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A case study on lean occupational safety

Mesut ULU[1], Semra BİRGÜN[2,*]

ABSTRACT

Occupational illnesses and occupational injuries remain significant problems in contemporary countries. Especially in the fourth industrial revolution, with the changing technology and business model requirements, employees are at more risk because they have to be much faster and fulfill different functions. Due to present risks, dangerous working conditions, and inadequate measures, each year hundreds of thousands of people suffer from occupational illnesses or have occupational accidents. While occupational health and safety (OHS) practices protect employees, it is possible to increase productivity by ensuring that employees work in a safe and healthy work environment with the Lean Occupational Safety approach based on the "Zero Accident" principle. In this paper, a case study is presented by using a Lean-OHS model that it is an original model that incorporates continuous improvement by taking advantage of lean philosophy, tools and techniques while fulfilling the OHS principles. The research was carried out in a university's pharmacology and pharmaceuticals laboratory, and it improved working conditions and made the workplace safer by turning 18 of 20 threats into acceptable ones.

Keywords: *Lean; Occupational health and safety; Case study; Laboratory; Risk assessment.*

INTRODUCTION

To achieve perfection in production, it is possible with lean philosophy to eliminate/minimize all waste in the system and thus to realize the production at the desired quality, quantity, and place in the most economical way without interrupting the resources.

Lean, while reducing costs and increasing productivity, focuses on people. With team spirit, it gives people authority and responsibility and enables them to embrace the job, even the institution, with motivation. Approach is the same for work safety as it is for production. According to Hafey [1], Lean Safety, a human-centered leadership tool, answers the question “what's in it for me” that all employees think about.

In companies where lean occupational safety is applied, occupational safety trainings such as hazard estimation training, accident simulation training, are given as of the start of the employment. People are expected to work in accordance with the given standards and are monitored through performance indicators. In addition to what is done with work safety, it is ensured that the employees look at the work environment with safety perspective. Each employee is responsible for himself and the work safety of the unit he is responsible for. It focuses on the probability of occurrence of risks that will cause accident. In case of an accident, the root cause of the accident is investigated, and all units are informed. Visual management tools are used to raise awareness for occupational safety and ensure its continuity. The situation regarding occupational safety is reflected transparently with various signboards, boards, indicators, etc. Apart from occupational safety meetings and trainings, Visual Management and 5S/6S, which are tools that ensure occupational safety of lean philosophy, can be recommended.

The clean, healthy and safety work environment called Gemba is ensured by 5S/Gemba Kanri's application steps [2]: S1-Seiri: sort-clean out, S2-Seiton: set in order -configure, S3-Seiso: shine -clean&check, S4-Seiketsu: standardize-conformity and S5-Shitsuke: sustain of self discipline – custom and practice. A safer environment is provided by arranging them (S2), because of debugging only the necessary tools, equipment, materials, etc., production/non-production resources and keeping them in the workplace (S1). In addition, the third S reduces the number of machine breakdowns and prevents accidents. At the end of 5S, a good, orderly, and healthy workplace is

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[1] Bandirma Onyedi Eylul University, Department of Occupational Health and Safety, Balıkesir, Turkiye
[2] Dogus University, Department of Industrial Engineering, Istanbul, Turkiye
** E-mail address. sbirgun@dogus.edu.tr ; semrabirgun@gmail.com*
Orcid id: https://orcid.org/0000-0002-5591-8674 Mesut Ulu, 0000-0001-5018-6120 Semra Birgün
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obtained. The sixth S (safety) [2] ensures that the workplace has a completely healthy, safe and clean environment with error-proofing, safety instructions and symbols and safety trainings.

The lean approach, which was applied to increase the value of the product created by eliminating waste and which was initially implemented in the manufacturing sector, was not limited to manufacturing, and was successfully applied in every sector, whether it produced goods, services or information. There are many publications on lean applications and the use of lean techniques. Åhlström and Karlsson [3] accounting, Vinodh, S., et al [4], Birgün and Kulaklı [5] environmental sustainability, Durmuşoğlu [6], Shah and Ward [7], Birgün, Özkan and Gülen [8] manufacturing, Melton [9], Abdulmalek and Rajgopal [10] process industry, Behrouzi and Wong [11] supply chain, Flynn et al [12], Rosso and Saurin [13], Wilson et al. [14], Coffey et al. [15], Kanamori et al., [16], Robinson et al. [17] health, Aziz and Hafez [18], Ghosh and Young-Corbett [19], Rozenfeld et al [20] construction, Birgün, Gülen and Özkan [21], Birgün and Gülen [22], business processes publications are just a few. Although lean studies for such performance improvement from various sectors are very intense, studies combining lean principles and OHS are relatively few. Samples of published studies on lean occupational safety are given in Table 1.

