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RESEARCH ARTICLE

INVESTIGATION OF THE SEASONALITY OF OCCUPATIONAL ACCIDENTS IN MINE OPERATIONS

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ABSTRACT

Mine operations might be viewed as relatively risky in terms of worker safety when compared to other industries. Every year, there are a lot of occupational accidents and near-misses at mining sites. Most of the time, data from these circumstances are recorded, but they are typically not properly utilized. Information gathered from occurrences helps researchers understand how various conditions affect accidents and their frequency. The information obtained from such investigations may provide practical advice on how to prevent happening again. For instance, there are many studies in the literature that analyze mining accidents according to their countries, yearly frequency, work areas, and types of work; however, there isn't a single study that looks at the relationship between meteorological conditions and the seasonality of the accidents. The correlations between seasonal and regional variables, such as temperature, humidity, and pressure, and occupational accidents that occurred in mines with various climatic features, chosen from two different nations, were examined in this study. The findings indicate that there is a strong relationship between the frequency of accidents and the seasons, however this relationship would be weaker if incidents were looked into on a monthly basis. In conclusion, this article demonstrates that temperature and humidity in mining operations during severe weather conditions have a significant impact on occupational accidents.

Keywords: *Occupational accidents, Mining, Seasonality, Temperature, Humidity*.

1. INTRODUCTION

Mining is a very important sector for the development of humanity, which has shaped history since ancient times, from the industrial revolution to the present. Today, many products necessary for life are obtained as a result of mining activities [1]. With the spread of industrialization globally, occupational accidents have emerged in relation to the human-oriented working environment and the tools used, leading to economic losses [2]. Compared to developed countries, occupational accidents with death, injury and property damage are at very high levels in Turkey [3]. Among the sectors in which these accidents occur, the mining sector has the highest death rate [4].

The human body is affected by the climatic conditions of the environment in which it lives [5]. Underground and surface workers in the mining sector are exposed to a wide variety of hazards, such as high heat and humidity, pressure, poor ventilation, poor lighting, falls, noise and vibration, tight openings, stress, and dust and gases generated during operation [6]. As a result of these effects, a decrease in the concentration of employees and work efficiency can occur. Many parameters that affect the performance of employees throughout their careers. With the effect of these factors, the performance and motivation of the employees can be adversely affected which can result in a higher number of occupational accidents.

One of the most important external factors in physical working conditions is climate and weather conditions. The temperature of the workplace is the first consideration when discussing weather conditions. Extremely hot or cold weather can adversely affect the workers and lead to a work accident. As a result of excessive heat, employees in the workplaces experience depressed mood, anxious mood, weakness, inattention, weakness and excessive sweating, resulting in muscle spasms and pains due to the salt excreted from the body [7]. Those who work in mines in hot and humid conditions take frequent breaks to reduce their body temperature and there is a decrease in productivity [5]. If the temperature is low or below normal, it becomes difficult for the employees to operate physically and mentally. In cold weather conditions, workers suffer from shivering, cold, frostbite in certain parts of the body and cold burns. As a result of working for extended durations under low temperatures, excessive fatigue can occur, and poor performance and focusing problems are experienced. This situation can lead to work accidents [7]. Another factor related to weather and climatic conditions is humidity. Extremely high or low humidity can adversely affect the health and productivity of employees [7]. High humidity makes it difficult to sweat, which makes various ailments including asthma, joint problems, cardiovascular disorders, and respiratory problems more likely to develop [8]. Employee performance suffers as a result of these disruptions, and workplace mishaps may happen.

2. PREVIOUS STUDIES

In literature, numerous studies have focused on mining accidents based on various factors such as their nations, frequency, job regions, and types of work. Köse et al., (1990) examined the occupational accidents that occurred between 1983-1988. As a result of the study, it was seen that the employees who started to work without training experienced accidents and this increased the number of accidents occurring in the enterprise. Additionally, it has been found that accidents tend to happen more frequently in the summer and on the first four days of the week than on any other days of the week. Further, it was noted that research conducted at the end of working hours revealed a higher rate of accidents [9].

According to Güyagüler and Bozkurt (1992), the expense of work-related accidents is more than the expense of taking preventative measures. It has been underlined that accidents have decreased as a result of the steps developed have to improve workplace health and safety [10].

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Önder et al. (2005), found that the hot work environment had an impact on the physiological and psychological well-being of those who worked in underground mining. The study emphasizes the likelihood of workplace accidents as a result of these impacts. Computer algorithms may be used to assess the present level of heat stress and the effectiveness of the recommended solutions, according to researchers [5].

The impact of accidents on productivity between 1943 to 2009 was examined by Korkmaz (2011). According to the research, other employees suffered as a result of deadly workplace accidents. It has been stressed as a result that it impacts employees' performance and lowers their productivity [11].

Yaşar et al. (2015) discussed significant disasters that happened in Turkey and throughout the world throughout history. In the study, it was noted that multiple people were impacted whenever an occupational disaster happened and that mining, which resulted in the deaths of numerous employees, is in the "extremely risky" category [12].

Occupational incidents, according to Durşen (2016), are the main reason behind workplace accidents. These accidents can also be brought on by the physical impacts of the workplace or by psychological hazards like stress at work, a heavy workload, or irregular hours [13].

According to Turan (2019), when occupational accidents are evaluated according to months, departments, and accident types, usually are affected by seasonal factors like temperature, humidity, and pressure from two different nations' metal and coal mines [14].

In conclusion, while examining the influence of other factors on mining accidents, many subjects such as experience, stress, and efficiency were discussed and examined; however, it was concluded that sufficient research was done only in 2019 in on whether the effects of weather conditions (temperature and humidity) on the accidents occurring in underground and surface mines. In the study, the relationships between seasonal and geographical variables including temperature, humidity, and pressure, as well as occupational accidents that occurred in metal and coal mines chosen from two different nations, were explored. Additionally, based on the year and shift, it was established which period the accidents were concentrated in, and the reasons of the associated accidents were described [14]. The goal of this study is to determine whether there is a relevant correlation between occupational accidents and seasons in places with various climates by integrating weather data with the distribution of mining accidents throughout the year.

3. METHODOLOGY

In this study, occupational accident data of four different mines were collected and the relevant occupational health and safety data were collected. Meteorological data (temperature, humidity and pressure) of the periods in which the accidents occurred manually recorded. Figure 1 illustrates the approach taken in this study and the processes involved.

