or Some Chemicals

Nitrile gloves should be provided for sensitive laboratory personnel against latex allergy. There is a price difference of 3.50 Euro between a box of latex gloves (unit price 9.50 Euro) and a box of nitrile gloves (unit price 13.00 Euro). It is difficult to determine an exact cost, as how many boxes of nitrile gloves will be used, because the usage will vary depending on the analysis frequency and the number of personnel.

The approximate total cost of occupational health and safety precautions to be taken in two research laboratories (C and B) have been calculated as 10,000.00 Euro and shown in Table 3.5.

CHAPTER FOUR
CONCLUSIONS

Analytic Hierarchy Process (AHP) and Fine-Kinney Method (FKM) were selected for the occupational health and safety assessment studies in two research laboratories namely chemistry (C) and biology (B). Possible risks in the studied laboratories and the safety precautions to be taken against to the possible risks were determined with the help of the aforementioned risk assessment methods. Also, cost analysis were performed for suggested precautions and corrective actions arranged in AHP and Fine-Kinney Method for biology (B) and chemistry (C) laboratories.

4.1 Analytic Hierarchy Process (AHP)

The decision making problem in AHP was constituted of two stages. At the first stage, the decision points were determined as accident severities such as extreme dangerous (ED), very dangerous (VD), dangerous (D) and less dangerous (LD) by asking some questions to the laboratory personnel about occupational accidents. Then at the second stage, the factors affecting the decision points were determined as safety precautions such as completely (C), mostly (M), partially (P) and never (N). After structuring the decision hierarchy with two stages, comparison matrixes between the factors were composed in a square matrix with 4×4 dimensions for accident severities and in a square matrix with 3×3 dimensions for safety precautions. The percentages for the importance distribution of the factors were calculated and accident indexes in the studied laboratories were determined. In this study, an accident index in the studied laboratories was calculated for each extreme dangerous (ED) accident as 0.53, for each very dangerous (VD) accident as 0.32, for each dangerous (D) accident as 0.10 and for each less dangerous (LD) accident as 0.05 points (Table 4.1). The results showed that the extreme dangerous (ED), very dangerous (VD), dangerous (D) and less dangerous (LD) accidents in the studied laboratories have a significance value of 53%, 32%, 10% and 5%, respectively (Table 4.1). The safety indexes were calculated for the precautions taken in the studied laboratories for completely (C) applied as 0.70, for mostly (M) applied as

0.24 and for partially (P) applied as 0.06 points (Table 4.1). It could be said that completely (C), mostly (M) and partially (P) applied precautions in the studied laboratories have a significance value of 70%, 24% and 6%, respectively (Table 4.1). Finally, the consistency for comparison of the factors was evaluated at the end of the AHP modelling. The consistency ratio (CR) of the accident severities and safety precautions were found as 2.5% (0.0248) and 6.2% (0.0622), respectively (Equation 3.18 and 3.23, respectively). A consistency ratio (CR) smaller than 10% means that the matrices are consistent (Ersoy, 2013). Therefore, it can be concluded that the comparison matrixes of the accident severities and safety precautions were found consistent in the content of this study. It can be concluded that the the matrixes were appropriate for the modelling study.

The occupational accidents and their damages were investigated asking some survey questions to the chemistry (C) and biology (B) laboratory personnel. Some of the occupational accidents were detected from our monitoring study for the possible accidents and some of them were prepared by taking into consideration of the previous occupational accidents in the studied laboratories. After the answers were collected from the laboratory personnel, the accident and safety indexes were calculated by using AHP method to determine the weight of the safety precautions and the accidents impacts. The safety indexes (SI) were found as 1.3817, 1.7794, 1.6053, 1.6053, 1.3817, 1.3817, 2.1899, 1.7092, 1.7092, 1.5558, 2.2522 and 1.7092 for B-1, B-2, B-3, B-4, B-5, B-6, B-7, B-8, B-9, C-1, C-2 and C-3, respectively (Table 4.1). Moreover, the accident indexes (AI) were determined as 2.0117, 0.8999, 1.1642, 1.0933, 2.1840, 2.1548, 0.2854, 0.6605, 0.5591, 1.5131, 0.2300 and 0.5685 for B-1, B-2, B-3, B-4, B-5, B-6, B-7, B-8, B-9, C-1, C-2 and C-3, respectively (Table 4.1).