Table 1. Samples of studies on lean occupational health and safety

Author	Year	Explanation
Gnoni et al. [23]	2013	The near-miss management system was created with worker safety in mind.
Arezes et al. [24]	2013	They concluded that the lean philosophy and its tools are an added value for improving safety conditions in industries. After surveying this study, it was found that 83.4% of the employees agreed that the work environment was improved after implementing lean practices.
Longoni et al. [25]	2013	By giving actual evidence on lean methodologies, they assessed OHS performance. Ten case studies have demonstrated that lean approaches have a favorable effect on OHS performance.
Geçevska et al. [26]	2015	The lean production approach ensures maximum use of all resources by eliminating all waste, and also increases the safety of employees. Lean also improved ergonomic and stress-related adverse health effects.
Babur et al. [27]	2016	In their work, they offered a systematic approach to the design of lean-oriented OHS systems based on axiomatic concepts. It has been demonstrated that the recommended OHS system design is derived from the shipbuilding industry and implemented to a real shipyard system.
Hafey, R. [1]	2017	Lean tools, such as particularly the application of the 5S methodology, standardized working approaches, poka-yoke solutions, visual management tools and problem solving methods have been recognized for making a positive impact on workplace safety.
Dos Santos and Dos Santos Nunes [28]	2017	They offered an analytical framework for assessing ergonomic risks that combined scientific rigor with lean practices.
Fernandes et al. [29]	2018	In this study, they claimed that the 5S is a powerful tool for organizing and optimizing the workplace environment. The results of this study showed that it is possible to reduce the risk by 64% after applying 5S+1S=6S.
Jimenez et al. [30]	2019	They took the 5S approach, elevated it to the 6S level of safety, and put it through its paces in a coed high school laboratory.
Hamja et al. [31]	2019	Based on their research, they concluded that the lean mindset improves OHS and fosters synergy in the apparel business.
Wu et al. [32]	2019	Using system dynamics and simulation, they designed a construction safety system based on several lean construction tools and demonstrated the large beneficial impact lean adoption had on enhancing overall safety.
Mutaza et al. [33]	2020	It has shown that the implementation of 5S will assist the organization in reducing industrial accident, but requires that strategies such as the inspection process are clearly stated. In this study, the effect of 5S application on accident-free industries was also obtained successfully.

Małysa and Furman [34]	2021	They discussed how lean manufacturing technologies may be used to boost worker safety in the steel sector.
Abu Aisheh et al. [35]	2021	They investigated the application of the lean construction principle and its effect on occupational health and safety.
Anandh et al. [36]	2022	They aimed to develop an applicable methodology that helps increase safety in the construction industry and ultimately reduces construction accidents with lean concept
Ulu and Birgün [37]	2022	They introduced an alternative theoretical framework for lean OHS.

Lean approach would positively affect the performance criteria in any organization [38]. Nahmens and Ikuma [39], Ghosh and Young-Corbett [19], Rozenfield et al [20] stated in their study that as a result of the application of lean principles in the construction sector, where deaths and accidents are very common, the risk of accidents and accident rates, the total number of lost days, labor absenteeism are reduced, and a safer workplace and higher productivity are provided. Since Lean principles aim to reduce waste in work processes and occupational accidents are wasteful and non-value-adding events in any organization, Ghosh and Young-Corbett [19] expressed that to safeguard workers from occupational hazards is a natural outcome of the Lean Construction.

On the other hand, the models have developed those integrated lean principles with OHS. Kruse, Veltri and Branscum [40] proposed a conceptual integrated safety, health, and environmental management system framework for high performance driven organizations. Babur, Çevikcan and Durmuşoğlu [27] developed a holistic model by using Axiomatic Design principles and demonstrated its feasibility in a shipyard. The "Lean Occupational Health and Safety (Lean-OHS) Model" was introduced by Ulu and Birgün [37] to help businesses better adhere to OSHA's health and safety standards.

In this paper, a case study, and its results regarding the implementation of the Lean-OHS model proposed by Ulu and Birgün [37] are presented. This paper has been organized as follows: Lean-OHS model is firstly explained briefly in section 2; a case study of model application in detailed is presented in section 3, and results and discussion are in section 4.

LEAN-OHS MODEL DESCRIPTION

A reference model for developing an efficient OHS system in line with lean methodologies has been suggested by Ulu and Birgün [37]. This concept was developed to safeguard workers by reducing potential hazards, promoting uniformity, and guaranteeing long-term viability. The main phases of the model are shown in Figure 1.

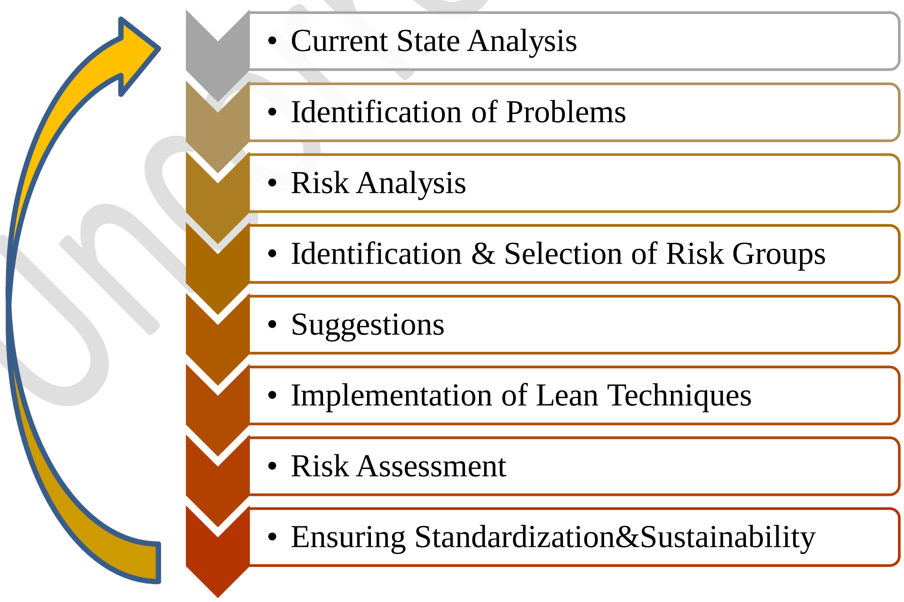


Figure 1. Lean Occupational Health and Safety (Lean-OHS) Model

The model shows a cyclical feature to ensure continuous improvement. In addition to the benefits to be provided by the implementation of the Lean-OHS model, it is expected that higher achievements will be achieved over time as the lean culture is established in the organization.

