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A Retrospective Analysis of The Causes of Industrial Fires in Istanbul Occurring Between 2015 and 2020

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Abstract

This study was conducted to analyze the causes of industrial fires that occurred in Istanbul from 2015 to the first half of 2020. An official application was made to the Istanbul Metropolitan Municipality Fire Brigade Department, which has archive data on this subject, to conduct the research and a sample set was created by filtering industrial fires from the data pool obtained after the approval of the application. In the analysis phase of the 4600 industrial fire data reached, the distributions of the fires according to years, the intended use of the property where the fire took place, the cause of the fire and the district where the fire took place were examined using the Chi-square analysis method. SPSS 22 software package was used in the analysis and the level of significance was determined as 0.05. The examination of the results of the analysis indicated that the leading cause of industrial fires in Istanbul between 2015 and 2020 was electrical equipment with a rate of 44.8%. Electrical equipment was followed by hot work equipment, heating equipment, cigarettes, flammable and explosive chemicals, cooking equipment and arson, respectively. In the study, the reasons of the fires obtained as a result of the analysis of the data were examined, a comparison with the US industrial fire statistics was made and recommendations for improving data and preventing the recurrence of industrial fires were made. In addition, it was emphasized that robust statistics on the causes of fires played an important role in the development of fire prevention strategies and legislation.

Keywords: Analysis, Causes of fire, Industrial fires, Istanbul

1. INTRODUCTION

With the discovery of fire, the energy that emerged as a result of combustion to meet the most basic needs of humanity has begun to be used positively. Combustion is an “exothermic” reaction that results in the release of heat and light as a result of the combination of flammable material, oxygen and heat source at the right rate (Daéid, 2004). With this reaction, many needs, such as cooking food, heating, lighting and transportation, are met. The resulting combustion reaction is beneficial for living things and the environment provided that it occurs in a controlled manner, but when it is uncontrolled, it is called fire and poses a serious danger to humans and environmental health (Şengöz, 2018).

With the rapid development of science and technology, industrial facilities that produce products from raw materials have started to use more chemicals, electrical equipment and hot work

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equipment and fires and explosions have occurred as a result of activities carried out without taking precautions. While the development of technology makes human life easier, the wrong or unconcious use of the same technology leads to various disasters (Çelik et al., 2020).

Industrial fires and explosions cause intense leakage and release of chemicals. Therefore, it affects not only the fire setting but also the surrounding area. Toxic and asphyxiant gases, which are released depending on the type of burning substance, can cause people living in the region to develop chronic diseases in the long term and also result in soil and water pollution (URL 1).

On July 10, 1976, an explosion occurred in a TCP reactor (trichlorophenol) in the Italian town of Seveso, and a white gas cloud spread into the environment. The name of this poisonous gas is "dioxin". Following the explosion, some casualties, including first animal deaths, then human deaths, severe skin burns, and later great risks for cancer cases, began to be seen in the town. After this grave accident, the European Commission published some directives to prevent accidents and reduce their consequences, and they were named "Seveso Directives." Although directives and guidelines have been updated and additional measures have been taken, major accidents continue to occur today (Vesilind et al., 2010).

The Emergencies Database (EMDAT), which consists of records that have been kept by the Center for Research on Epidemiology of Disasters (CRED) at the Catholique de Louvain University (Belgium) since 1988, is one of the most comprehensive data sources on technological and natural disasters. This research center is also supported by the US Office of U.S. Foreign Disaster Assistance (OFDA). A disaster must meet at least one of the four criteria below so that it can be included in the EM-DAT database.

- A death toll of 10 or more,
- 100 or more casualties,
- Emergency declaration,
- International call for help (Girgin and Yetiş, 2007).

Many fire and explosion incidents that meet these criteria have occurred in our country. The accident with the highest loss occurred in the Soma district of Manisa province on May 13, 2014. A total of 301 people lost their lives in the fire that broke out in the coal mine. The incident was recorded as the deadliest mining disaster in the Republic of Türkiye (URL 2).

According to the 2022 report of the UCTEA Chamber of Chemical Engineers Istanbul Branch, industrial fires and explosions mainly occurred in the "metal," "textile," "wood, paper, furniture," and "rubber and plastic" sectors. At least 73% of all fires and explosions occurred in these four sectors. According to the data in the report, of the industrial fires in Türkiye, 50.6% occurred in the Marmara Region and 28.8% in the Aegean region, with the majority of the fires in the Marmara region occurring in Istanbul (URL 3).

Therefore, studies to be conducted on the causes of industrial fires in Istanbul province and the implementation of the measures to be taken as a result of the accurate evaluation of the data will significantly affect the fire graph of Türkiye.

In a study published in August 2014, the factors that caused fires in industrial enterprises in Kocaeli province between 2005 and 2011 were examined and a total of 1,177 fire cases were analyzed. As a result of the research, it was stated that experts were commisioned to determine the causes of fires that could not be identified by the fire brigade, and the results found by the experts were not delivered to the archive department of the fire brigade directorate. As a result of the study, it was stated that healthy data on the causes of industrial fires could not be reached (Genc and Pekey, 2014).

In this context, with this study that was carried out using 4,600 data in which the causes of fires were determined, it is thought that the measures to be taken against the causes of industrial fires can be increased and the fires that are likely to occur in the future can be reduced.

In addition, increasing the control mechanisms and sanctions by public institutions and organizations and complying with the suggestions and recommendations of employer and worker organizations, universities, and professional organizations is very important for the solution of the problem.

The materials and structural elements used in a building turn into fuel in a fire. Knowing the chemicals used in production, complying with safety measures and storage conditions, and taking fire safety measures as required by laws, regulations, and standards during the design phase of a building is vital for the environment and human health (Kök, 2020).

2. FIRE SAFETY LEGISLATION IN TÜRKİYE

2.1. Regulation on Fire Protection of Buildings

The first regulation issued on a large scale in Türkiye regarding protection from fire and its effects was the "Istanbul Municipality Fire Protection Regulation" published in 1992. This regulation applied only to the province of Istanbul and was implemented only by the Istanbul Municipality. Later, similar regulation research studies were also conducted by Izmir, Bursa, Antalya, and Mersin Municipalities. However, different regulations issued and implemented by metropolitan municipalities caused some confusion. There was no legislation on fire safety measures in the provinces and districts outside the metropolitan borders.