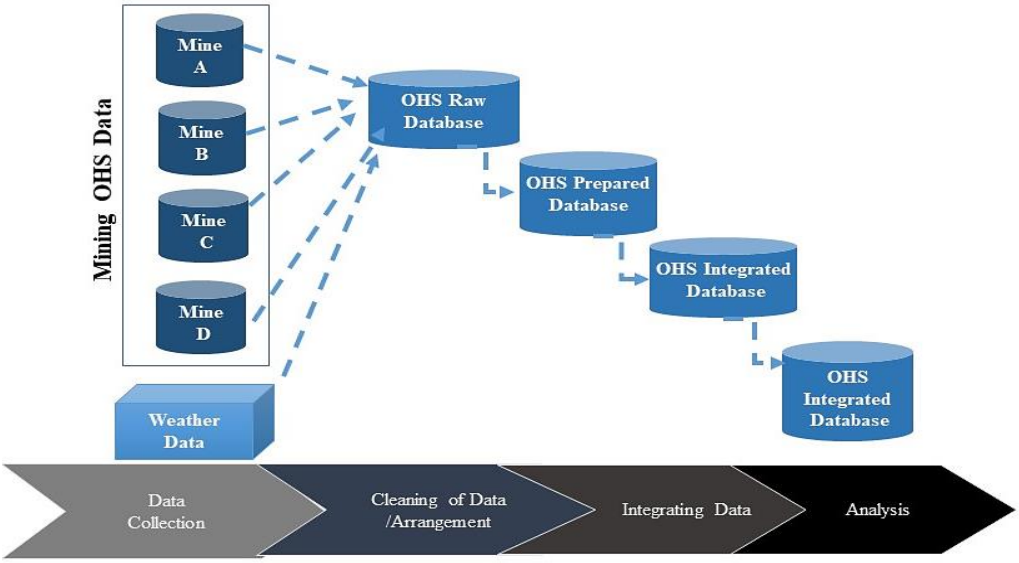

Figure 1. Stages of the method used in the study.

Data collection*:* incident data for two full years for each operation were collected from OHS systems and manually recorded files. The average maximum and lowest temperatures, humidity, and pressure for the and times when the incidents happened were carefully gathered from the web.

Cleaning and editing data: All of the accidents that occurred over the years were individually evaluated in the data collected from the mines. In the course of the year, the common data points in four mines were arranged, and irrelevant parameters were eliminated.

The following common information has been discovered when the data from the mines are examined:

- accident date
- accident time
- type of accident
- accident site
- accident department
- ore produced
- shift hour

Similarly, it was determined that the pressure did not significantly change throughout the year and would not contribute to the study when the characteristics relating to the weather conditions (temperature, humidity, and pressure) were studied.

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Integration of data*:* The database was updated every day with information on accidents and the weather so that the records of accidents in mines from various eras can be compared and analyzed with meteorological data from mines (day, month, season, year).

Analysis of data*:* The final phase of the study used the business intelligence method to analyze the mine graphs on a monthly and seasonal basis (processing the raw data to make it more meaningful and useful). Monthly and seasonal averages were compared against annual accident shares per month or season. These analyses led to an investigation into whether the weather had a relation on the accidents.

4. BACKGROUND INFORMATION ABOUT THE MINES

Mine A is an open pit mine that produces copper and is located in the United States. The mine is in the southern region of the country. While the winters are warm, dry, and often clear throughout the year, the summer months are hot and steamy.

Mine B is a facility that produces metallic ore in Turkey. Mining techniques that combine open pit and underground methods. Blasting fragments the material. In open pits, truck and hydraulic excavators are used; underground, the standard cut-and-fill process is used. Rainfall in the area is heavy during the winter and spring.

Mine C is located in the northwest of the United States and produces potash as an open pit with truck-excavator production. The mine's location is in an area with a four-season climate, which has four distinct seasons. Winters are extremely cold, snowy, and partially overcast, whereas summers are brief, pleasant, dry, and clear.

Mine D is an open pit mine that produces coal in the western part of the United States. In the mining operation, trucks, and excavators are used. The climate of the area where the mine is located is hot, humid, and rainy in the summer; very cold, windy, and snowy in the winter; and typically partially overcast all year.

5. RESULTS

5.1. Weather Conditions of The Regions

Table 1 provides the yearly averages for temperature, humidity, and pressure for the locations where the mines are located.

Table 1. Annual average temperature, humidity and pressure averages of the regions where the mines are located.

Mines	Average Low Temperature	Average High Temperature	Average Humidity (%)	Average Pressure (Bar)

Mine A	20.2	32.1	29.8	1,011
Mine B	8.2	20.2	46.4	879
Mine C	0.6	12.5	66.7	1,015
Mine D	0.4	5.2	63.5	1,016

These facts indicate that Mine A is located in a hot, dry, and pressure-normal region. Mine B is situated in a region with a moderate climate, low humidity, and low pressure. Mines C and D are situated in chilly, somewhat humid, and pressure-normal locations.

5.1.1. Temperature-accident relationship

The data of the low and high-temperature averages measured in the regions where the mining operations are located are matched with the monthly and seasonal distributions of the accident shares in each mine.

Monthly basis

Monthly temperature accident distribution of Mine A is given in Figure 2.

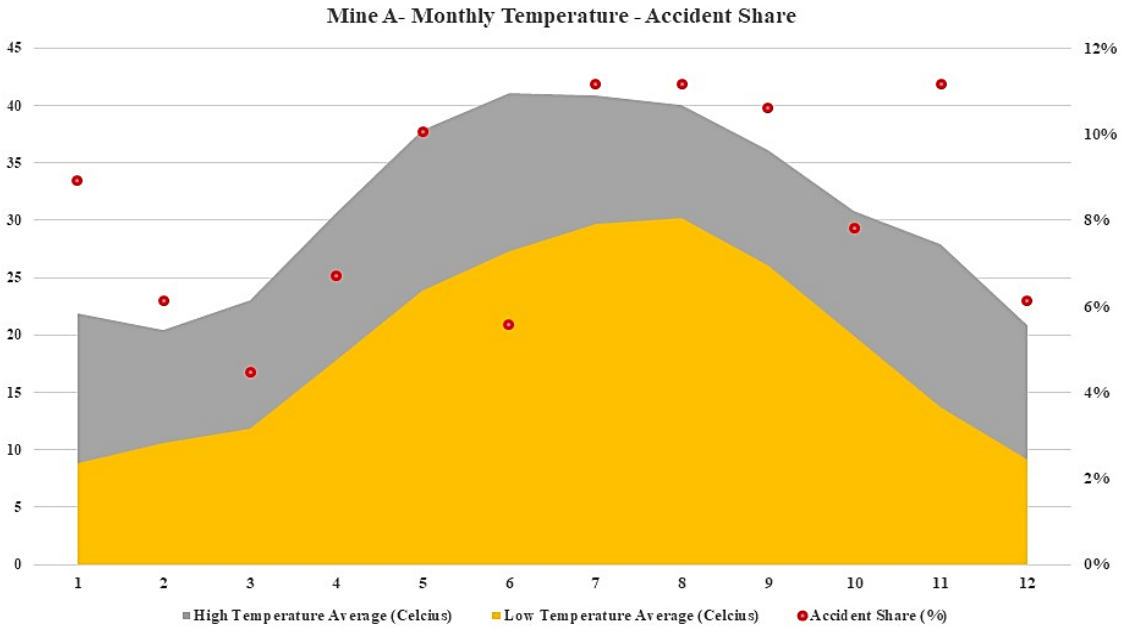

Figure 2. Monthly average temperature and accident share distribution of Mine A.

According to this distribution, accidents are intensified between the 5th-11th months; while between the 12th-4th months relatively few accidents occur. The correlation coefficient between the two series was found to be positive at 50%. It is possible to say that there is a moderate relationship.

In Figure 3, the monthly temperature accident distribution of Mine B is given. Accordingly, accidents are concentrated between the months 8th-12th of the year, and a relatively low number of accidents occur in the first 7 months of the year. The correlation coefficient between the two series was positive 49%. It is possible to say that there is a moderate relationship.