A detailed description of the model can be obtained from Ulu and Birgün's [37] paper. The steps of the model can be summarized as follows:

- Analyzing the current state of the system to be examined in terms of occupational safety requirements and determining the relevant characteristics
- Identifying situations that exist in the system and are seen as problems in terms of occupational safety by keeping records such as photographs and videos, etc.
- Identifying hazards, rating risks, and deciding on control measures
- Carrying out a risk assessment, identifying significant and high-value risks and making decisions to eliminate these risks
- With respect to the OHS rules, suggesting solutions using lean techniques to reduce the risk size
- Preparing an implementation plan and realizing the recommendations according to the plan
- Re-measurement and evaluation of risk factors for improved state achieved
- Standardizing the steps performed in the first seven steps, and repeating these steps in certain periods to sustain a safe and reliable system

With the periodic repetition of the model steps, practitioners will be on their way to excellence in occupational safety. The following section describes the application of Lean-OHS model for a laboratory.

AN APPLICATION OF LEAN- OHS MODEL

The application of the model was carried out in a laboratory in the Faculty of Pharmacy of a foundation University. The faculty has five laboratories: Laboratory of Analytical Chemistry, Laboratory of Pharmaceutical and Pharmacology, Laboratory of Pharmacognosy, Laboratory of Pharmaceutical Botany, and Laboratory of Biotechnology. The first three laboratories, respectively, are in the same corridor, while the last two laboratories are located in another corridor. The Pharmaceutical and Pharmacology Laboratory, which is in the middle of three laboratories, was selected as the application area. In selecting this laboratory, factors such as the presence of measurement and analysis devices used by all laboratories in common, the presence of both student and research laboratories, and the lack of occupational safety measures were effective.

ANALYSIS OF THE CURRENT STATE OF THE LABORATORY

Pharmaceutical and Pharmacology Laboratory (PPL) research about drug analyses, drug effects and usages about the origins of drugs, their acquisition, their effects in the body, side effects, poisoning conditions, and their treatment.

There are about 500 different chemicals in the PPL and over 2000 chemicals in total. In the laboratory, apart from explosive and radioactive material, flammable material, oxidizer, toxic substance, harmful substance, corrosive substance, environmentally harmful substance, carcinogenic substance, mutagen substance and toxic substances for reproduction are studied.

6 faculty members work continuously in the laboratory, as well as many students can use the laboratory alternately for research, thesis, or homework. Since there are not enough analyzers in all laboratories, the staff members have to use the instruments of another laboratory for the measurement and analysis of their experiments.

IDENTIFYING PROBLEMS IN THE LABORATORY

At this stage, the following problems were identified which were classified in terms of OHS in the PPL.

Improper storage of chemicals, surplus chemical, pressure tubes, chemical waste in glass bottles, chemicals stored in a household refrigerator, chemicals not stored in their original packaging, chemicals with unknown content, irregular cables, stacking, insufficient ventilation system, lack of OHS environment measurements, non-ergonomic environments and groups, lack of instructions, not using personal protection and equipment, randomly placed fire tubes, messy and irregular work environment, missing first aid supplies, laboratory doors, toxic gases from the oven, and fume cupboards.

RISK ANALYSIS

Risk analysis and evaluation using the Fine Kinney method [41] was performed in order to analyze the risks and dangers present in the laboratory. Probability, frequency, and results values of 20 activities / events are taken from Table 2 below and risk scores are calculated in the laboratory. All processes and problems were photographed, and a risk analysis table was prepared.

The dye used in this study is Reactive Orange 16.Reactive Orange 16 is an anionic dye and azo belongs to the class. In Table 1 its characteristics are summarized. Its general characteristics are shown. Figure 1.

Table 2. Fine Kinney Rating Scale [41]

Probability		**Frequency**			**Possible Consequence**		
Value	Category	Value	Description	Category	Value	Description	Category
0,2	Practically impossible	0.5	Very rare	Once a year or less	1	Should be considered	Mild-harmless or trivial
0.5	Slim chance	1	Quite rare	Once or several times a year	3	Important	Minor-low job loss, minor damage, first aid
1	Pretty unlikely	2	Rare	Once or several times a month	7	Severe	Major-significant damage, external treatment, workday loss
3	Rare but maybe	3	Sometimes	Once or a few times a week	15	Very severe	Disability, limb loss, environmental impact
6	Likely	6	Often	Once or a few times a day	40	Too bad	Death, full disability, severe environmental impact
10	Very strongly likely	10	Continuously	Continuously or more than once per hour	100	Disaster	Multiple deaths, major environmental disaster

IDENTIFICATION AND SELECTION OF RISK GROUPS

Thanks to the risk assessment, the values of the risk scores are colored according to the risk assessment criteria. There were 20 different risks in total and the order of importance of these risks is given in the last column of the Table 3.

Table 3. The risk assessment results [41]

Risk Score	Risk Color	Risk Group	Identified Number
R<20		*Acceptable Risk*: Trivial risk, not a precautionary priority.	**0**
20<R > 70		*Definite Risk:* Potential risk, should be applied under supervision.	**5**
70<R > 200		*Significant Risk*: Should be improved in the long term (within the year).	**7**
200<R>400		*High Risk*: Essential risk, should be improved in the short term (within a few months).	**8**
R > 400		*Very High Risk*: The necessary measures should be taken immediately / or the closure of the facility, building, environment should be considered.	**0**

RECOMMENDATIONS FOR SOLUTIONS

As a consequence of the laboratory's risk evaluation, the following recommendations were made to rectify and decrease high and substantial risks:

- ***Storage of Chemicals:*** For the storage of chemical substances, it is necessary to establish an inventory system in which all chemical substances are registered in the laboratory and to separate them with an appropriate classification. Chemicals must be examined separately according to the chemical storage matrix and carefully placed in cabinets or shelves without contacting each other. The racks must be firmly attached to the wall and the front parts must have protection sets or covers. The danger will be minimized by using the ***5S*** method from lean techniques to eliminate impropriety in the storage of chemicals.
- ***Surplus Chemicals:*** While sufficient storage of chemicals will be appropriate, it is necessary to store surplus chemicals because of the long procurement processes of the university and the supply of chemicals from abroad. For this reason, the surplus amounts of chemical substances must be stored in a suitable storage tank for the environment temperature and ventilation system to be created outside the building. In addition, chemicals should be grouped according to their properties and stored in separate sections. By using ***5S*** method of lean techniques, storage areas will be arranged in the laboratory and the locations of misplaced chemicals will be changed.
- ***Pressure Tubes:*** Pressure tubes should be fixed to the walls and placed outside the laboratory if possible, so as not topple. For this, as a lean technique, ***kaizen***, will be used.
- ***Chemical Wastes:*** Chemical wastes should collect in different containers according to their characteristics, then stored in a place outside the building and they should be annihilated with agreement with ministry approved transport and disposal institutions for the disposal of chemical wastes. Also, by creating in the laboratory waste management and policies and waste storage, labeling, transportation, and disposal procedures should be implemented according to the established rules of the necessary instructions for proper and appropriate disposal of the material it is necessary to store them in the process. This application needs to be checked periodically and regularly.

For chemical wastes, waste instructions should be created by applying ***visual factory*** requirements and chemical wastes should be regulated by applying ***5S*** method.

- ***Storing Chemicals in The Fridge:*** For chemicals that need to be stored in the fridge, refrigerators with special chemicals should be provided instead of household refrigerators. Storage of chemicals in the cold using ***kaizen*** will take place safely.
- ***Storing Chemicals in Different Containers:*** Chemical substances should not be stored in unsuitable containers. In containers suitable for storing chemicals, the necessary information such as what is in the material,

percentages if the mixture is composition, content information, etc. should always be labeled and pasted into containers. Improper use of chemicals will be prevented by using ***visual factory*** and ***kaizen*** for labeling process.

- ***Unknown Chemicals:*** What chemicals are in the laboratory and how much they should be known, and an inventory list should be made for this. In addition, material safety forms of all chemicals must be collected and transferred to the computers used in the laboratory and provided for a short access. Safety data sheets of chemicals should be recorded regularly on laboratory computers. When processing with chemicals, the necessary procedures must be done by examining the 16 headings of the material safety data sheets. The safety data sheets should be set in order using the ***5S*** method.
- ***Irregular Cables:*** Irregular and disorganized cables should be passed through cable channels and made regular. Unnecessary cables should be removed, and cables should not be extended to the crossing paths. Layout for cables is planned to use the ***5S*** method.
- ***Stacking:*** The materials stowed on the cabinets should be fixed and placed or the materials that may fall over the cabinets should be removed and placed in appropriate cabinets or counters. The storage problem will be minimized for materials stowed using the ***5S*** method.
- ***Ventilation System:*** It should be ensured that there is sufficient fresh air required by the employees in the closed workplaces, and the determination of the adequate air volume should be taken into consideration the working method, the number of employees and the work performed by the employees. Wastes and leftover that may harm the health of the employees by polluting the work environment should be taken out immediately. A mechanical (forced) ventilation system should be installed separately from the general ventilation system in such a way as to remove suffocating, toxic or irritating gas and dust, mist, smoke, and bad odors out of the environment. When a mechanical ventilation system is used, the system should always be operational; for non-operating ventilation systems, if it is dangerous in terms of occupational health and safety, a control system reporting the failure should be installed, maintenance and repair of mechanical and general ventilation systems and appropriate filter usage and replacement should be done annually by authorized persons. In passive (artificial) ventilation systems, air flow should be in such a way that it does not disturb the employees, it does not adversely affect the physical and psychological conditions of the employees, and it does not create a sudden and high temperature difference.
- ***OHS Environment Measurements:*** OHS environment measurements should be carried out at regular intervals in the laboratory. OHS environmental measurements consist of chemical measurement, dust measurement, noise measurement, vibration measurement and lighting measurements. Since dust, vibration and noise do not occur in the PPL, these measurements are not necessary. Therefore, chemical measurement and lighting measurement should be made in the laboratory.

Chemical and lighting measurements were taken at the places shown in Figure 2 in the pharmaceutical and pharmaceutical chemistry laboratory. What is expressed with A is lighting, and what is expressed with VOC shows the points where the chemical measurement is done.

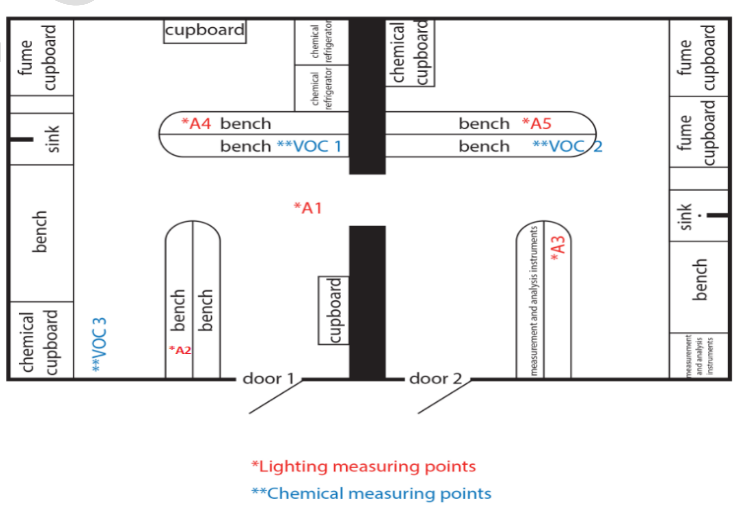


Figure 2. Measured points

The results of lighting measurement are shown Table 4. A2 and A3 regions are the most inadequate for lighting in the laboratory. It is inevitable that faculty members and students working in these regions will experience work accidents. Insufficient lighting causes fatigue, irritation, blurring of the eyes, decreased ability of the eyes to adapt, color reversals and health problems such as headaches. Since the lighting problem for the PPL will be solved in the long term, no changes have been made during the study. The results of the chemical measurement are shown in Table 5.