The first large-scale regulation prepared with the participation of many non-governmental organizations, fire departments, universities, and professional chambers under the coordination of the "General Directorate of Civil Defense" is the "Regulation on Fire Protection of Buildings", which was published and came into force in 2002 to eliminate the shortcomings, solve different implementation problems between municipalities, guide business owners, minimize the loss of property and life that may occur as a result of fires, and ensure that the measures are taken correctly and adequately (URL 4).

As with all laws and regulations, this regulation also changed and developed over time and was published in the Official Gazette (date: December 19, 2007 and number: 26735) and took its place in the legislation as the "Regulation on the Protection of Buildings from Fire." The regulation is still up to date, with occasional amendments (BYKHY, 2007).

2.2. Some Laws and Regulations Harmonizing Seveso and EU Directives with the Legislation of Our Country Enacted to Prevent Industrial Accidents

2.2.1. Occupational Health and Safety Law

The "Occupational Health and Safety Law," numbered 6331, which came into force on June 30, 2012, is an important law that has caused working life in Türkiye to enter a new era. Previously, the concept of occupational safety, which was regulated by the "Labor Law No. 4857" and its relevant regulations, had an incoherent structure. With the "Occupational Health and Safety Law", occupational safety legislation has been gathered under a single roof. Health and safety conditions in workplaces have now become a concept that covers all employees. The new approach emphasizes that employers should have their employees work under effective cooperation and take holistic protection measures to prevent accidents in the workplace (Occupational Health and Safety Law, 2012).

2.2.2. Regulation on Preventing Major Industrial Accidents and Reducing Their Effects

This regulation has taken its current form with the repeal of the "Regulation on the Control of Major Industrial Accidents" published in 2010 and the "Regulation on the Prevention and Reduction of the Effects of Major Industrial Accidents" published in 2013. It is referred to as BEKRA, its abbreviated name.

Facilities and businesses within the scope of this regulation are responsible for preventing industrial accidents, in the event of a major accident, limiting the effects of the accident in a way that will cause the least harm to human and environmental health, and taking all necessary precautions. According to the regulation, business owners have a lot of obligations based on the hazardousness rate of the business (BEKRA, 2019).

2.2.3. Regulation on Classification, Labeling and Packaging of Substances and Mixtures

This is the most up-to-date regulation today, which includes provisions on the labeling, packaging, classification of substances and mixtures, and inventory reporting of harmful substances and mixtures to be introduced to the market.

With the updates, the 15 hazardous classes were increased to 28 in this regulation, and the term “harmful classes” was introduced instead of hazard classes. The term “preparation” used in the previous regulation was replaced by the term “mixture”, and hazard signs and pictograms were replaced by “signs of harm.”

In addition to the classifications of explosives, including flammable solids, liquids, gases, and aerosols and oxidizing solids, liquids, and gases; gases under pressure, self-reactive substances and mixtures, self-heating substances and mixtures, pyrophoric liquids and solids, substances and mixtures in contact with water, organic peroxides, and corrosives for metals have been added (URL 5).

2.2.4. Regulation on the Protection of Employees from the Dangers of Explosive Environments

ATEX 137 directive 99/92/EC is known as the compliance regulation. With this regulation, employers have been given obligations to determine explosion and fire risks in workplaces, prevent the formation of explosive atmospheres, classify places likely to have explosive atmospheres, and provide special safety requirements for the workplace and work equipment (Regulation on the Protection of Employees from the Dangers of Explosive Environments, 2013).

2.2.5. Regulation on Equipment and Protective Systems Used in Potentially Explosive Environments

ATEX 100a Directive 94/9/EC is known as the compliance regulation. This regulation gives employers the obligation to create zones according to the explosion protection document and then to carry out control and maintenance procedures by designing appropriate equipment and machinery within the scope of the legislation (Regulation on Equipment and Protective Systems Used in Potentially Explosive Environments, 2016).

2.2.6. Other Regulations

Apart from the above-mentioned legislation, ensuring fire safety is indirectly included in many other regulations. For example, for a business to open and operate, it must have a workplace license. To obtain a workplace license, the business owner must fulfill the provisions of the "Regulation on Business Opening and Operating Licenses Numbered 2005/9207."
In addition, the production, storage, sale, use, recovery, transportation, and disposal of harmful chemicals are subject to certain rules in accordance with the "Environmental Law Number 2872"

and its relevant regulations. Fulfilling these obligations also contributes to fire legislation (Environmental Law, 1983).

3. MAIN CAUSES OF INDUSTRIAL FIRES AND EXPLOSIONS AND MEASURES

In order to prevent fires and explosions, it is very important to identify the sources of fire. Most fires and explosions can be prevented with the occupational safety measures to be taken by experts in the field of fire sources by applying scientific methods.

3.1. Combustible Dusts

In most industrial facilities, solid flammable and explosive dust is used under certain conditions. This dust presents a fire or explosion hazard when ignited in an atmosphere or oxidizing environment.

Weber, the first researcher who was interested in dust explosions, focused on the cohesion (molecule attraction force) and diffusion phenomena between dust particles in a study he conducted in 1878 and analyzed the explosion and combustion of wheat flour particles (Ergül, 2012).

Often overlooked and extremely deadly, combustible dust is one of the causes of fire in food manufacturing, woodworking, chemical manufacturing, metalworking, pharmaceuticals and almost in every industry that we can name. Controlling dust explosions is not easy. In a typical case, combustible material comes into contact with an ignition source, causing a small fire. In this case, if there is dust in the area, the result can be much worse. The primary explosion causes this dust to remain in the air. The dust cloud can then ignite, causing a secondary explosion that can be many times the size and intensity of the primary explosion. If enough dust has accumulated, these secondary explosions have the potential to collapse the entire facility. For this reason, it is very important to prevent the accumulation of these substances that can cause flameless combustion in places where dust masses are abundant (Önder, 1999).

Examples of explosions in the US resulting from flameless combustion, whose research was concluded and recorded in the literature, include the barley powder explosion in June 1987, the methane and coal dust mixture explosion in the coal silo in April 1981 and the corn silo explosion in 2017(Serçe, 2006).

Although it is difficult to completely eliminate dust to prevent dust explosions, dust collection units and appropriate ventilation systems should be installed in workplaces and regular cleaning and maintenance should be done so that dust can be prevented from reaching a dangerous level.