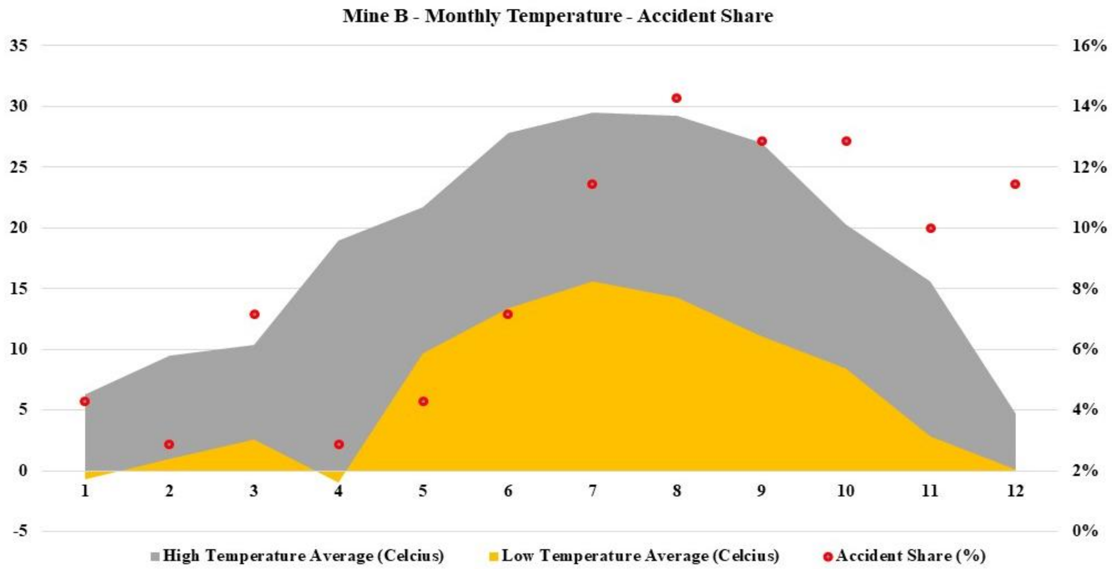

Figure 3. Monthly average temperature and accident share distribution of Mine B.

In Figure 4, monthly temperature accident distribution of Mine C is given. According to this figure, while the accidents are concentrated between the at 10^{th}-2^{nd} months, relatively a smaller number of accidents occur between the 3^{rd}-9^{th} months. The correlation coefficient between the two series was calculated as negative 39%. It is possible to say that there is a moderate relationship.

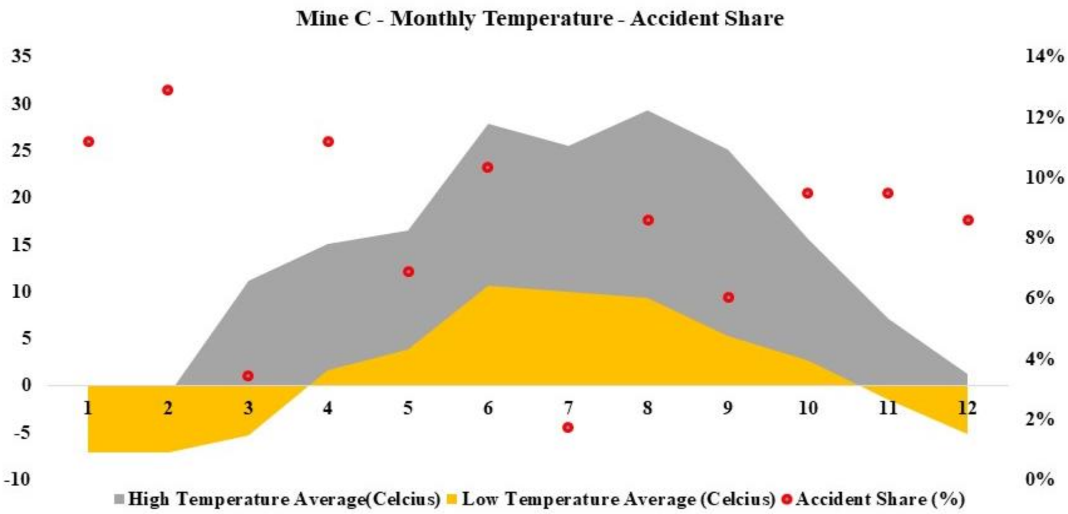

Figure 4. Monthly average temperature and accident share distribution of Mine C.

In Figure 5, the monthly temperature accident distribution of Mine D is given. According to this, while the accidents are concentrated between 12^{th}-1^{st} months, relatively less number of accidents occur between 2^{nd}-11^{th} months. The correlation coefficient between the two series was calculated as negative 38%. It is possible to say that there is a moderate relationship.

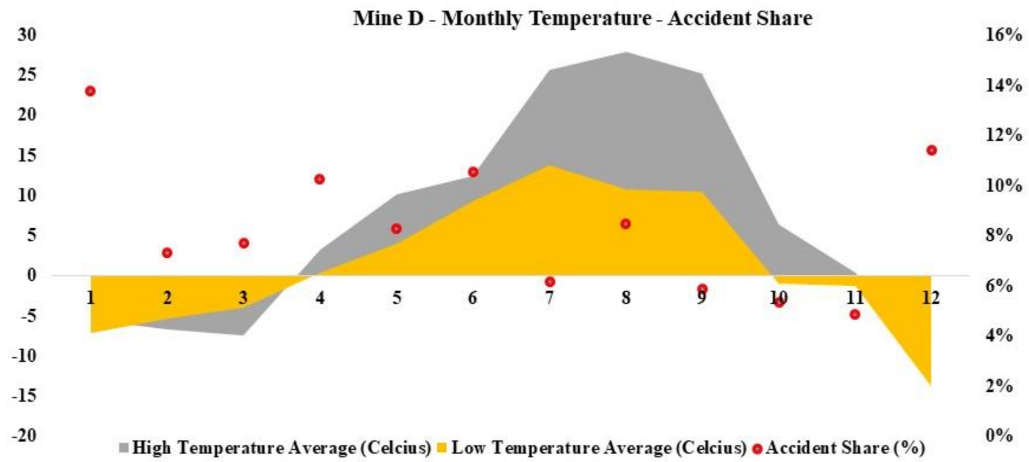

Figure 5. Monthly average temperature and accident share distribution of Mine D.

Season Basis

In Figure 6, the seasonal temperature accident distribution of Mine A is given. Accordingly, while accidents occur more intensely in summer and autumn, there are relatively fewer accidents in the winter and spring seasons. The correlation coefficient between the two series was found to be positive and 62%. It is possible to say that there is a moderate relationship.