5S, kaizen and visual factory methods should be used to reduce the density of chemicals in the environment.

Table 4. Lighting measurement results

No.	Measure-ment Point	Environmental Conditions		Measure-ment History	Measure-ment Clock	Measure-ment (Lux)	Bound-ary Values (Lux)	Uncertainty Calculated in 95% Confidence Range	Lighting Type
A1	Passageway	20.2 (ºC) 103.52(kPa)	70.1(%) 0(m/s^2)	06.12.2016	11:00 11:01	245	100	+/- %20	Natural and Artificial (Fluorescent)
A2	Work bench	20.2 (ºC) 103.52(kPa)	70.1(%) 0(m/s^2)	06.12.2016	11:01 11:02	47	500	+/- %20	Natural and Artificial (Fluorescent)
A3	Work bench	20.2 (ºC) 103.52(kPa)	70.1(%) 0(m/s^2)	06.12.2016	11:02 11:03	53	500	+/- %20	Natural and Artificial (Fluorescent)
A4	Work bench	20.2 (ºC) 103.52(kPa)	70.1(%) 0(m/s^2)	06.12.2016	11:03 11:04	544	500	+/- %20	Natural and Artificial (Fluorescent)
A4	Work bench	20.2 (ºC) 103.52(kPa)	70.1(%) 0(m/s^2)	06.12.2016	11:04 11:05	321	500	+/- %20	Natural and Artificial (Fluorescent)

Table 5. Chemical measurement results

Volatile Organic Compounds	Measurement Results (µg)	Volatile Organic Compounds	Measurement Results (µg)
Benzene	9,1524	Toluene	<5
Dichloromethane	35,8752	Ethylbenzene	<5
Cis-1,2-dichloroethylene	78,8201	m / p-Xylene	<5
Chloroform	146,2457	o-Xylene	<5
1,1,1-Trichlorethane	36,5932	1,3,5-Trimethylbenzene	<5

- ***Ergonomics:*** The chimneys of the fume cupboards that are studied to create an ergonomic environment should be extended and brought to the middle sections of the laboratory with a long ceiling height. In addition, the nitrogen tank used in the tap system should be brought. The employees should be given the necessary ergonomics training to prevent the wrong actions and the employees should be taught rest break and relaxation exercises in the laboratory.

- ***Instructions:*** Having instructions in the lab ensures that what staff members do during a panic is fast and accurate. The PPL must have labeling instructions, waste instructions, cleaning instructions, and instructions for fire and emergency situations. ***Visual factory*** method should be used for this.
- ***Personal Protective and Equipment:*** The aprons that are used in the personal protective and equipment to be used in the laboratory and are used continuously will prevent the chemical spill on us. There should also be laboratory aprons for faculty members, and they should only be used in the laboratory. Gloves should definitely be used when working with irritant or corrosive substances. The mask should be used to avoid inhalation of ambient chemicals.
- ***Fire Tubes:*** The fire tubes should be placed in places that are easy to reach by making periodic checks and the materials should not be placed on them or around them. Fire tubes should be at shoulder level i.e., 90 cm above the ground. In addition, 1-kilogram fire tubes should be placed near the working benches. The situation should be corrected by applying ***kaizen*** method.
- ***First Aid:*** For important emergency interventions, the supply of missing materials in the medicine cabinet and the variety of materials should be increased. The situation should be corrected by applying kaizen before - after.
- ***Irregular Working Environment:*** Maintaining order in the working environment results in decreased work accidents due to snagging and falling, slipping, and falling and inattentiveness because of these. At the same time, disorder reduces productivity while causing chaos. Environment irregularity must be avoided by using the ***5S*** method.
- ***Laboratory Doors:*** By drawing the area where the laboratory doors are opened, it can be realized for the faculty and students that the need to be careful in these areas. The situation should be corrected by applying ***kaizen*** before - after.
- ***Furnace:*** For the furnace, the flue gas pipe must be installed and given out of the window.
- ***Fume Cupboards:*** The vacuum system of the fume cupboards should draw the gas phase well and regular checks should be made. The sliding doors of the draw cookers should be operated with the brake system, there should be no sudden discharges or falls. Sliding doors should reach the last point and there should be no matter escape from the environment. The covers of the fume cupboards must be opened upwards. Thus, the valve is opened to work, and the respiratory zone is closed so that the harmful effects of gases will not be exposed. Exhaust chimneys should be raised to prevent damage to the students and to ensure better extraction of the stoves.

IMPLEMENTATION OF SUGGESTIONS AND LEAN TECHNIQUES

At this stage, *5S* ([42]; [43]; [44], [45]), *Visual Factory* ([46]; [47]; [48]) and *Kaizen* ([49]; [50]; [51]) techniques were applied to realize the recommendations made in step five.

5S APPLICATIONS

As the first step in 5S technique applications, a “5S application team” was formed with faculty members and students doing research in the laboratory. The application area was examined, and the first case photos were taken. An action plan has been created that contains process steps; layout plans and existing status photos were created, and the process was provided to manage effectively by keeping a continuous record in the computer system.