Table 4.1 The results of the safety and accident indexes calculations

		Biology Research Laboratory									Chemistry Research Laboratory			
	Weight of the precautions taken	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	
Completely (C)	0.7013	0	0	0	0	0	0	0	1	1	0	0	1	
Mostly (M)	0.2364	4	7	6	6	4	4	8	4	4	5	8	4	
Partially (P)	0.0623	6	2	2	2	6	6	1	1	1	5	2	1	
Never (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Safety index (SI):	1.3194	1.7794	1.5430	1.5430	1.3194	1.3194	1.9535	1.7092	1.7092	1.4935	2.0158	1.7092	
	Weight of the accidents impact	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	
Extreme Dangerous (ED)	0.5329	1	0	0	0	2	0	0	0	0	0	0	0	
Very Dangerous (VD)	0.3197	2	0	2	1	2	3	0	1	1	2	0	1	
Dangerous (D)	0.1014	4	3	2	4	2	2	1	2	1	2	0	2	
Less Dangerous (LD)	0.0460	7	5	7	7	6	4	4	3	0	3	5	1	
	Accident index (AI):	1.8999	0.5342	1.1642	1.0473	2.1840	1.3459	0.2854	0.6605	0.4211	0.9802	0.2300	0.5685	
Accidents	**Impact of accidents**	**B-1**	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**C-1**	**C-2**	**C-3**	**Total and percentage (%)**
Sub-totals	ED	1	0	0	0	2	0	0	0	0	0	0	0	3 3.16%
	VD	2	0	2	1	2	3	0	1	1	2	0	1	15 15.79%
	D	4	3	2	4	2	2	1	2	1	2	0	2	25 26.31%
	LD	7	5	7	7	6	4	4	3	0	3	5	1	52 54.74%
Total and percentage (%)	Total accidents	14	8	11	12	12	9	5	6	2	7	5	4	95
	% of accidents	14.74%	8.42%	11.58%	12.63%	12.63%	9.47%	5.26%	6.32%	2.11%	7.37%	5.26%	4.21%	100.00%

Finally, the safety precautions and the accident severities were compared as regarding. The safety and accidents indexes were correlated and a negative exponential relationship ($y = 86.11e^{-2.92x}$) was detected between the safety index and the accident index in the studied laboratories (Figure 4.1). This relationship was an evidence that the increased safety precautions have a positive effect on reducing the occupational accidents in the studied laboratories. The regression coefficient between safety and accident indexes was calculated as $R^2 = 0.941$ (Figure 4.1). Higher R^2 value as 0.941 means that the safety precautions are effective in the protection and hazard reduction of the occupational accidents.