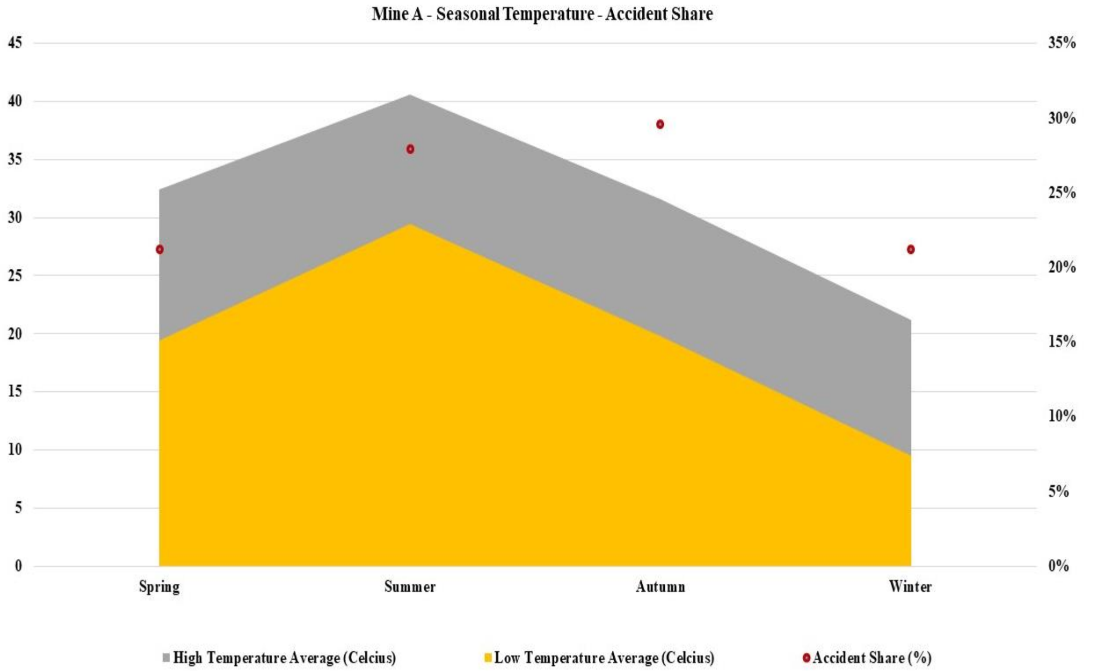

Figure 6. Distribution of seasonal average temperature and accident share of Mine A.

In Figure 7, the seasonal temperatures and accident distribution of Mine B are given. Accordingly, while accidents occur more intensely in summer and autumn, there are relatively fewer accidents in the winter and spring seasons. The correlation coefficient between the two series was positive and 72%. It is possible to say that there is a high degree of a positive relationship.

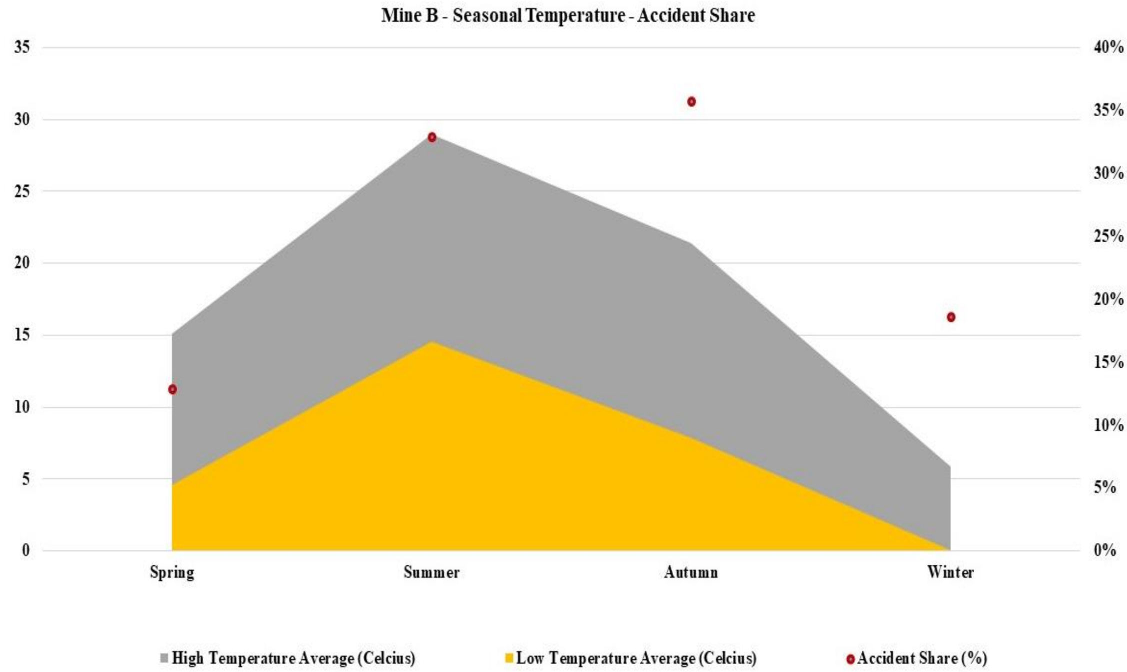

Figure 7. Distribution of seasonal average temperature and accident share of Mine B.

In Figure 8, seasonal temperature accident distribution of Mine C is given. Accordingly, while the accidents are more intense in the autumn and winter seasons, there are relatively fewer accidents in the spring and summer seasons. The correlation coefficient between the two series was negative and 90%. It is possible to say that there is a very high degree of a negative relationship.

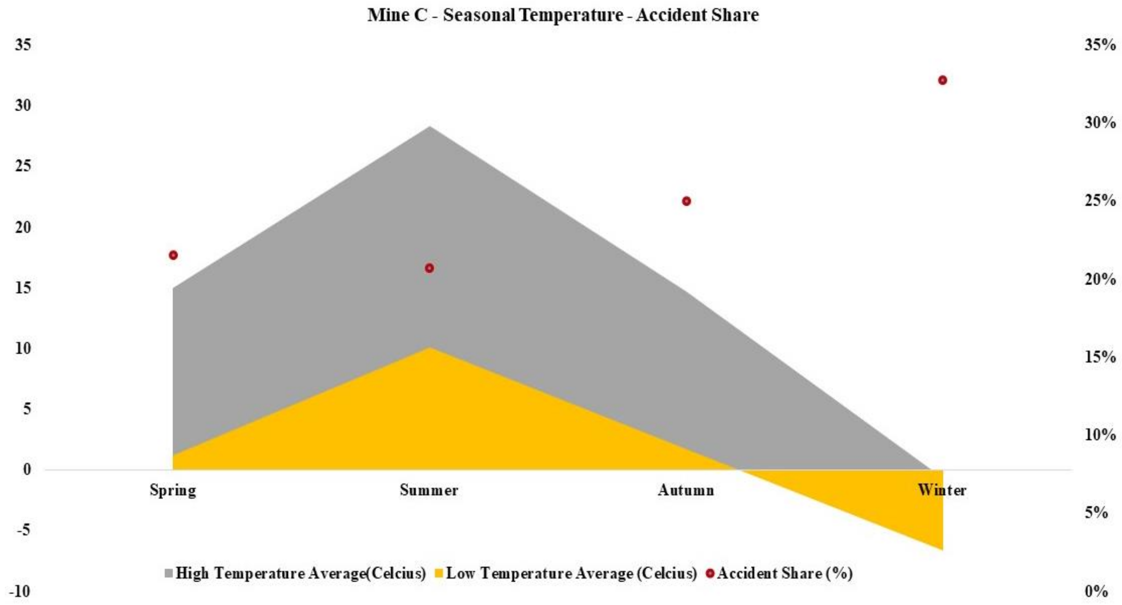

Figure 8. Distribution of seasonal average temperature and accident share of Mine C.