3.2. Hot Work

While hot work is often associated with welding and torch cutting, it also includes many other activities, including burning, heating and soldering, which pose a fire hazard. Hot work is also a major problem with combustible dust fires, as sparks from the work can also ignite surrounding areas. In one case in North Carolina, three contract welders were severely burned when the wood dust in the silo was ignited by welding sparks. At the end of the investigation, it was determined that before the work started in the silo, hot work was started without removing the dust and that there was no fire protection and prevention plan (URL 6).Welding generates excessive heat and the main danger comes from intense heat near the arc, sparks and spatters. These spatters can reach up to about 10 meters from the welding area.

Explosive and flammable chemicals must be at least 11 meters away from places where open flame and welding works are conducted. Fire extinguishers should be kept ready at all times during welding and hot work procedures should be applied (Turan, 2015).

To prevent such accidents, alternative methods should be considered instead of the hot work method if possible. If welding is to be done, it should be ensured that the area is free of flammable or combustible materials including dust, liquids and gases. Internal audits by occupational safety experts and external audits by state authorities should be carried out. In addition, the employee dealing with hot work should have professional competence and should not be allowed to start working without wearing appropriate personal protective equipment.

3.3. Harmful Chemicals

Recognizing flammable materials and knowing their properties can help us prevent disasters. It is the employer's duty to know, report and take precautions about the harms, dangers and storage conditions of chemicals used in all workplaces, their risks of fire and what to do in case of a possible accident.

The "regulation on classification, labeling and packaging of substances and mixtures" classified substances in terms of their physical hazards as follows (URL 5).

- Explosives
- Flammable gases and aerosols
- Flammable liquids and solids
- Gases, liquids and solids with oxidizing properties
- Gases under pressure
- Substances and mixtures that has a tendency to spontaneous reaction
- Substances and mixtures with self-heating properties
- Liquids and solids with pyrophoric properties
- Substances and mixtures capable of reacting with water
- Organic peroxides
- Abrasives for metals

The common rule in the use and storage of all chemical substances is to work with an awareness of the dangers of chemicals. Information about the hazards is written in the material safety data sheet (MSDS) that comes with products. Risk analyses, emergency action plans, environment measurements and employee training should be done at regular intervals, equipment and installation maintenance should not be delayed, fire precautions should be taken and employees should not be allowed to work without wearing personal protective equipment.

3.4. Equipment and Machines

Faulty equipment and machinery are also major causes of industrial fires. Heating and hot work equipment is typically the biggest issue here. In particular, furnaces that are not properly installed, operated and maintained are a source of fire hazards (URL 7). In addition, any mechanical equipment can pose a fire hazard due to the friction between its moving parts. This risk can be practically eliminated by following recommended cleaning and maintenance procedures, including lubrication. Even seemingly harmless equipment can be dangerous under improper conditions. In many cases, equipment that is least likely to be considered a fire risk can turn out to be the biggest problem when companies do not recognize the risk and take appropriate steps. Risks that you do not know exist cannot be prevented and employees cannot prevent them. Employees should be given safety awareness education on working with equipment. The equipment and the area around the machines must be kept clean. Especially electrical equipment covered with dirt or grease poses a great risk. The manufacturer's recommended maintenance procedures should be followed for all equipment and machinery. By preventing overheating, the risk of fire should be reduced and the equipment should be operated in the best condition with regular maintenance (URL 6).

3.5. Electrical Hazards

Electricity is one of the most important inventions in human history. In addition to the benefits it provides for human life, it is clear that it can cause great harm, even death if necessary care is not paid (Efeoglu et al., 2006).The most common electrical accidents include electric shock and fire.[15] Electricity is one of the most common causes of fire in the world and our country. An important feature of electrical fires is that they develop very suddenly. For example, electrical panel fires happen and rise to an incredible temperature very quickly.

Electrical fires have four main causes. These are overload, insulation, lack of planned maintenance and metallic failures (Kır et al., 2019).

Equipment, where electrical fires are most common, includes transformers, panels, motors and cables. Electrical energy is the igniter side that starts the fire. At least 60 watts of power, 5 joules of energy and 0.3 amperes of current are needed for electric current to cause a fire. In a 220 volt faulty system, the fire start time of electrical energy was calculated as 83 milliseconds (Kır et al., 2019).

Detecting the faulty current caused by insulation faults and ensuring that the circuit is cut immediately if the leakage current value exceeds the specified value is done with fire protection relays or leakage current relays.

As a result of the experiments, it has been understood that a leakage current of 300 mA can cause fire by bringing the surrounding materials to the ignition temperature in a short time. In fire protection, the residual current relay value is 300 mA (URL 8). Additional protection is required against the danger of direct contact with the basic protection relays that must be placed to protect the installation from fire. To prevent electrical hazards, a mechanism of 30 mA for humans and 300 mA for installation should be set up (Paker, 2017).

The key to preventing electrical fires is awareness, supervision and control. In addition, the precautions given below must be followed.

1. Circuits must not be overloaded (Kaya and Kaya, 2019).
2. In multi-story buildings, electrical cables are distributed from shafts to floors. A fire that occurs at the exit of the panel, which may occur in the basement, can spread to the whole building with the cables in the shaft. The airflow in the shaft also causes the fire to grow. For this reason, plugs with fire-preventing or retarding insulating materials should be applied to the floor passages of the shafts (URL 9).
3. Cables should be selected from flame-retardant material.
4. The joints of the cables must be well insulated and the cable cross-sections must be chosen appropriately.
5. Temporary equipment should not be left plugged in when not in use.
6. The use of extension cables should be avoided.
7. Where necessary, antistatic equipment should be used.
8. Circuit breaker currents must be selected appropriately.
9. Grounding must be appropriate.
10. Residual current relays and arc fault detection devices should be used(URL 8).
11. Panel covers must provide adequate insulation. At least one-meter circumference of the electrical panel, its projection and top must be free of flammable material(URL 9).
12. When necessary, ex-proof electrical equipment should be selected.
13. Smoke detection systems and automatic fire extinguishing systems should be installed in transformers and electrical panels.
14. There should be a regular cleaning plan to remove combustible dust and other hazardous materials from areas where equipment and machinery are located.
15. There should be an expert regularly observing and controlling electrical fire risks.

16. The proper functioning of electrical and grounding installations must be approved by authorized institutions or organizations.

As a result, while taking fire protection and prevention measures, experience, knowledge, education and compliance with the legislation and National/International standards are the issues that should be given importance.