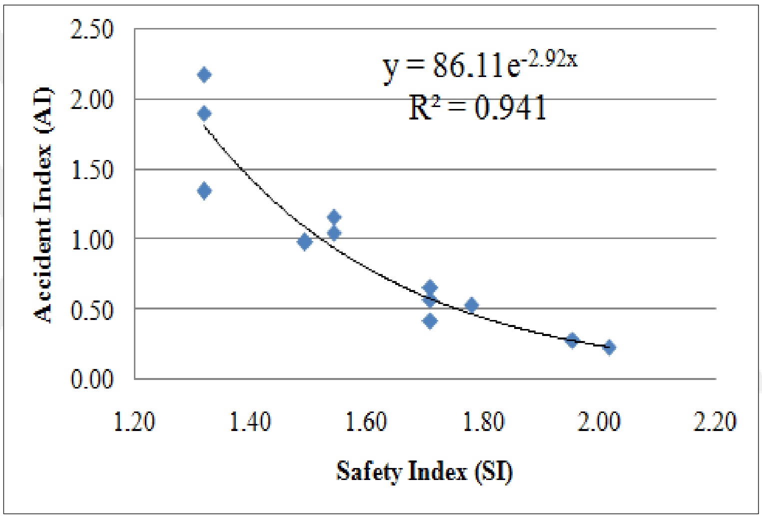


Figure 4.1 The relationship between safety and accident indexes

Within the scope of this thesis study, two laboratories (C and B) and their sub-departments (from C1 to C3 and from B1 to B9) were examined in terms of occupational accidents and occupational precautions covering a period of five years (2014-2019). There were 95 occupational accidents totally in the two studied laboratories (C and B) (Table 4.1). Specifically; 3.16%, 15.79%, 26.31% and 54.74% were resulted as ED, VD, D and LD, respectively (Table 4.1). ED, VD, D and LD accidents had negative impacts on the laboratory personnel as leaving permanent disability, requiring hospital treatment and/or leaving temporary disability, outpatient treatment and no disabilities or needing first-aid, respectively.

22.11%, 17.89%, 15.79%, 11.58%, 10.53% and 8.42% of the accidents happened due to the musculoskeletal injuries, sharp object injuries, stumble and fall, chemical contamination, falling of the objects and poisoning, respectively (Data not shown). The aforementioned accidents represented an amount of 86.32% of the total accidents in the studied laboratories. It would be sensible to prioritize taking actions to prevent the aforementioned accidents. In addition to these results, 4.21%, 4.21%, 3.16%, 1.05% and 1.05% of the accidents were due to the contamination of the studying sample, infections originating from laboratory activities, allergy and electric shock and flooding, respectively (Data not shown). There was no occupational accident due to explosion-burning occurred in the studied laboratories during the observation period of this study or before the selected period (2014-2019).

In order to minimize the most common accidents in the studied laboratories, it is possible to take some safety precautions. They could be listed as follow:

1. The most common accident was found as the musculoskeletal injury with a percentage of 22.11%. Occupational health and safety training should be provided to all laboratory personnel. Health surveillance of laboratory personnel should be done regularly. Standard bench heights and table heights should be provided during analysis process and pc studies process.

2. The sharp object injury was the second most common occupational accident by 17.89% of the total accidents. Occupational health and safety training and informative posters should be provided in all laboratories. Laboratory personnel should use personal protective equipments (PPEs). The first-aid chest's materials should be always checked in a case of first-aid is need.

3. The stumble and fall was the third most common occupational accident by 15.79% of the total accidents. The laboratory personnel may be stumble and fall due to the electric cables on the ground, doorsills and waterpipes on the floor, untidy laboratory and floor cleaning in the studied laboratories. The electric cables, doorsills and waterpipes should be put below ground. Proper storage for the materials against untidiness in the studied laboratories should be provided. Warning signs after clean up the floor should be placed for all studied laboratories.

4. To prevent the chemical contamination which was 11.58% of the total accidents, occupational health and safety training should be provided. All laboratory personnel should be use PPE such as ab coat, lab glasses, masks and nitrile gloves. All laboratory supervisors supply appropriate PPEs to all laboratory personnel.

5. The falling of the objects was 10.53% of the total accidents, therefore the cabinets and fume hoods should be fixed on the walls in a case of vibration, falling or an earthquake. Open shelves of the cabinets should be closed, besides, no materials put on the cabinets. Any of the chemicals used in the studied laboratories should not be placed on the open shelves. The laboratory supervisors must supply proper chemical cabinets and the laboratory personnel put chemicals into the chemical cabinets.

6. The poisoning was 8.42% of the total accidents and in order to minimize the accident, occupational health and safety training should be provided. Fume hoods should be provided if the analysis requires. Periodic maintenance for fume hoods and ventilation system should be done for every year. The appropriate PPE is the cartridge respirator instead of medical mask in case of gas releasing from the analysis and chemicals to provide poisoning.