In Figure 9, the seasonal temperature accident distribution of Mine D is given. Accordingly, while the accidents are more intense in the winter and spring seasons, there are relatively fewer accidents in the summer and autumn seasons. The correlation coefficient between the two series was found to be negative and 59%. It is possible to say that there is a moderate negative relationship.

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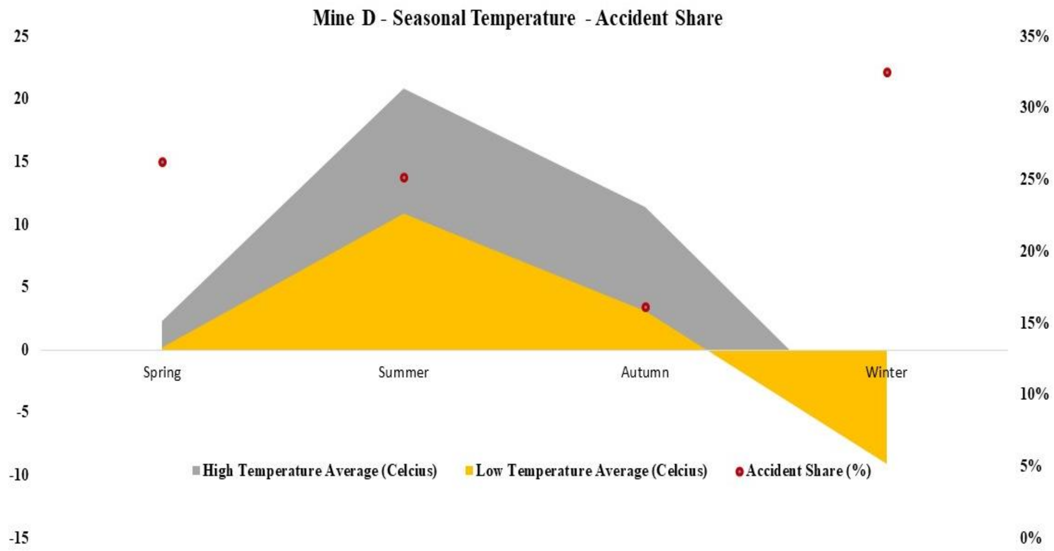

Figure 9. Distribution of seasonal average temperature and accident share of Mine D.

5.1.2. Humidity–accident relationship

In this section, the daily average humidity (%) data of the regions where the mining operations are located are matched with the monthly and seasonal distributions of the accident rates (monthly or seasonal accident number/total annual accident number) in each mine.

Monthly basis

Figure 10. It gives the moisture and accident distribution of Mine A on a monthly scale.

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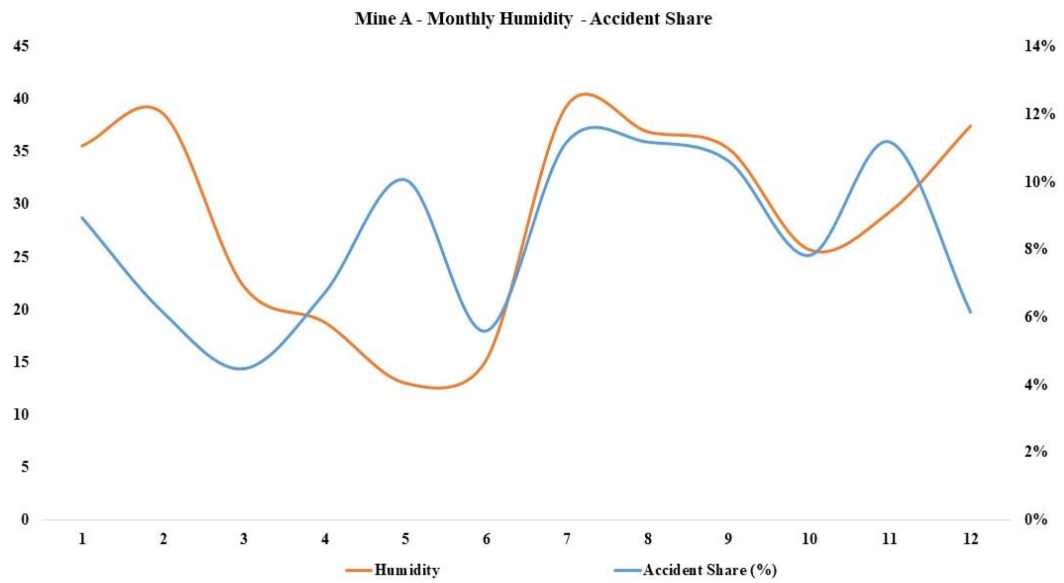

Figure 10. Monthly average humidity and accident share distribution of Mine A.

According to this distribution, the accidents are concentrated between the 5th-11th months, while the 12th-4th months are the periods when relatively few accidents occur. The correlation coefficient between the two series was found to be positive at 33%. It is possible to say that there is a low degree relationship.

In Figure 11, the monthly moisture and accident distribution of Mine B is given. According to this figure, while the accidents are concentrated between the 8th-12th months, in the first 7 months of the year, a relatively lower number of accidents occur. The correlation coefficient between the two series was positive at 10%. It is not possible to say that there is any relationship.

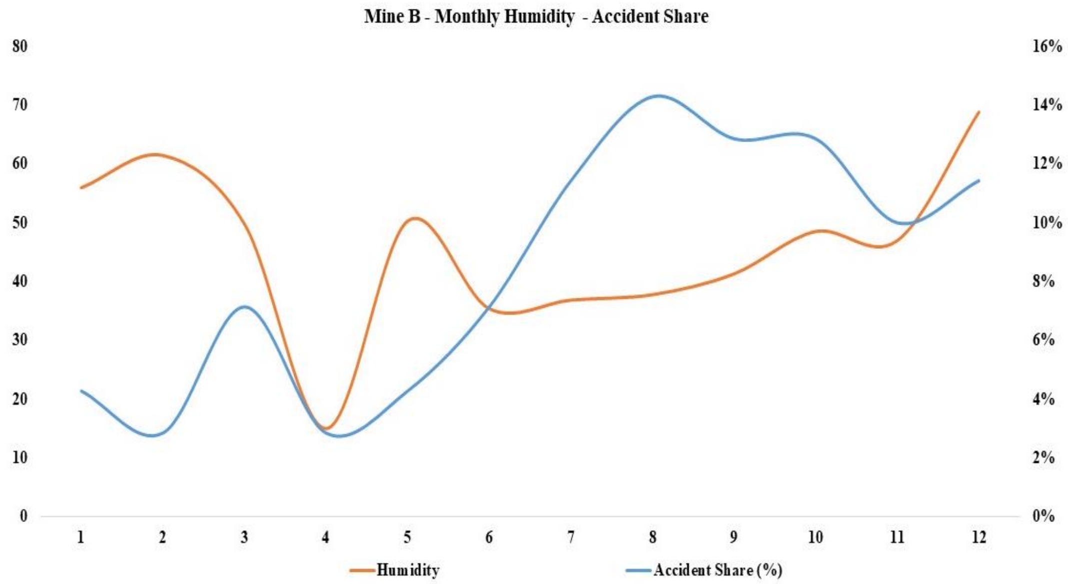

Figure 11. Monthly average humidity and accident share distribution of Mine B.