4.MATERIALS AND METHODS

4.1. Material Supply

An official application was made to the Istanbul Metropolitan Municipality Fire Brigade Department, which has a department that archives the causes of fires, prepares fire reports and has statistical data on fires, to conduct this research on the causes of industrial fires in Istanbul province, where most of fires have occurred in Türkiye. Upon the approval of the application petition, the data of 4600 industrial fires that took place in Istanbul, starting from 2015 to the first 6 months of 2020 were obtained from the Istanbul Metropolitan Municipality Fire Brigade Department in a Microsoft Excel file.

4.2. Evaluation of Istanbul Fire Brigade

The evaluation of the 2020 statistical report of the Istanbul Metropolitan Municipality Fire Brigade Department indicated the following results:

Staff capacity: There were 4281 employees working within the IMM Fire Department as of 2020 and 361 volunteer firefighters at 27 volunteer fire stations assisted these employees.

Vehicle capacity: There were a total of 860 vehicles, including 49 ambulances, 358 fire engines, 158 rescue vehicles, 260 support vehicles and 35 featured vehicles within the body of the IMM Fire Brigade Department as of 2020.

The number of stations: There were a total of 124 stations in the Istanbul Fire Department, including 97 professional and 27 volunteer stations and fire and ambulance services were carried out together in 35 stations.

Fire response time: According to the 2019 data, the Istanbul Fire Department responds to fires within 5.38 minutes (URL 10).

4.3. Methods

4.3.1. Data Filtering

During the collection of data, the data pool consisting of all fires in Istanbul was examined and the data were filtered in two stages.

In the first stage, filtering was done to cover years from 2015 to the first 6 months of 2020.
In the second stage, it was done to elicit industrial fires by choosing the following facilities:

- Workshops
- Energy generation plants
- Factories
- Gas plants
- Food processing facilities
- Manufacturing facilities
- Business centers
- Office blocks
- Carpentry shops

4.3.2. Grouping of the Data

The reasons identified and reported as the causes of 4600 industrial fires were grouped so that we could compare them with the results of a literature review and make them easier to understand.

Electrical equipment: Sources, such as cables, transformers, group sockets, searchlights, electrical panels and electrical installations, which were evaluated as the cause of fires, were grouped under this title.

Heating equipment: Sources, such as chimneys, stoves, ovens, fryers, water heaters and stoves, which were seen as the cause of fires, were grouped under this title.

Hot work equipment: Equipment that creates overheating and sparks due to welding and cutting processes, which were seen as the cause of fires, were grouped under this title.

Cooking equipment: Equipment, such as aspirators and hoods, which were seen as the cause of fires, were grouped under this title.

Flammable and explosive chemicals: All flammable, explosive and chemical materials, including fuel oil, other petroleum-derived fuels, and LPG, that caused fires were grouped under this heading.

Unclassified causes: Incidents such as fires started accidentally by children and overturned candles were grouped under this heading.

Natural events: Natural events such as lightning strikes and earthquakes were grouped under this title.

The causes of industrial fires were examined under 10 headings, including those caused by cigarettes, arson and undetected ones.

4.3.3. Data Analysis

After all fire data were filtered, frequency and percentage analyses of the data set consisting of 4600 industrial fires were performed. At this stage, the distribution of industrial fires by years, the intended use of the facility where the fire took place, the source of the fire and the district of the facility where the fire took place were examined. Then, the chi-square analysis method was applied to determine whether industrial fires differed according to the year when the fire occurred, the intended use of the facility and the source of the fire. The analyses were conducted on the SPSS 22 software package and the level of significance was determined as 0.05.

5. RESULTS

5.1. Findings of Industrial Fires

Table 1 shows the distribution of industrial fires by year. Although the number of fires by year was found to be close to each other, the maximum number of fires took place in 2015 (19.2%) and the minimum number of fires occurred in the first half of 2020 (8.7%).

Table 1. Distribution of industrial fires by year

		f	%
Year	2015	882	19.2
	2016	833	18.1
	2017	873	19.0
	2018	783	17.0
	2019	827	18.0
	The first half of 2020	402	8.7
	Total	4600	100.0

Table 2 shows the distribution of the causes of industrial fires. The most common cause of industrial fires was found to be electrical equipment with 44.8%. It was seen that the least common causes were natural events with 0.0004% and unclassified events such as accidental fires caused by children and overturned candles with 0.1%. The source of 4.2% of the fires had not been determined.

Table 2. Distribution of the causes of industrial fires

		f	%
Causes	Natural events	2	.0
	Electrical equipment	2059	44.8
	Heating equipment	681	14.8
	Arson	49	1.1
	Hot work equipment	823	17.9
	Cigarettes	487	10.6
	Flammable and explosive chemicals	246	5.3
	Cooking equipment	58	1.3
	Unclassified	4	.1
	Undetected	191	4.2

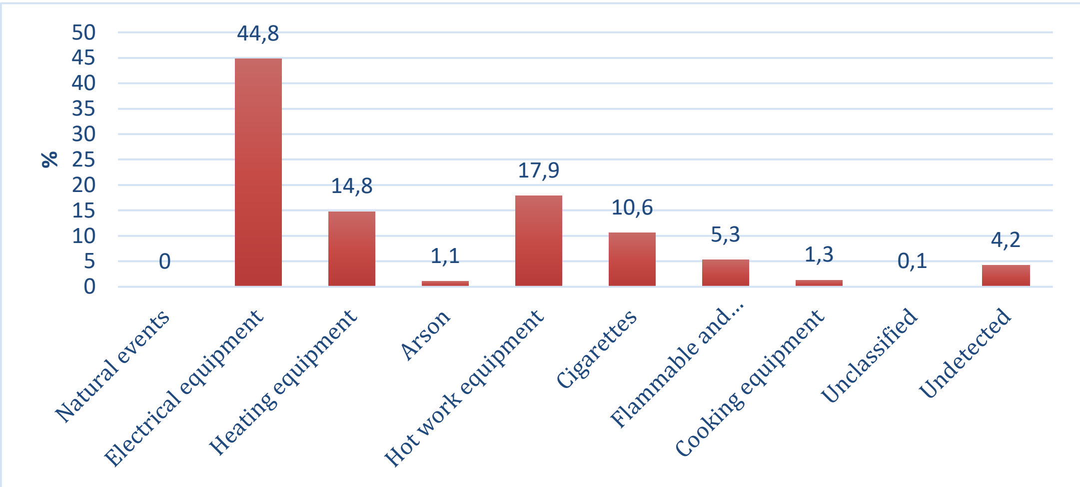

Figure 1. The percentage distribution of the causes of industrial fires

Table 3 shows the distribution of facilities where general industrial fires occurred according to their intended use. It was found that most fires occurred in workshops with 26.3%, manufacturing facilities with 23% and factories with 19.8%. The least number of fires were seen in gas plants with 0.0004%, energy generation plants with 0.2% and food processing facilities with 0.5%. This distribution suggests that gas, energy, and food processing plants have higher fire prevention levels than workshops and factories.