If a generalization is made for the studied laboratories, it is possible to decrease the number of the occupational accidents with the increased number of safety precautions in the light of the AHP modelling.

4.2 Fine-Kinney Method (FKM)

Possible risks caused from occupational accidents in the laborotories were assessed with Fine-Kinney Method (FKM) based on chemical (chemical contamination, poisoning due to gases releasing from the analysis), physical (electric shock, explosion-burning, falling of the objects, musculoskeletal injuries, sharp object injuries, stumble and fall, flooding) and biological (infections originating from laboratory activities, contamination of the studying sample, allergy due to latex gloves or some chemicals) factors.

The risk was measured by multiplying the possibility, frequency and effect parameters to each other. The possibility, frequency and effect parameters get quantitative values according to the range of Fine-Kinney Method (FKM). The determined risks were arranged from worse to better and assessed with Fine-Kinney Method (FKM). A risk value as low as 20 represents a situation of low risk and it is considered acceptable for the laboratory work. The precaution is not primary for the risk. A risk value between 20 to 70 indicates that it is a possible risk and it should bring under control. A situation with a risk value in a range of 70 to 200 is considered an important risk and correction is needed. Also, there can be higher risk situations; a risk value of 200 to 400 indicates that correction is urgently needed. A very high risk value of more than 400 indicates that the risk is not tolerated and necessary precautions must be taken immediately. If the work cannot be made safe a permanent shutdown becomes necessary for the laboratory, building or the environment (Kinney & Wiruth, 1976). The classified risk values were fitted into a sequence from not tolerated risk to insignificant risk. Corrective actions against to the risks were wrote into the risk assessment report in the content of this study (Table 4.2).

Table 4.2 Risk assessment report for Fine-Kinney Method (FKM)

RISK ASSESSMENT REPORT FOR FINE-KINNEY METHOD										
NO	Risk	Source of Danger	Possible situation if danger turns into accident	Affected People	Risk Rating				Decision	Corrective Action
					Possibility	Frequency	Effect	Risk Value		
1	Electric Shock	Electrical equipment	More than one accident involving death	All personnel and building	10	0.5	100	500	Not tolerated risk	Training, Periodic control of the system, Accessible height for the electrical fuses, Objects must be removed in front of the electrical fuses, Nonconducting mat in front of the electrical panels, Using residual current device
2	Explosion-Burning	Gas cylinders, chemicals, fire-extinguishers	Cause death	All personnel and building	6	0.5	100	300	Strong risk	Training, Proper storage for chemicals, Cylinders must be fixed on the wall, Periodic maintenance for fire-extinguisher for every year, Conducting fire drills
3	Infections Originating from Lab. Activities	Analysis	Cause death or working day loss	Lab personnel	6	1	40	240	Strong risk	Training, Health surveillance, Periodic maintenance of laminar air flow cabinets, Disinfection, PPE
4	Chemical Contamination	Analysis	Transient damage/injury, hospital treatment	Lab personnel	6	3	7	126	Important risk	Training, PPE
5	Falling of the Objects	Materials on the open shelves, cabinets, fume hoods	Fatal accident	Lab personnel	3	1	40	120	Important risk	Training, Cabinets and fume hoods must be fixed on the walls, Open shelves must be closed, No materials on the cabinets, No chemicals on the open shelves - put them in proper chemical cabinets