In Figure 12, the monthly moisture and accident distribution of Mine C is given. According to this figure, while the accidents are concentrated between the 10^{th}-2^{th} months, a relatively low number of accidents occur between the 3^{th}-9^{th} months. The correlation coefficient between the two series was calculated as positive 56%. It is possible to say that there is a moderate relationship.

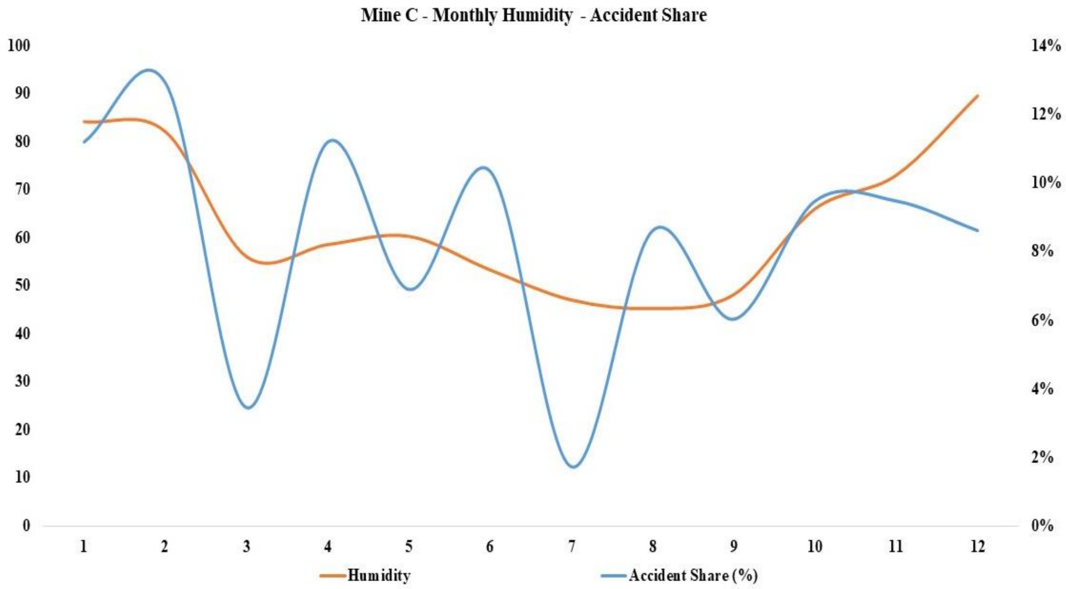

Figure 12. Monthly average humidity and accident margin distribution of Mine C.

In Figure 13, the monthly moisture and accident distribution of Mine D is given. According to this figure, while the accidents are concentrated between the 12th-1st months, relatively a smaller number of accidents occur between the 2th-11th months. The correlation coefficient between the two series was calculated as positive 34%. It is possible to say that there is a low degree of relationship.

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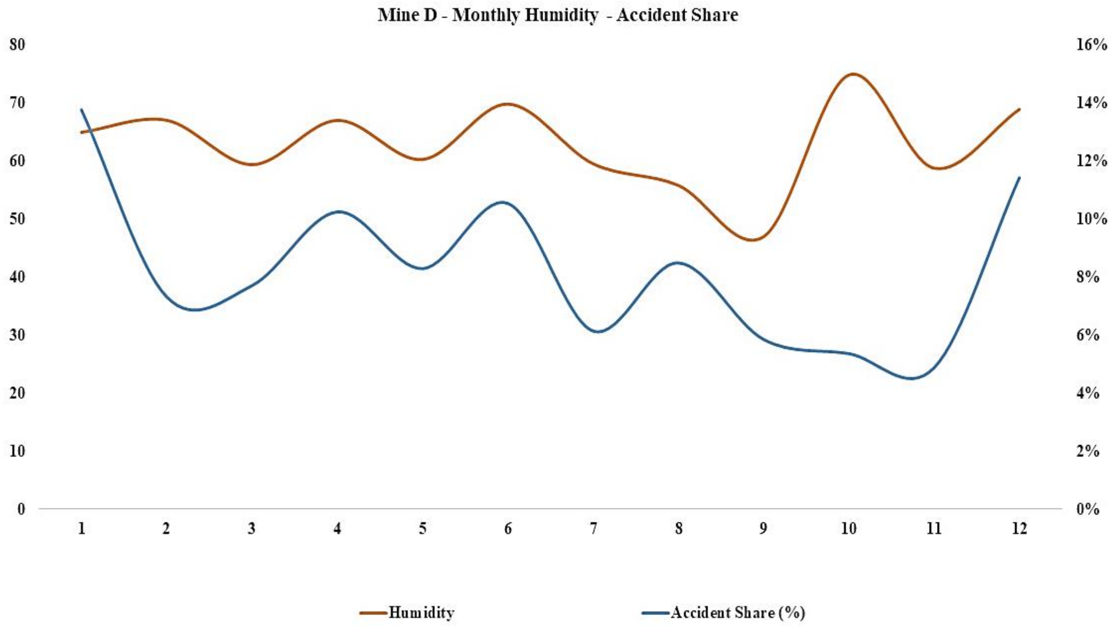

Figure 13. Monthly average humidity and accident share distribution of Mine D.

Season Basis

The seasonal humidity-accident distribution of Mine A is given in Figure 14. Accordingly, while accidents occur more intensely in summer and autumn, there are relatively fewer accidents in the winter and spring seasons. The correlation coefficient between the two series was found to be positive and 31%. It is possible to say that there is a low degree of relationship.

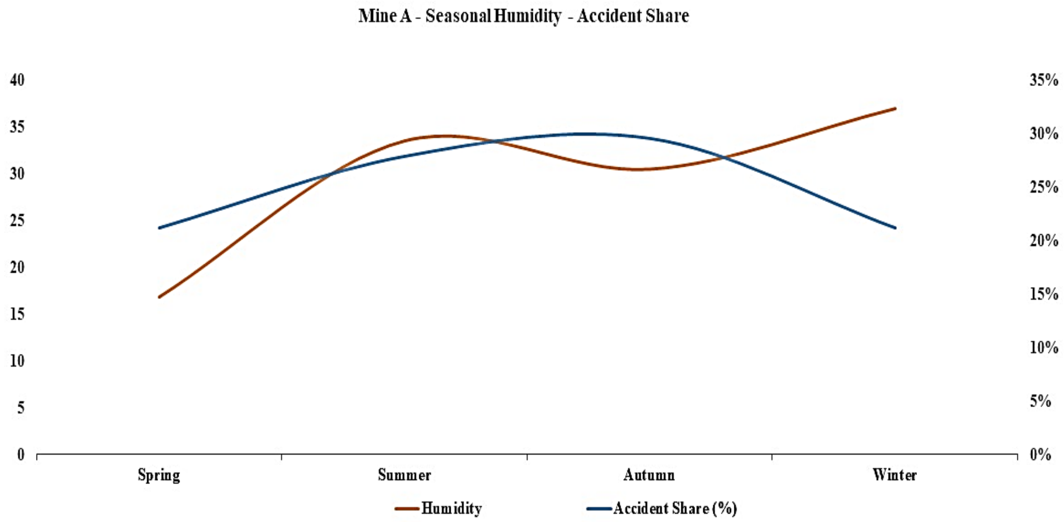

Figure 14. Distribution of seasonal average humidity and accident margin for Mine A.