Table 4 presents the chi-square analysis and comparison of the variables of year and intended use of industrial facilities where fires took place. As a result of the analysis, it was found that there was a significant difference between the year of the fires and the intended use of industrial facilities where the fires occurred ($\chi 2(40) = 62.218$, $p<.05$).

The examination of the percentages obtained indicated that the majority of the fires occurred in "workshops," which was followed by "manufacturing facilities" in 2015, 2016, 2017 and 2018, while most of the fires in 2019 and 2020 took place in "manufacturing facilities" and "workshops."

Table 3. Distribution of facilities where industrial fires were seen according to their intended use

		f	%
Intended use of the facility	Workshop	1212	26.3
	Energy generation plant	7	.2
	Factory	911	19.8
	Gas plant	2	.0
	Food processing facility	23	.5
	Manufacturing facility	1056	23.0
	Business center	620	13.5
	Office blocks	545	11.8
	Carpentry shop	224	4.9

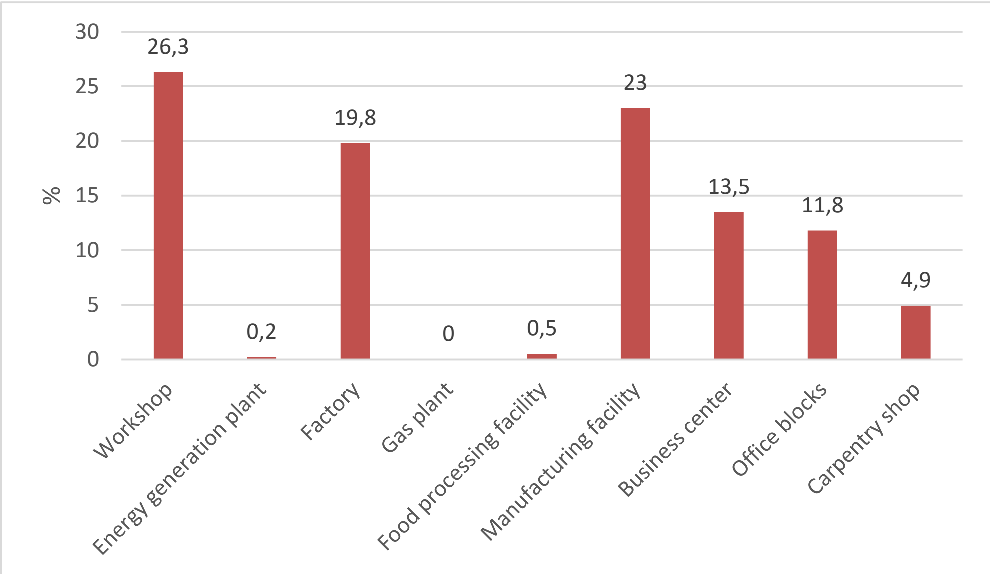

Figure 2. Distribution of facilities where industrial fires were seen according to their intended use

Table 6 shows the chi-square analysis for the comparison of the causes of industrial fires and the intended use of the facilities. As a result of the analysis, it was found that there was a significant difference between the industrial fires and the intended use of the facilities in terms of the causes of the fires ($\chi2(72)=375.009$, $p<.001$).

The examination of percentages obtained indicated that the majority of fires in all facilities were caused by electrical equipment, which was followed by heating equipment and hot work equipment. While cigarette-induced fires were often observed in workshops, office buildings, manufacturing facilities, business centers and factories, it was not encountered in power generation plants, gas plants and food processing facilities. This finding suggests that organizational measures are taken more seriously in power generations and gas and food processing facilities and that such workplaces are more strictly inspected by competent authorities. Fires caused by arson mostly occurred in workshops, factories and manufacturing facilities.

Table 4. Comparison of the year of the industrial fires and the intended use of facilities

Intended use of facilities		Year					
		2015	2016	2017	2018	2019	2020
Workshop	f	260	243	241	190	179	99
	%	29.5	29.2	27.6	24.3	21.6	24.6
Energy generation plant	f	3	3	1	0	0	0
	%	.3	.4	.1	0.0	0.0	0.0
Factory	f	157	155	171	171	189	68
	%	17.8	18.6	19.6	21.8	22.9	16.9
Gas plant	f	0	0	0	2	0	0
	%	0.0	0.0	0.0	.3	0.0	0.0
Food processing facility	f	4	2	6	5	4	2
	%	.5	.2	.7	.6	.5	.5
Manufacturing facility	f	205	179	184	184	203	101
	%	23.2	21.5	21.1	23.5	24.5	25.1
Business center	f	105	113	114	102	127	59
	%	11.9	13.6	13.1	13.0	15.4	14.7
Office blocks	f	109	92	109	94	96	45
	%	12.4	11.0	12.5	12.0	11.6	11.2
Carpentry shop	f	39	46	47	35	29	28
	%	4.4	5.5	5.4	4.5	3.5	7.0

Table 5 shows the chi-square analysis conducted to compare the causes of industrial fires by year. As a result of the analysis, there was no significant difference between the year of the industrial fires and their causes ($\chi2(45)=49.485$, $p>.05$).