Seiri - Sorting: At this stage, an inventory plan was created, and documentation has been made for the tools, materials and chemicals and the locations of these materials were determined in the PPL. Classification has been made for tools, equipment and chemicals that are frequently used, occasionally used, rarely used and never used, and unused materials have been completely removed from the laboratory. Very rarely used ones were temporarily stored in a cabinet in the laboratory. Materials that are used frequently and occasionally are left in the laboratory and made ready for the next application stages.

Weekly inspections were carried out in the laboratory to ensure the continuity of 5S studies.

Seiton - Set in order: In the PPL, there are chemicals used in research and experiments and tools, fume cupboards, measurement and analysis devices used for these test devices. The users of these devices and materials have been determined and they have been enabled to work more efficiently. Furthermore, potential hazards in the working environment were determined, to prevent the chemicals from reacting in each other and the formation of causes such as flammability, explosion and fire, the following applications were carried out by examining the safety data sheets handling and storage in detail ([52];[53]) and taking into account the warnings in Figure 3.

- ✓ labeled according to warning signs,
- ✓ surplus chemicals are placed in suitable storage racks,
- ✓ chemical wastes were placed in the solid waste and liquid waste areas with durable barrels and glass containers, thus preventing the accumulation of wastes in different areas around,
- ✓ ensure that chemicals stored in different containers or not labeled are kept in their original containers or suitable containers with labels,
- ✓ chemicals were purchased only as required, warehouse controls and movements were made to be easily monitored, emergency measures were taken,
- ✓ computer and device cables in an irregular and cluttered state that may cause tripping or electric shocks are gathered in cable ducts
- ✓ the materials placed randomly on the cabinet were placed inside the empty shelves or cabinets, thus the possibility of falling due to tipping or shaking was reduced to zero.
- ✓ the benches are free from clutter and irregularity and are positioned so that unnecessary materials are away from the countertops and near the most used materials.
- ✓ special tools and equipment used by the faculty members are placed on the shelves where they work.
- ✓ a space is reserved for common materials, unnecessary and less used materials are placed in a compartment of the cabinet and the interior doors of the cabinet are labeled.

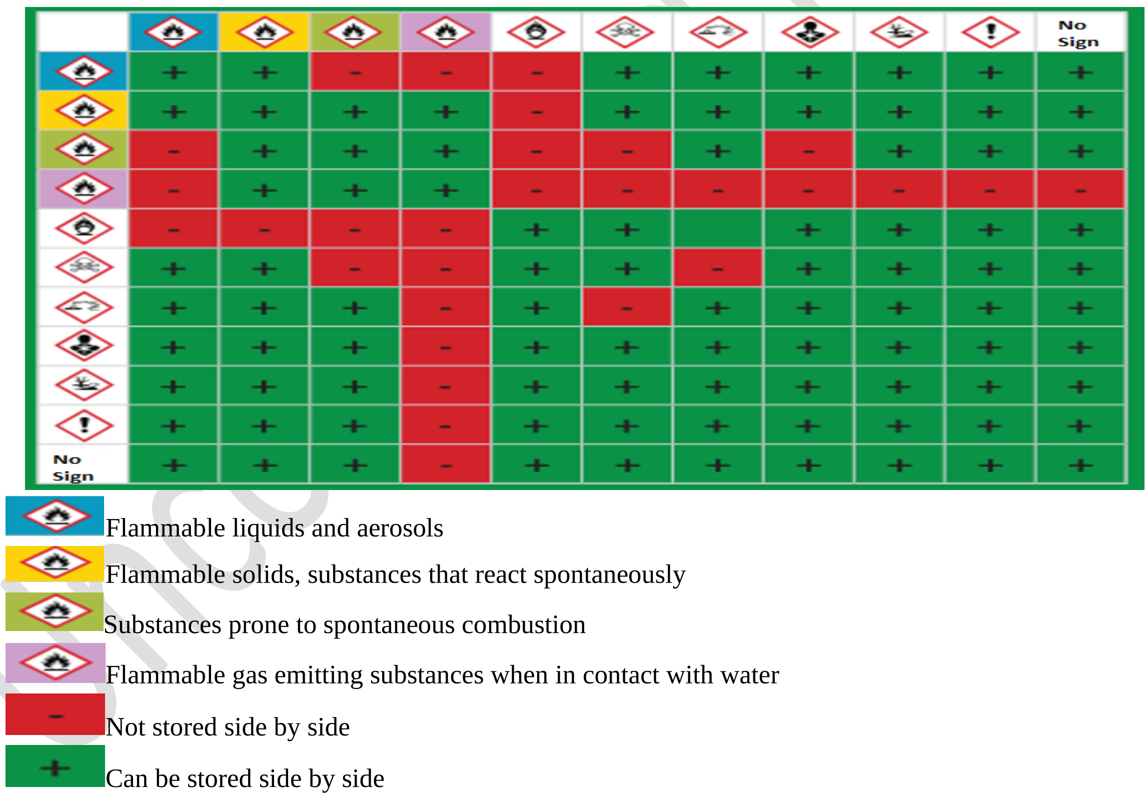


Figure 3. Storage classification of chemicals

Seiso - Shine: The aim at this stage is to increase productivity to the highest level by making the laboratory healthy, hygienic, clean, safe and suitable for working students and faculty members. In addition, cleaning activities reduce the formation of volatile components in the environment. Therefore, cleaning and control standards have been prepared and the continuity of the application has been ensured. The cleaning of the laboratory was carried out regularly and under the supervision of an academic member.