The seasonal humidity and accident distribution of Mine B are given in Figure 15. Accordingly, while accidents occur more intensely in summer and autumn, there are relatively fewer accidents in the winter and spring seasons. The correlation coefficient between the two series was negative and 51%. It is possible to say that there is a moderate negative relationship.

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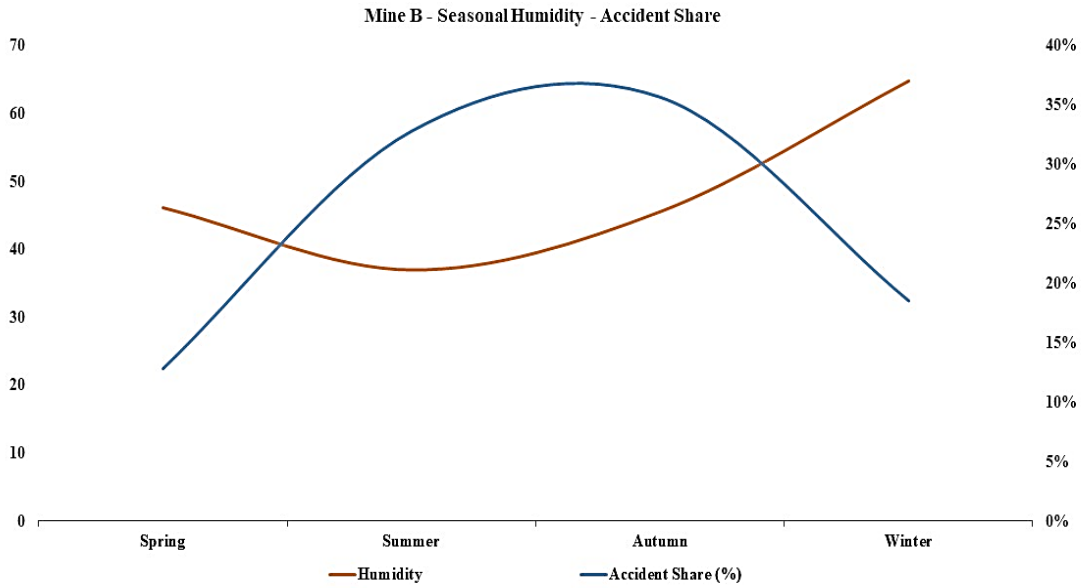

Figure 15. Distribution of seasonal average humidity and accident margin for Mine B.

The seasonal humidity accident distribution of Mine C is given in Figure 16. Accordingly, while the accidents are more intense in the autumn and winter seasons, there are relatively fewer accidents in the spring and summer seasons. The correlation coefficient between the two series was positive and 98%. It is possible to say that there is a very high degree of a positive relationship.

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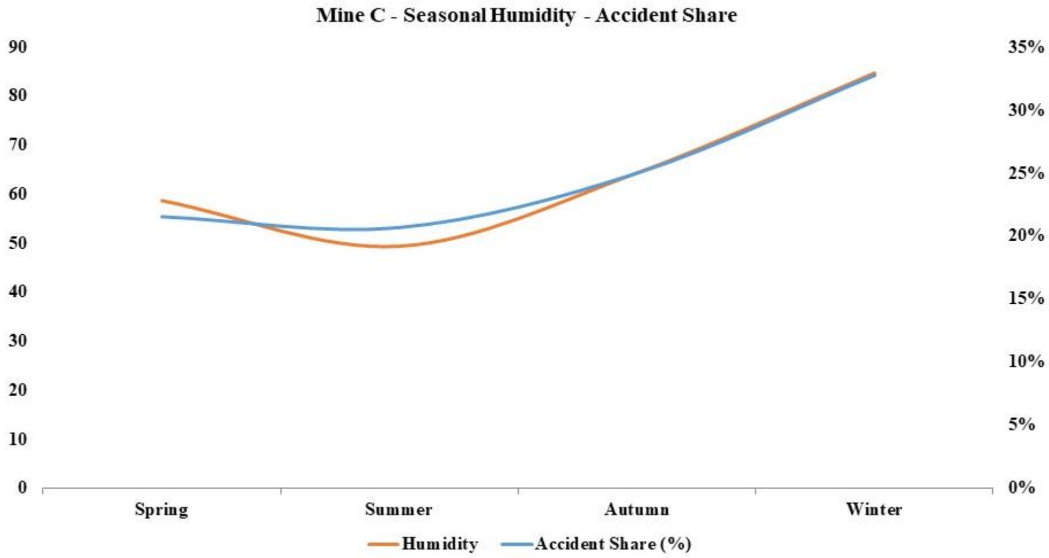

Figure 16. Distribution of seasonal average humidity and accident margin for Mine C.

The seasonal humidity accident distribution of Mine D is given in Figure 17. Accordingly, while the accidents are more intense in the winter and spring seasons, there are relatively fewer accidents in the summer and autumn seasons. The correlation coefficient between the two series was found to be positive and 96%. It is possible to say that there is a very high degree of a positive relationship.

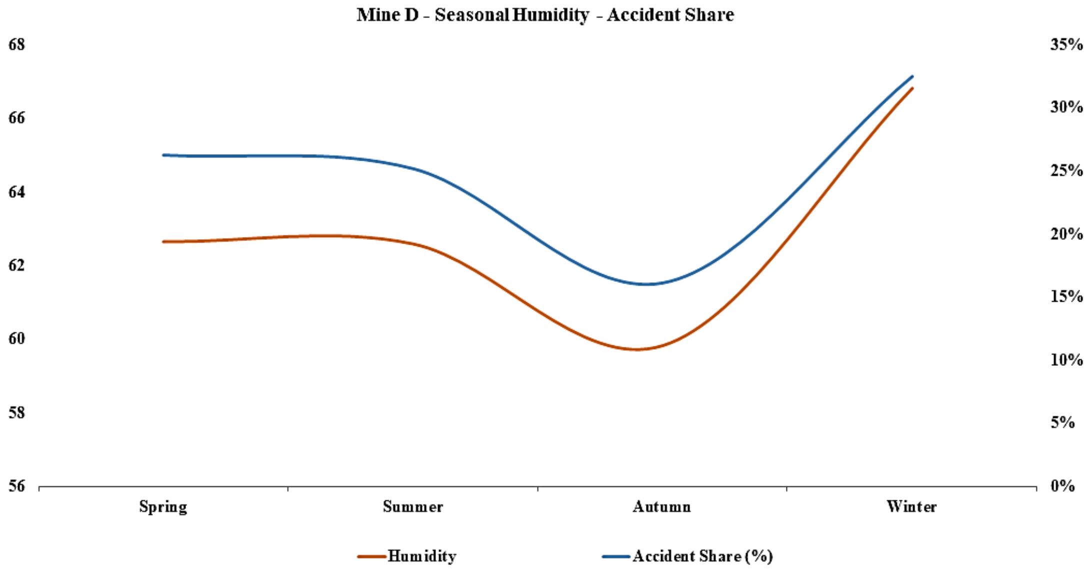

Figure 17. Seasonal average humidity and accident margin distribution of Mine D.