Table 5. Comparison of the causes of industrial fires by year

Causes of the fires		Year					
		2015	2016	2017	2018	2019	2020
Natural events	f	0	0	0	1	1	0
	%	0.0	0.0	0.0	.1	.1	0.0
Electrical equipment	f	394	377	408	341	362	177
	%	44.7	45.3	46.7	43.6	43.8	44.0
Heating equipment	f	135	131	122	112	125	56
	%	15.3	15.7	14.0	14.3	15.1	13.9
Arson	f	8	12	7	10	11	1
	%	.9	1.4	.8	1.3	1.3	.2
Hot work equipment	f	161	128	156	149	143	86
	%	18.3	15.4	17.9	19.0	17.3	21.4
Unclassified	f	2	0	1	1	0	0
	%	.2	0.0	.1	.1	0.0	0.0
Cigarettes	f	92	90	92	95	82	36
	%	10.4	10.8	10.5	12.1	9.9	9.0
Undetected	f	37	34	29	24	46	21
	%	4.2	4.1	3.3	3.1	5.6	5.2
Flammable and explosive chemicals	f	41	47	53	45	39	21
	%	4.6	5.6	6.1	5.7	4.7	5.2
Cooking equipment	f	12	14	5	5	18	4
	%	1.4	1.7	.6	.6	2.2	1.0
Total	f	882	833	873	783	827	402
	%	100.0	100.0	100.0	100.0	100.0	100.0

Table 6. Comparison of the causes of industrial fires and the intended use of facilities where the fires occurred

Causes of the fires		Intended use of facilities								
		Workshop	Energy generation plant	Factory	Gas plant	Food processing facility	Manufacturig facility	Business center	Office blocks	Carpentry shop
Natural events	f	0	0	1	0	0	0	0	1	0
	%	0.0	0.0	.1	0.0	0.0	0.0	0.0	.2	0.0
Electrical equipment	f	561	3	304	1	12	476	350	285	67
	%	46.3	42.9	33.4	50.0	52.2	45.1	56.5	52.3	29.9
Heating equipment	f	190	0	143	0	6	167	72	67	36
	%	15.7	0.0	15.7	0.0	26.1	15.8	11.6	12.3	16.1
Arson	f	16	0	13	0	0	11	5	3	1
	%	1.3	0.0	1.4	0.0	0.0	1.0	.8	.6	.4
Hotworkequipment	f	190	4	247	1	2	202	80	63	34
	%	15.7	57.1	27.1	50.0	8.7	19.1	12.9	11.6	15.2
Unclassified	f	2	0	0	0	0	0	1	1	0
	%	.2	0.0	0.0	0.0	0.0	0.0	.2	.2	0.0
Cigarettes	f	124	0	57	0	0	80	72	90	64
	%	10.2	0.0	6.3	0.0	0.0	7.6	11.6	16.5	28.6
Undetected	f	47	0	62	0	2	42	14	8	16
	%	3.9	0.0	6.8	0.0	8.7	4.0	2.3	1.5	7.1
Flammable and explosive chemicals	f	69	0	75	0	0	67	21	12	2
	%	5.7	0.0	8.2	0.0	0.0	6.3	3.4	2.2	.9
Cooking equipment	f	13	0	9	0	1	11	5	15	4
	%	1.1	0.0	1.0	0.0	4.3	1.0	.8	2.8	1.8

6. DISCUSSION

When the distribution of the causes of 4600 industrial fires was examined, it was determined that they were mostly caused by electrical equipment with 44.8%. The high rate of fires caused by electrical equipment may be due to the increase in the number of electrical machinery and equipment used in workplaces every other day, the wear of the installations over time, negligence of business owners for replacement of the worn installations, lack of periodic controls of the electrical installations once a year despite the laws and regulations and the lack of knowledge of business owners.

Istanbul province involves a large part of the Turkish economy and industrial business. In this context, reaching healthy data about the province of Istanbul in thisstudy shows that Istanbul Metropolitan Municipality Fire Brigade Department keeps fire data regularly and in detail.

According to the report published by NFPA on industrial fires in 2018, approximately 37,910 industrial facility and workshop fires occurred in the United States between 2011 and 2015 and 26,730 were unclassified fires in outdoor areas, 7,770 were building fires and 3,410 involved vehicles. In this report, the causes of industrial fires in buildings in the USA during the period of 2011-2015 were classified under 6 categories as follows: electrical equipment, heating equipment, intentional (arson), cooking equipment, hot work equipment and exposure fire. The percentages of the classification of the causes are shown in Figure 3(NFPA, 2018).

The comparison of the causes of industrial fires in Istanbul with the US data indicated that electrical equipment was the leading source of the fires in both locations (Figure 3-4).

The examination of the distribution of industrial fires in Istanbul according to the intended use of facilities showed a significant difference. It was seen that the majority of the fires occurred in workshops with 26.3%, manufacturing facilities with 23% and factories with 19.8%. On the other hand, the minimum number of fires was found to occurin gas plants with 0.0004%, energy generation plants with 0.2% and food processing facilities with 0.5%. This distribution suggested that the fire prevention levels of gas, energy and food processing facilities were higher than those of workshops, manufacturing facilities and factories.

It was determined that cigarette-induced fires were seen in workshops, office buildings, manufacturing facilities, business centers and factories, while they were not encountered in power generation plants, gas plants and food processing facilities. This finding suggests that organizational measures are taken more seriously in energy generation plants, gas plants and food processing facilities and that more stringent inspections are carried out by authorities.

It was found that industrial fires caused by arson occurred in very few numbers with a rate of 1.1%. This low rate suggests that there may be fires caused by arson among fires of unknown origin that have a rate of 4.2%.

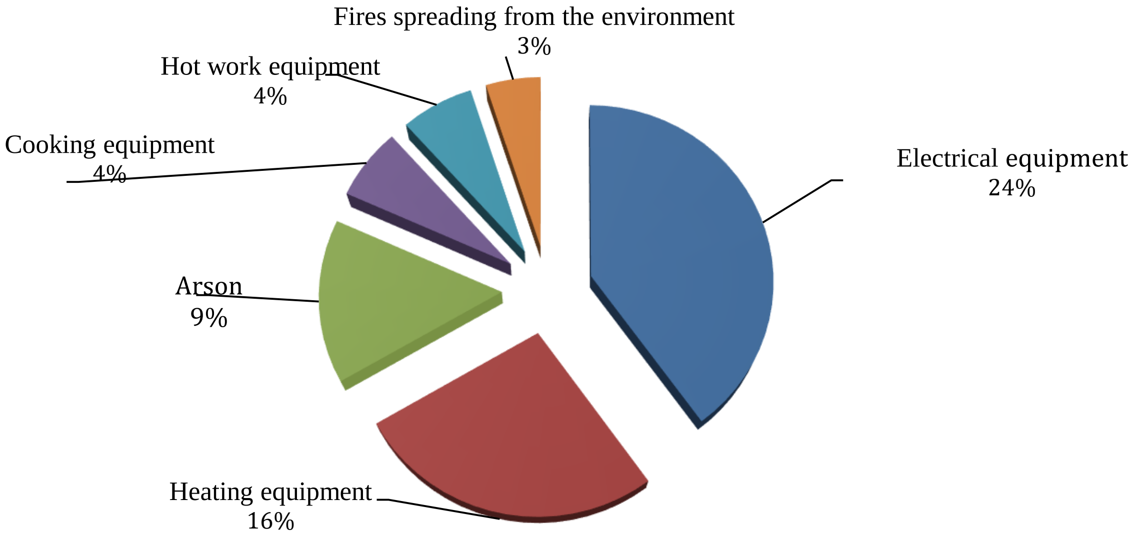

Figure 3. Causes of industrial fires (The USA 2015-2020)