Table 4.2 continues

RISK ASSESSMENT REPORT FOR FINE-KINNEY METHOD										
NO	Risk	Source of Danger	Possible situation if danger turns into accident	Affected People	Risk Rating				Decision	Corrective Action
					Possibility	Frequency	Effect	Risk Value		
6	Musculoskeletal Injuries	Standing during analysis, lifting heavy things	Permanent damage/injury, working day loss	Lab personnel	3	2	15	90	Important risk	Training, Providing break times, Exercising, Health surveillance, Standard bench heights, Standard table heights for the studies with pc
7	Poisoning	Gases releasing from the analysis, chemicals using in the analysis	Transient damage/injury, hospital treatment	Lab personnel	6	2	7	84	Important risk	Training, Fume hoods usage if the analysis reguires, Periodic maintenance for fume hoods and ventilation system for every year, cartridge respirator, PPE
8	Sharp Object Injuries	Analysis	Minor loss/injury, first aid need	Lab personnel	6	3	3	54	Possible risk	Training, Informative posters, PPE, Always check the first-aid chest's materials
9	Contamination of the Studying Sample	Wastewater, biological sludge, soil, solid waste	Minor loss/injury, first aid need	Lab personnel	3	3	3	27	Possible risk	Training, Disinfection, Preventive inoculation, Health surveillance, PPE
10	Stumble and Fall	Electric cables, doorsills and waterpipes on the floor, untidy lab., floor cleaning	Transient damage/injury, hospital treatment	Lab personnel	3	1	7	21	Possible risk	Put the electric cables, doorsills and waterpipes below ground, Proper storage for the materials in the lab., Placing warning signs after clean up the floor
11	Allergy	Latex gloves, chemicals	Minor loss/injury, first aid need	Sensitive lab personnel	1	1	3	3	In-significant risk	Training, PPE, Providing nitrile gloves instead of latex gloves
12	Flooding	Valve breakdown, rain water leakage	Escape with little or no harm	All personnel and building	1	0.5	1	0.5	In-significant risk	Periodic maintenance of the water system, before leaving from the lab. always perform a final control

The highest risk was found to be electric shock in FKM. Explosion-burning and infections originating from laboratory activities had strong risk values according to the FKM (Table 4.2). The risk of chemical contamination, falling of the objects, musculoskeletal injuries and poisoning were found to be important risks in FKM (Table 4.2). Sharp object injuries, contamination of the studying sample and stumble and fall were in the group of possible risks according to the FKM (Table 4.2). Allergy and flooding were calculated as insignificant risks in FKM (Table 4.2). The source of the dangers could be summarized as electrical equipment, materials or devices used in the laboratory, the analysis itself, the physical action of the personnel, the chemicals used, the samples worked, exposed cables or pipes and wet floor (Table 4.2). Not tolerated risks can lead to multiple accidents or even death, while strong risks can result in death or lost working days (Table 4.2). Important risks can lead to death, permenant or transient damage/injury, or may require hospital treatment (Table 4.2). They can also cause a loss of working days (Table 4.2). Possible risks may result in transient damage/injury or require hospital treatment (Table 4.2). In addition, it can be circumvented with minor loss/injury or first aid (Table 4.2). Insignificant risks can likewise be circumvented with minor loss / injury or first aid (Table 4.2). It is possible to get rid of it with little or no harm (Table 4.2). The most important precautions that can be taken are the training required to create the OHS culture for the laboratory personnel. Specific precautions that can be taken based on the detected risks were shown in Table 4.2. It is the duty of the rectorship to do the health surveillance while the training and preventive inoculation are the duties of the deaconship for the studied laboratories within the scope of this thesis. Generally, it has a great importance to supply PPE to laboratory personnel and control their use of PPE in the studied laboratories. Necessary precautions to be taken in terms of infrastructure have been determined in this study. These include accessible height for the electrical fuses, standard bench heights and putting the electric cables, doorsills and waterpipes below ground (Table 4.2).

4.3 Cost Analysis

Considering the occupational health and safety precautions required to be taken according to the two risk assessment methods used, namely AHP and FKM, the approximate cost of the safety precautions was calculated as 10,000.00 Euro in chemistry (C) and biology (B) research laboratories (Table 4.3). The cost of the safety precautions to be taken on the basis of each risk was shown in the Table 4.3.