6. CONCLUSION

In this study, accident frequencies and weather conditions such as temperature and humidity were examined on a monthly and seasonal scale. It was found that while there is a positive and moderate correlation with temperature in Mines A and Mine B, which are located in relatively warm and temperate regions; a negative and low correlation with temperature was calculated in Mine C and Mine D, which are located in relatively colder and humid regions (Table 2). Although it is not possible to draw a strong conclusion from here; while there is a relatively significant and positive or negative relationship with temperature according to the region, a significant relationship with humidity appears to be a positive relationship only in Mine C on a monthly scale. This is evaluated as impact of thermal comfort and work schedules during warmer months.

Table 2. Table showing the relationship between the selected weather parameters and the accident monthly correlation (r values).

Parameter	Mine A	Mine B	Mine C	Mine D
Average Low Temperature & Accident	0.50	0.57	-0.34	-0.40
Average High Temperature & Accident	0.51	0.41	-0.44	-0.37
Average Humidity & Accident	0.33	0.10	0.56	0.34

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As a result, Mine A and Mine B, which are located in relatively warm and temperate regions, showed a positive and moderately strong correlation with temperature. Mine C and Mine D, which are located in relatively colder and humid regions, showed a negative and low correlation with temperature (Tablo 2). Although it is difficult to make firm conclusions from this, it is possible to conclude that in regions with a colder climate, accidents tend to occur more frequently on periods when the temperature is low: while in hot regions, accidents tend to occur more frequently during times when the temperature is high. Only in Mine C does a significant and strong association with humidity seem to be positive on a monthly timeframe.

Results of correlation computations on a seasonal scale seem to show more favorable outcomes (Table 3). For Mines A and B, which are situated in warm and temperate regions, respectively, there is a positive medium to high degree link between seasonal temperature and accidents. It was determined that Mine C and Mine D had a strong to moderately strong negative connection with seasonal temperature and accidents. This leads to the conclusion that when the temperature rises, accidents occur more frequently in hotter places while they occur less frequently in colder regions. Mine managers can take this into account and make adjustments accordingly. While Mine C and Mine D appear to have a very high and positive connection with moisture, Mine A and Mine B show positive low and negative low correlations with moisture. It is possible to infer from this study that accidents happen more frequently in cold and humid areas at times of increased humidity.

In line with these results, for the control of work accidents; temperature and humidity levels should be taken into account and the awareness of employees should be increased during the periods of intense accident times. Although seasons, temperature, pressure and humidity are not the definitive causes of accidents, it is a fact that the number of accidents is related to them.

Table 3. Seasonal correlation (r values) in the table showing the relationship between the selected weather parameters and the accident.

Parameter	**Mine A**	**Mine B**	**Mine C**	**Mine D**
Average Low Temperature & Accident	0.64	0.71	-0.88	-0.56
Average High Temperature & Accident	0.59	0.73	-0.91	-0.62
Average Humidity & Accident	0.31	-0.51	0.98	0.96

These results provide a good starting point for discussion and further research. Seasonality, timing and location of occupational accidents are topics that have huge potential on understanding where occupational incidents are concentrated the most. Further studies should investigate the time of day, time of shift, daily weather conditions, activities, and locations impact on occupational accidents.

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REFERENCES

[1] Bilim, N., Dursun, A.E., ve Bilim, A. (2015). Maden ekipmanlarına bağlı iş kazalarının genel değerlendirmesi ve çözüm önerileri. Türkiye 5. Uluslararası Maden Makinaları Sempozyumu ve Sergisi, 1-2 Ekim, Eskişehir.

[2] Durdu, H. İ. (2014). İş kazalarının ekonomik analizi ve bazı sektörler bazında değerlendirilmesi. Sosyal Güvence Dergisi, 5, 67-91.

[3] Camkurt, M. Z. (2013, Mayıs - Ağustos – Kasım). Çalışanların kişisel özelliklerinin iş kazalarının meydana gelmesi üzerindeki etkisi. TÜHİS İş Hukuku ve İktisat Dergisi, 24(6) / 25(1-2), 70-101.

[4] Tozman, B. (2010). Türkiye madencilik sektöründe iş kazalarının istatistiksel analizi. Eskişehir Osmangazi Üniversitesi, Fen Bilimleri Enstitüsü, Maden Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, Mayıs, 45s.

[5] Önder, M., Saraç, S., ve Eren, N. (2005, Aralık). Yeraltı ocaklarında ısı stresinin etkileri ve analizi üzerine bir paket program. Madencilik, 44(4), 39-46.

[6] Bhattacherjee, A., and Kunar, B. M. (2016). Miners' Return to Work Following Injuries in Coal Mines. Medycyna Pracy, 67(6), 729-742.

[7] Camkurt, M. Z. (2007, Mayıs/Ağustos). İşyeri çalışma sistemi ve işyeri fiziksel faktörlerinin iş kazaları üzerindeki etkisi. TÜHİS İş Hukuku ve İktisat Dergisi, 20(6) / 21(1), 80-106.

[8] Üçüncü, K., Aydın, A., ve Tiryaki, S. (2015). Kapalı mekanlarda insan faktörü ve odun esaslı malzemelerin havanın bağıl nemine etkisi. Mühendislik Bilimleri ve Tasarım Dergisi, 3(3), 533-540.

[9] Köse, H., Şenkal, S., ve Aközel, A. (1990, 21-25 Mayıs.). "GLİ Tunçbilek Bölgesi yeraltı işletmelerindeki kaza istatistikleri". Türkiye 7. Kömür Kongresi Bildiriler Kitabı, Zonguldak, 363-381.

[10] Güyagüler, T., ve Bozkurt, R. (1992). Kömür madenciliğinde meydana gelen iş kazalarının maliyetleri. Türkiye 8. Kömür Kongresi Bildiriler Kitabı, TMMOB, Zonguldak, 552, 331-343.

[11] Korkmaz, O. (2011). İş kazaları ile verimlilik arasındaki ilişki: Türkiye Taşkömürü Kurumu örneği. Journal of Yasar University, 6(23), 3805-3813.

[12] Yaşar, S., İnal, S., Yaşar, Ö., and Kaya, S. (2015). Big Mining Disasters From Past to Present, Madencilik, 54(2), 33-43.

[13] Durşen, M. (2016). Yeraltı kömür işletmelerinde çalışanların psikososyal risklerinin değerlendirilmesi. T.C. Çalışma ve Sosyal Güvenlik Bakanlığı İş Sağlığı ve Güvenliği Genel Müdürlüğü, İş Sağlığı ve Güvenliği Uzmanlık Tezi, Ankara, 88s.

[14] Turan, S. (2019). Madenlerde meydana gelen iş kazalarının mevsimselliğinin ve kaza zamanının incelenmesi. Gümüşhane Üniversitesi, Fen Bilimleri Enstitüsü, İş Sağlığı ve Güvenliği Anabilim Dalı, Yüksek Lisans Tezi, Temmuz, 79s.