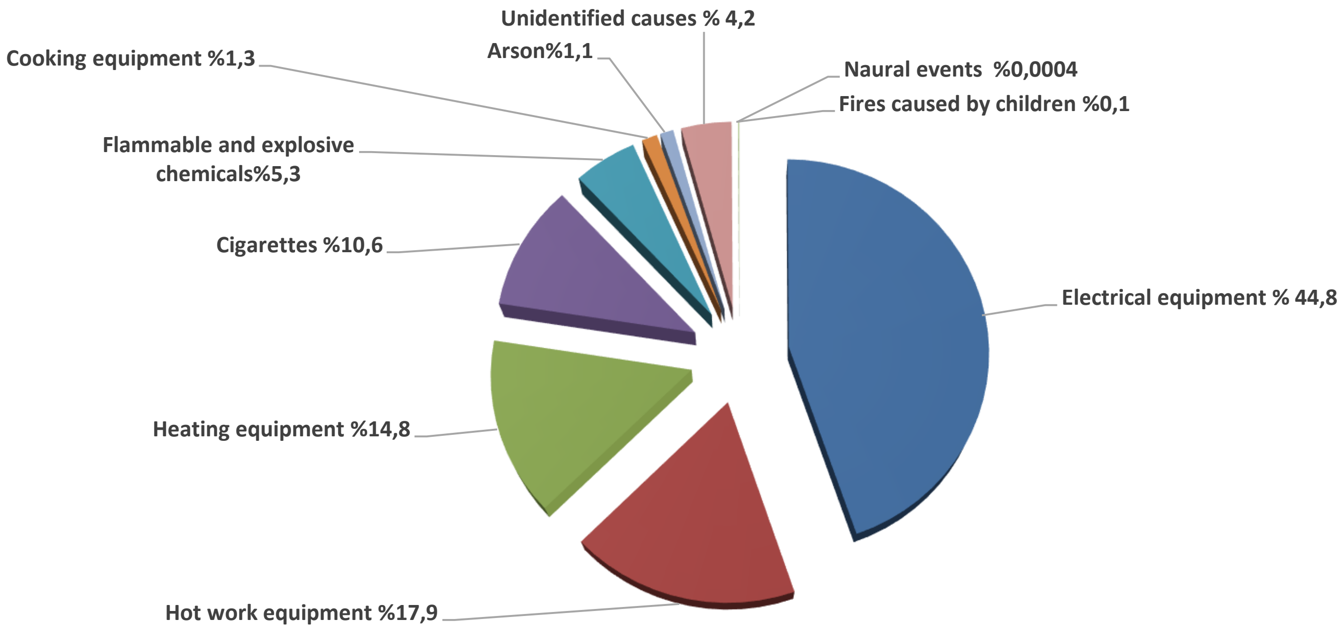

Figure 4. Causes of industrial fires (Istanbul 2015-2020)

7. CONCLUSION

The examination of the results of the analysis indicated that the leading cause of industrial fires in Istanbul between the years 2015-2020 was electrical equipment with a rate of 44.8%, which was followed by hot work equipment with 17.9%, heating equipment with 14.8%, cigarettes with 10.6%, flammable and explosive chemicals with 5.3%, cooking equipment with 1.3% and arson with 1.1%. The least observed causes were natural events with 0.0004% and unclassified events with 0.1%, such as fires caused by children and overturned candles. It was found that the source of 4.2% of the fires could not be determined. The finding of this study that fires caused by electrical equipment were an important problem in other countries as well as in our country was supported by some studies in the literature.

It is recommended that studies on the prevention of electrical fires should be given importance and that the electrical and grounding installations should be regularly checked by experts.

It should not be forgotten that dust particles in industrial facilities can turn into a major disaster with a small spark. If chemicals are used in the workplace, their properties should be well known and the storage conditions and usage rules written on the material safety sheets should be strictly followed.

It is very important to determine the causes of fires by the relevant authorities and share the statistics on this issue for determining the processes to be applied for the prevention of fires and establishing new legal regulations.

Accurate data entry is of great importance in achieving the purpose of such statistical studies. It will make analysts' job much easier if the institutions that are data sources use the same language for certain targets and take care to create the appropriate classification methods while entering data.

Data types that contain uncertainty or are defined as unclassified, other, or undetected prevent the emergence of real data. Studies are needed to reduce these data types and increase the diversity of data on fires. It is recommended that fire accelerants, the number of dead and injured clarified by hospital reports and the number of arson clarified by the investigations of judicial authorities should be included in the statistical data.

It is recommended to take the necessary precautions at the process stage by determining proactive approaches to prevent the recurrence of industrial fires. Studies on the selection of construction materials, building exit capacity, the number of escape routes, escape distances and widths and fire detection, warning and extinguishing systems should be carried out before the establishment of a facility.

In its 2022 report, the UCTEA Chamber of Chemical Engineers Istanbul Branch recommended that risky production facilities should be located in Organized Industrial Zones and should not pose a risk to residential areas. In particular, facilities belonging to the chemical sector should be gathered in Organized Industrial Zones (OIZ). When OIZs are established, their locations should be decided by taking the opinions of professional organizations, the people of the region, and non-governmental organizations on whether the region can handle this burden in terms of public and environmental health, ecologically, and logistically, and the Organized Industrial Zones should be effectively supervised by competent institutions.

In industrial fires, employees should act in accordance with Emergency Plans and move quickly to the assembly point. Those trapped inside must be rescued by the fire brigade and trained teams. Fire in buildings can spread to other flammable materials and grow very fast, explosions may occur, and depending on the flammable materials, it may show suffocating and poisoning effects. For this reason, even the fire brigade and the firefighting team of the workplace should intervene in the fire by ensuring their own safety first (URL 3).

Employees are the most important factor in preventing and reducing fires and explosions, so they should be periodically trained to recognize and prevent hazards related to industrial fires. For industrial fires, employees in industrial facilities should be trained on explosion and fire risks, extinguishing, degrees of ignition, flammable and explosive materials, flammability of materials used or produced, and fire resistance of these materials (Karatutlu et al., 2019).