Seiketsu - Standardization: At this stage, the level of compliance with the changes made during the sorting, set-in-order and shining phases of the 5S application is checked. After the first 3S application, it is aimed to eliminate deficiencies in the 3S steps applied in this step where continuity is ensured. In the scope of the standardization phase, the order and arrangement provided, the continuity and the new deficiencies must be met without disturbing this order and arrangement by periodic checks. The return of unnecessary tools and equipment to the work

It was observed that the old habits of the faculty members and students working in the laboratory continued in the editing stages. Faculty members and working students were found to have problems adapting to the first 3S applications. The importance of achieving the goals of the 5S study, increasing continuity, and ensuring permanence in the phases were addressed by holding meetings in this respect.

Shitsuke-Sustain: The sustain phase is the most important step of the 5S and ensures continuity and efficiency of all applications. The sustain stage is of great importance for the effectiveness and motivations of the faculty members in 5S activities. In order to discipline 5S activities, continuity must be ensured, and strict controls must be carried out. Meetings were held to show the benefits of the studies and to remind the faculty members working in this respect. The meetings enabled them to continue their work consciously for 5S continuity and efficiency. At the same time, faculty members were asked for ideas on how to improve the activities and tried to develop an environment in which employees could control each other on the continuity of practices.

KAIZEN APPLICATIONS

Improvements have been made using "*before - after Kaizen in practice*" within the scope of Kaizen applications:

- ✓ pressure tubes are fixed to the wall, minimizing the risk of overturning and related explosions,
    - ✓ chemical wastes were collected in barrels instead of small bottles, and benefits were achieved in terms of space saving, work convenience, prevention of environmental problems and OHS,
    - ✓ by purchasing a special chemical refrigerator instead of a household type refrigerator, short circuit, flash-explosion and fire caused by the refrigerator were minimized,
    - ✓ instead of draining the nitrogen by tilting, filling the tank with the desired amount by attaching a tap has prevented the employees from non-ergonomic postures and reduced volatility,
    - ✓ ergonomics, ease of work and occupational health and safety are ensured by positioning fume cupboards in suitable places and opening glass doors upwards,
    - ✓ the fire tubes are located close to the places where there will be fire and explosion, and the small fire tubes are fixed to the counter tops, so emergency situations can be responded to in a short time.
    - ✓ other laboratories are used for measurement and analysis processes that are not in the PPL, and often fall and carelessness due to door slams occur. This situation was prevented by drawing warning lines.

The lighting problem could not be fixed throughout the operation. Kaizen examples are given in Table 6.

VISUAL FACTORY APPLICATIONS

Within the scope of **Visual Factory applications,** visual management has been implemented to improve the performance of lab employees and prevent them from falling into error, to increase the sense of belonging and motivation to work, and to make the workspace more comprehensible. The current state of the laboratory was analyzed, and the necessary visuals and instructions were determined.

Table 6. Kaizen studies for pressure tube and fume cupboard

Recommendation No / Date	**01**	**Recommendation No / Date**	**05**
Section	Pharmaceutical and Pharmacology Laboratory	**Section**	Pharmaceutical and Pharmacology Laboratory
Subject	Pressure tube	**Subject**	Fume Cupboard
Before Kaizen	**After Kaizen**	**Before Kaizen**	**After Kaizen**
Description: Overturning of pressure tubes by concussion	**Description:** Pressure tubes are fixed to the walls to prevent toppling.	**Description:** Non-ergonomic use of two fume cupboards opening of glass doors sideways	**Description:** Upward opening of ergonomic fume cupboard and glass doors
Sketches Diagrams Photos 	**Sketches Diagrams Photos** 	**Sketches Diagrams Photos** 	**Sketches Diagrams Photos** 
Gains	Occupational health and safety, Ease of work, Environmental improvement	Gains	Ergonomics, Ease of work, Occupational health and safety

Explanatory images and instructions for OHS care are prepared and hung on the walls (Figure 4a). Educational information on OHS issues was prepared and hung in the necessary places (Figure 4b). By labeling, cabinets and shelves containing chemicals are marked according to the danger of the chemical (Figure 4c). Suitable warning signs for waste and surplus chemicals are positioned (Figure 4d).

Posters providing information about laboratory safety and the effects of chemicals are hung in the required places as in Figure 4.

Instructions for quick and safe access to equipment and vehicles have been prepared. Thus, it was possible to speed up the workflow, reduce simple errors and make communication clear thanks to the visuals, graphics, charts and instructions placed in the workspace.

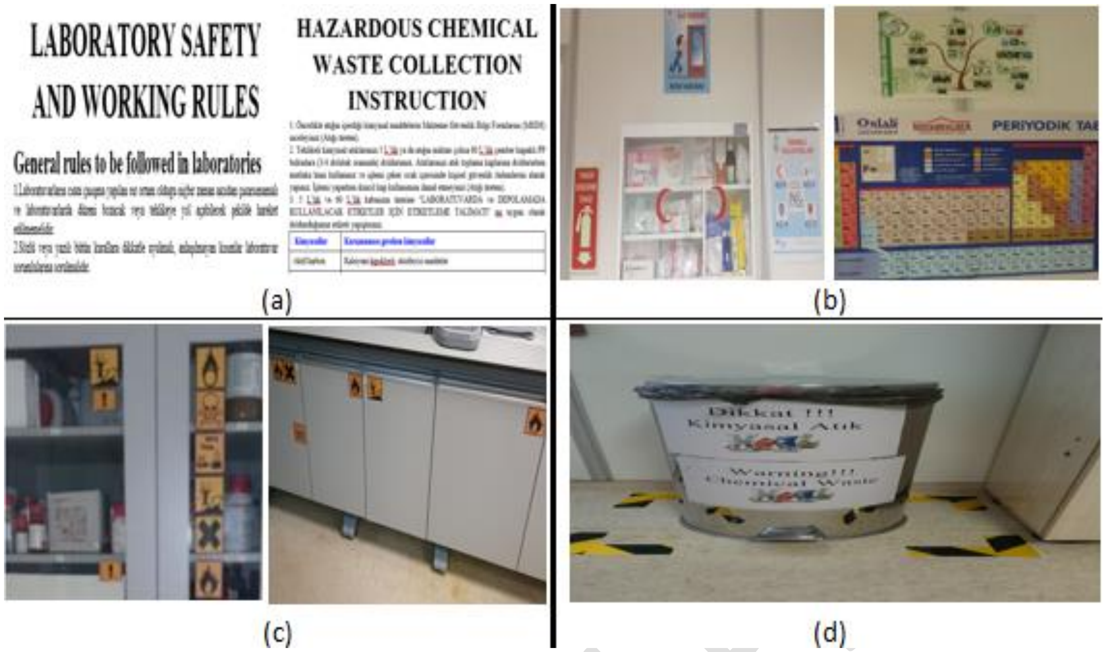
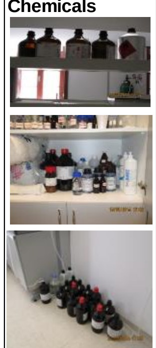