Table 4.3 The approximate total cost of safety precautions

The risk	**The occupational health and safety precautions**	**The approximate total cost**
Electric Shock	nonconducting mats: (6.50 Euro/unit) × (5 unit/lab)* = 32.50 Euro	137.50 Euro
	residual current devices: (35.00 Euro/unit) × (3 unit/lab)* = 105.00 Euro	
Explosion-Burning	fire-extinguishers: (18.00 Euro/unit) × (2 unit/lab)* = 36.00 Euro	7733.00 Euro
	fire detectors: (23.50 Euro/unit) × (2 unit/lab)* = 47.00 Euro	
	maintenance for fire-extinguishers in a year: (3.50 Euro/unit) × (12 unit/year)** = 42.00 Euro	
	chemical cabinets (90 min fire-resistant): (1902.00 Euro/unit) × (4 unit/lab)* = 7608.00 Euro	
Infections Originating from Laboratory Activities and Chemical Contamination	[(8.00 Euro/lab coat) + (3.00 Euro/lab glasses) + (26.50 Euro/cartridge mask)] × (11 lab personnel)** = 412.50 Euro	412.50 Euro
Falling of the Objects	close the open shelves on the benches for 1 lab	118.00 Euro
Musculoskeletal Injuries	standard bench: (176.50 Euro/m^2) × (4 m^2/for 3 labs)* = 706.00 Euro	746.00 Euro
	standard table: (40.00 Euro/unit) × (1 unit/lab)* = 40.00 Euro	
Poisoning due to Gases Releasing from the Analysis	repairing broken fume hoods: (118.00 Euro/unit) × (2 unit/lab)* = 236.00 Euro	708.00 Euro
	periodic maintenance for ventilation systems: (236.00 Euro/unit) × (2 unit/lab)* = 472.00 Euro	
Sharp Object Injuries	first-aid chests: (35.00 Euro/unit) × (3 unit/lab)* = 105.00 Euro	105.00 Euro
Stumble and Fall	warning signs: (4.00 Euro/unit) × (10 unit/lab)* = 40.00 Euro	40.00 Euro
Total cost		**10,000.00 Euro**

Note: The cost of the materials used for safety precautions were calculated according to the market prices (February 15th, 2021). Recent Euro exchange rate was used to convert the Euro currency to Turkish Liras (1 € = 8.50 TL, February 15th, 2021).
*: number or laboratories needing for it
**: total number in B and C labs

4.4 Recommendations

Our study included two research laboratories namely chemistry (C) and biology (B) laboratories in the content of this thesis. Chemistry (C) laboratory has been completely renovated and renewed its infrastructure before this thesis study. All of its personnel are professional laboratory employees. Undergraduate/graduate student employment is at a minimum level. On the other hand, there are less professional personnel in the biology (B) laboratory compared to the chemistry (C) laboratory. Undergraduate/graduate student employment is at a maximum level. It has been observed that the majority of student personnel cause the employees to change frequently. Therefore, the personnel who have gained occupational health and safety awareness with their analysis experience leave and the laboratory supervisors have to train new employees from the beginning. As a result of modeling with AHP and FKM, it has been revealed that the laboratory infrastructure and occupational health and safety culture of the personnel have a strong effect on increasing safety and reducing accidents.

REFERENCES

Adar, E., Ince, M., Karatop, B., & Bilgili, M. S. (2017). The risk analysis by failure mode and effect analysis (FMEA) and fuzzy-FMEA of supercritical water gasification system used in the sewage sludge treatment. *Journal of Environmental Chemical Engineering, 5*, 1261–1268.

Bourrée, F., Salmi, L. R., Garrigou, A., Domecq, S., Brochard, P., Michel, P. (2014). A comparison of three methods to identify chemicals hazards in French research laboratories. *Safety Science, 68,* 324–330.

Demirel, S., & Sert, N. (2018). Bir plastik geri dönüşüm tesisinde ön tehlike analizi (PHA) ile risk değerlendirmesi. *Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 7* (2), 572-580.