There are many regulations on fire safety in our country. Within the scope of the legislation, many obligations, such as risk analysis and preparation of an emergency action plan, establishing emergency teams, organizing education programs, conducting fire exercises, installing fire detection, notification and announcement systems and performing regular tests to ensure that they are in working order, have been brought to business enterprises (BYKHY, 2007 and Regulation on Emergency Situations at Workplaces, 2021). It is recommended that new policies should be created by authorities to ensure that enterprises operate meticulously by complying with the provisions of the legislation.

REFERENCES

Çelik, İ. H., Usta, G., Yılmaz, G., Yakupoğlu, M. (2020). An assessment on the technological disasters experienced in Türkiye (between the years of 2000-2020). Artvin Coruh University International Journal of Social Sciences, 6(2):49-57. https://doi.org/10.22466/acusbd.776580

Daéid, N.N. (2004). Fire Investigation. CRC Press, New York, pp. 235. https://doi.org/10.1201/9780203646953

Efeoglu, H., Ertugrul, M., Cansiz, A., Karacali, T., Oral, E.A., Soysal, B., Sonmez, E., Dilber, R. (2006). Physics II Electricity Magnetism Laboratory Guide. Erzurum.

Environmental Law. (1983).T.C. Official Gazette (18132, 11 August 1983).

Ergül, H. S. (2012). Dust Explosion Phenomena in Mechanical Industry and AtexInstructions. Journal of Engineering and Architecture Faculty of Eskisehir Osmangazi University, 25(2):1-18.

Genç R, Pekey H. (2014). An Assessment of Fire Risks that May Occur in Industrial Facilities: Kocaeli Case. Electronic Journal of Professional Development and Research (EJOIR), Volume 2.

Girgin S, Yetiş Ü. (2007). Data Availability in Selected International Databases on Industrial Accidents That Occurred in Türkiye. Conference Paper · DOI:10.13140/2.1.2046.2724.

Karatutlu, C., Altıntaş, K. H.,Kaya, İ., Şahan, C. (2019). Examination of The Current Number of Fires in İndustrial Plants İntervention Units Engagedin Production in Turkey. Fire Safety Symposium and Exhibition Proceedings Book.

Kaya, B.&Kaya, Y. (2019). Combustion and Fire Caused by Electricity. Bayburt University Journal of Science, 2(1):152-157.

Kılıç, A. (2018). Causes of Fires in Developed Countries and Türkiye. Yangın ve Güvenlik Dergisi, 200: 8-10.

Kır, F., Özdemir, N. C., Topgaç Y.S. (2019). Electrical Fires and Prevention Methods. EMO VI Tesisat 2019, İzmir

Kök, F. (2020). Preventing the Damage to Human Health by The Gases Released in the Fire. National Environmental Science Research Journal, 3(2): 83-94.

NFPA (2018). Campbell R. Industrial and Manufacturing Properties. National Fire Protection Association; Report No: USS12J.

Occupational Health and Safety Law. (2012). T.C. Official Gazette (28339, 30 June2012).

Önder Y.E. (1999). Smoldering Combustion In A Horizontal Fuel Layer Which Is Object To An Air Flow Above Fuel Bed. Thesis (M.Sc.), Institute of Science and Technology, Istanbul Technical University

Paker S. (2017). Fire Protection Methods in Electric Power Installations. The Chamber of Electrical Engineers. Elektrik Mühendisliği, No: 462.

Regulation on Emergency Situations at Workplaces (update: 2021). T.C. Official Gazette. (31615, 1 October 2021)

Regulation on Equipment and Protective Systems Used in Potentially Explosive Environments. (2016). T.C. Official Gazette (29758, 30 June 2016).

Regulation on the Prevention and Reduction of the Effects of Major Industrial Accidents (BEKRA). (2019). T.C. Official Gazette (30702, 2 March 2019).

Regulation on the Protection of Buildings from Fire (BYKHY). (2007). T.C. Official Gazette (26735, 19 December 2007).

Regulation on the Protection of Employees from the Dangers of Explosive Environments (2013). T.C. Official Gazette(28633, 30 April 2013).

Serçe H.V. (2006) Smouldering Combustion. Thesis (M.Sc.), Institute of Science and Technology, Istanbul Technical University

Şengöz M.C.(2018) Investigation of fires caused by electricity and risk analysis by FMEA method. PhD Dissertation, Institute of Science, Isparta Süleyman Demirel University

Turan A. (2015). Safety in Welding Operations. Proceedings Book of the 9th Welding Technology Congress National Congress and Exhibition, Ankara, Türkiye, pp. 411-422.

URL 1, https://www.kmo.org.tr/resimler/ekler/13037fb4a690b19_ek.pdf?tipi=2&turu=H&sube=0 (Accessed: 16.02.2024)

URL 2, https://tr.wikipedia.org/wiki/Soma_Facias%C4%B1 (Accessed:16.02.2024)

URL3, https://www.kmo.org.tr/resimler/ekler/bf75f1541e47b5c_ek.pdf?tipi=2&turu=H&sube=7 (Accessed: 16.02.2024)

URL 4, https://www.mmo.org.tr/sites/default/files/c192b0c0d270dbf_ek.pdf (Accessed: 17.02.2024)

URL 5, https://kimyasallar.csb.gov.tr/uploads/file/Kas%C4%B1m%20Bilg.%20Sem.%20SEA%20sunum(1).pdf (Accessed: 17.02.2024)

URL 6, https://ohsonline.com/articles/2017/02/07/preventing-the-five-major-causes-of-industrial-fires-and-explosions.aspx (Accessed: 17.02.2024)

URL 7, https://www.mmo.org.tr/sites/default/files/09_.pdf (Accessed: 17.02.2024)

URL 8, https://www.emo.org.tr/ekler/440e2a33d76eeb0_ek.pdf (17.02.2024)

URL9,http://www.gaosbitfaiye.org/images/7d406e90-979f-475c-aaa8-43f6418ed263Elektrik%20%C3%B6nlem.pdf (Accessed: 17.02.2024)

URL 10, http://itfaiye.ibb.gov.tr/img/20201178551191407412289.pdf (Accessed: 02.12.2020)

Vesilind, P. A., Morgan, S. M., & Heine, L. G. (2010), Introduction to Environmental Engineering (3rd Edition),CL-Engineering.