Figure 4. Visual factory

RISK ASSESSMENT OF THE NEW SITUATION

At this stage, risk assessment was made by comparing current risk scores (R) with after lean R. Table 7 shows one of these 20 risks and Figure 5 shows all risk scores before and after lean model. Apart from the two risks, 18 pieces of risk have been converted into acceptable risks.

Table 7. An example of risk assessment

NO	Hazard (Pictures are representative)	Activities	Current Result	Probability	Frequency	Consequence	R	Recommended Activities	After Lean Improvement Picture (If Available)	Probability	Frequency	Consequence	R
1	Storage of Chemicals 	Improper storage of chemicals in the laboratory, placing chemicals on high shelves without protection and storing them on the ground. These chemicals may fall over by tipping with a concussion or footstroke. This spill is likely to harm employees.	Work accident, poisoning, injury and death	3	2	40	240	Chemicals are grouped into their contents and hazard classes. The danger will be minimized by grouping with the 5S method.		0,5	2	40	40
: 20	:	:	:	:	:	:	:	:	:	:	:	:	:

.

In Figure 5, the risk number 10 is in lack of ventilation system and the risk number 19 is that the furnace flue gas is not a pipe system. The reason why risk number 10 does not change after the application of lean techniques is due to the lack of ventilation system in the university because it is a historical building. The furnace flue gas pipe system of risk number 19 could not be installed because it could not be grown during the running time.

Figure 5. Risk scores

For the results of chemical measurement, it was attempted to reduce the concentration of chemicals in the air by eliminating the problems of environment layout study, waste control, storage of chemicals. Chemical measurement was performed again after the application of lean techniques. According to the results of the chemical measurements, no chemicals were found except toluene, which was found in very small amounts. Thus, the decrease in the amount of chemical inhaled in the air reduced the chance of catching occupational disease, in other words exposure value, caused by chemicals.

STANDARDIZATION AND SUSTAINABILITY

Sustainability is essential for the seven steps that have been taken to this stage to remain efficient, continuous and lasting. The sustainability standard is the process of placement, supervision, and execution. You need to follow and follow the rules here. Standardization and sustainability are achieved by making improvements to the system habitually. As lean job security is a cyclical model, risks that have not been improved or whose planning has been delayed need to be analyzed again through the current situation, bypassing the step of standardization and sustainability. A safe environment is essential to achieve zero accidents. The safe environment, however, will take place with the conduct being maintained in accordance with the instructions and standardized by all.

CONCLUSION

Diseases contracted on the job and accidents that occur on the job continue to be two of the most significant issues facing modern civilizations. Every year, hundreds of thousands of employees experience occupational diseases or accidents as a direct result of the hazards that are now prevalent, the unfavorable conditions in the working environment, and the remedies that have not been implemented.

Today, occupational health and safety practices applied to overcome occupational diseases and occupational accidents have started to be secured by law. Within the framework of the Occupational Health and Safety Management System, risk analysis will be performed, gaps will be uncovered and addressed, and strategies to mitigate existing risks will be drafted. As a result, work-related injuries and illnesses can be mitigated, even if they cannot be eliminated entirely.

In this study, a lean Occupational Health and Safety model was created for the application of lean techniques within the scope of occupational health and safety by using The Pharmaceutical and Pharmacology Laboratory of Bezmialem Vakıf University Faculty of Pharmacy. The current state was analyzed, and problems were identified in the Pharmaceutical and Pharmacology Laboratory with the lean occupational health and safety model. Risk analysis was performed using the Fine Kinney method in order to determine the risk dimensions in the current situation. Risk groups were determined by risk analysis and a total of 20 risk groups were determined; 8 were high risk, 7 were significant risk and 5 were definite risk. In order to reduce the risk scores (R) in the current risk analysis, lean techniques were used to suggest solution and lower risk scores were obtained as a result of the new risk assessment performed in the laboratory. Thus, more suitable working conditions have been obtained and the environment has been made safer.

As a result of the satisfaction of faculty members using the laboratory from this improved environment, the Secretariat General has allocated a room for central storage, and the collection and distribution of chemicals has begun from this room. Furthermore, it has been decided that the proposed model will also be applied to other laboratories.

It is hoped that the lean occupational safety model proposed in this study will serve as a guideline for creating a safe environment in industry, education, and service sector, in laboratories and workplaces such as chemistry, pharmacy, biotechnology, dentistry, medical etc.

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