Ding, G., Xin, L., Guo, Q., Wei, Y., Li, M., & Liu, X. (2020). Environmental risk assessment approaches for industry park and their applications. *Resources, Conservation & Recyling, 159,* 104844.

Ercan, M. (2016). *Tehlikeli atık bertaraf tesislerinin iş sağlığı ve güvenliği yönünden incelenmesi.* MSc Thesis, Çalışma ve Sosyal Güvenlik Bakanlığı İş Sağlığı ve Güvenliği Genel Müdürlüğü, Ankara.

Ersoy, M. (2013). The role of occupational safety measures on reducing accidents in marble quarries of Iscehisar region. *Safety Science, 57,* 293-302.

Fine, W. T. (1971). Mathematical evaluation for controlling hazards. *Journal of Safety Research, 3* (4), 157-166.

Gachlou, M., Roozbahani, A., &, Banihabib, M. E. (2019). Comprehensive risk assessment of river basins using Fault Tree Analysis. *Journal of Hydrology, 577,* 123974.

Health and Safety Executive [HSE]. (2003). *Safe working and the prevention of infection in clinical laboratories and similar facilities* (2nd ed.). UK: The Office of Public Sector Information.

Kinney, G. F., & Wiruth, A. D. (1976). NWC technical report. In *Practical risk analysis for safety management* (58-65). Naval Weapons Centre, China Lake, California, USA: NWC Technical Publication.

Leggett, D. J. (2012). Lab-HIRA: Hazard identification and risk analysis for the chemical research laboratory. Part 2. Risk analysis of laboratory operations. *Journal of Chemical Health & Safety, 19* (5), 25-36.

Lestari, F., Bowolaksono, A., Yuniautami, S., Wulandari, T. R., & Andani, S. (2019). Evaluation of the implementation of occupational health, safety, and environment management systems in higher education laboratories. *Journal of Chemical Health & Safety, 26* (4-5), 14-19.

Moreno, V. C., & Cozzani, V. (2018). Integrated hazard identification within the risk management of industrial biological processes. *Safety Science, 103,* 340–351.

Njoroge, S. W., & Nichols, J. H. (2014). Risk management in the clinical laboratory. *Annals of Laboratory Medicine, 34,* 274-278.

Omurbek, N, & Simsek, A. (2014). Analitik hiyerarşi süreci ve analitik ağ süreci yöntemleri ile online alışveriş site seçimi. *Yönetim ve Ekonomi Araştırmaları Dergisi, 22,* 306-327.

Saaty, T. L. (1994). How to make a decision: The analytic hierarchy process. *Interfaces, 24* (6), 19-43.

Sutrisno, A., Gunawan, I., &, Tangkuman, S. (2015). Modified failure mode and effect analysis (FMEA) model for accessing the risk of maintenance waste. *Procedia Manufacturing, 4,* 23 – 29.

Taylor, W. D., & Snyder, L. A. (2017). The influence of risk perception on safety: A laboratory study. *Safety Science, 95*, 116–124.

Yaralioglu, K. (n.d.). *Analitik hiyerarsi proses.* Retrieved March 15, 2016, from http://www.deu.edu.tr/userweb/k.yaralioglu/../Analitik_Hiyerarsi_Proses.d

Yaralioglu, K., & Koksal, H. (2003). Analytic hierarchy process as a managerial decision tool in the evaluation of new product ideas. *Ege Academic Review, Ege University Faculty of Economics and Administrative Sciences, 3* (1), 119-137.

Yilmaz, H., & Surat, H. (2015). Analitik hiyerarşi süreci kullanılarak en uygun ekoturizm etkinliğinin belirlenmesi. *Turkish Journal of Forestry, 16* (2), 164-176.

Zhu, C., Tang, S., Li, Z., & Fang, X. (2020). Dynamic study of critical factors of explosion accident in laboratory based on FTA. *Safety Science, 130*, 104877.