Review Article
https://doi.org/10.33904/ejfe.1131463

Eur J Forest Eng 2022, 8(1):40-45

Evaluation of Various Risk Factors Caused by Mechanized Equipment Used in Forest Operations

İnanç Taş*, Abdullah E. Akay

Bursa Technical University, Faculty of Forestry, 16310 Bursa, Türkiye

Abstract

Forestry is among the dangerous work classes due to its working conditions. Especially fatal accidents that may occur during forest operations take an important place in this regard. In addition to occupational accidents, there are various risks such as physical, chemical, biological, ergonomic. These risks are often ignored and can cause serious health problems in long periods. Considering the previous studies on this subject, the main risk factors can be classified as noise, particulate matter and gas. The noise caused by motor movements and particulate matter exposure caused by wood raw material or machine-ground interaction are important conditions. The release of waste gases to the environment during operations are often encountered. The main gases polluting the air include carbon monoxide (CO), sulfur oxides, hydrocarbons and nitrogen oxides. CO is very dangerous because of its rapid mixing with the blood. In this study, a synthesis of previous studies in machine-based risk factors during forest operations was provided and Fine Kinney Method, as one of the most common risk assessment methods used in the subject, were presented. This review paper providing a synthesis of previous studies in machine-based risk factors pointed out the working conditions of forest workers, importance of personal protective equipment and how to use risk assessment methods in the purpose of occupational health and safety.

Keywords: Noise, particulate matter, CO, forest operations, risk assessment, occupational health and safety.

1. Introduction

Technological developments emerge as a result of the work done to increase the life quality of people. Especially utilization of mechanization provides a serious increase in production capacity and speed. Thus, mechanization has become inevitable in almost all business lines today. One of the working areas where mechanization has developed significantly is the forestry sector. The utilization of machine power during forest operations has become quite intense. The fact that difficult and time consuming forestry activities can be done in a short time using mechanization which also increases the productivity in forestry operations. However, there are some risk factors that come with mechanization and have serious effects on human health. These risk factors are noise, particulate matter, waste gases, vibration, chemicals, thermal comfort, etc. (Aksüt et al., 2020). Among these risk factors, particularly noise, particulate matter, and waste gases are among the factors that forest workers encounter intensively in the working environments. Besides, CO is one of the most dangerous waste gases as it is difficult to sense and rapidly mixes with the blood.

In order to prevent or reduce the detrimental effects of risk factor, it is crucial to evaluate their risk using risk analysis techniques. There are two basic approaches, including reactive and proactive, in risk analysis. In the reactive approach, after the accident that occurs as a result of the occurrence of risks, the process of determining the cause of the accident and process of seeking a solution begins. Proactive approach, on the other hand, is an assessment type approach that includes estimating risks before they occur, their degree of importance, and reducing or completely eliminating these risks (Özkılıç, 2007; Felekoğlu and Taşan, 2017). Risk assessment refers to the process of estimating the size of the risk in a system and deciding whether the risk can be tolerated by considering the existing controls (Özkılıç, 2005; Ceylan and Başhelvacı, 2011). Although there are many risk assessment techniques available today, risk assessment methods are divided into two main groups as qualitative and quantitative methods (Ceylan, 2000; Kurt and Ceylan, 2001).

While risk assessment is made using verbal logic in qualitative methods, the expert estimates the risks based on his own intuition and experience. Estimated risks are not expressed in numerical values. Instead, the magnitude of the risk is defined by using expressions such as very high or high. Such assessments are subjective, but depend on the intuition and judgment of the expert. Therefore, it is not correct to make such risk assessments in critical systems. In the quantitative

*Corresponding Author: Tel: +90 224 3003430 E-mail: inanc.tas@btu.edu.tr
Received: 15 June 2022; Accepted: 24 June 2022

method, the risk is calculated with the help of numerical methods. In these methods, the values such as the probability of occurrence or the effect of the hazard are specified numerically, and these values are examined with logical or mathematical methods and the risk value is calculated. In particular, it has been reported that risk assessment approaches using Multi-Criteria Decision-Making Methods (MCDM) give more accurate results in a short time. In this study, three risk factors including noise, particulate matter, and CO related to forestry machines were evaluated based on the previous studies. Unlike the risk factors (such as vibration and thermal comfort) that cause personal effects on the individuals, these selected risk factors affect not only the machine operators but also other workers in the work environment. In the next stage, the capabilities of MCDM based Fine Kinney method in assessment of these risk factors were presented in the paper.

2. Risk Factors

2.1. Noise Factor

Noise is defined as sounds that have an irregular structure and can affect people mentally or physically. Staying in places where noise is intense for a long time can cause hearing loss. It is also effective in the emergence of problems such as sleep disturbance, decreased ability to work and stress (Güler et al., 1994). In short, noise can be expressed as unwanted, unpleasant, intolerable sounds (Watts, 1995). The effects of noise on working life are stated in the regulations together with the other necessary regulations. In these regulations, the exposure limit value is 87 dB, the highest exposure effective value is 85 dB, and the lowest exposure effective value is 80 dB (Official Newspaper, 2013). The effects of noise on humans are shown in Table 1. The maximum daily exposure times of the workers for various noise levels were listed in Table 2.

Table 1. Negative effects of noise on humans (Toprak and Aktürk, 2004)

Noise Levels (dBA)	Noise effects
30 dB (A) - 65 dB (B)	Discomfort, discomfort, anger, anger, sleep disorder and concentration disorder.
66-90 dB (B)	Physiological reactions, increase in blood pressure, acceleration of heartbeat and respiration, decrease in pressure in the cerebral fluid, sudden reflexes.
91-120 dB (B)	Increased physiological reactions, headaches.
121-140 dB (B)	Persistent damage to the inner ear, deterioration of balance.
>140 dB (B)	Serious brain damage.

Table 2. The maximum daily exposure times of the workers for various noise levels (Güvercin and Aybek, 2003)

Noise Levels (dBA)	Daily Exposure Times (hours)
90	4
95	2
100	1
105	0.500
110	0.250
115	0.125

When the effects of noise on human health are examined, it is stated that the most common negative effects of noise are effects such as noise perception and disruption of daily activities, although noise can damage the inner ear and cause other pathological changes. According to the World Health Organization's definition of health, noise should be considered a health hazard. The effects of noise on health can vary by many factors that depend on both the noise and the person. Noise level, frequency spectrum, duration and impulsivity change the effects. Gender, age, health status and mental character also reflect the effects (Osada, 1988).

The non-auditory health effects of environmental noise need to be considered due to the wide variety, serious and widespread exposure. Noise is common in daily life and can cause both auditory and non-auditory health effects. Noise-induced hearing loss remains quite common in occupational settings and is increasingly caused by exposure to social noise (for example, through personal music players). There are many ongoing studies on the non-auditory effects of exposure to environmental noise on public health. Observational and experimental studies show that exposure to noise causes discomfort, disrupts sleep and causes the need for sleep during the day, affects patient outcomes and staff performance in hospitals, increases the occurrence of hypertension and cardiovascular disease, and impairs cognitive performance in schoolchildren. On the other hand, hearing loss caused by occupational or recreational noise exposure is also quite common. Therefore, it poses a public health threat that requires preventive and therapeutic strategies (Basner et al., 2014).

A ranking is given in which the most important factors affecting hearing loss are firstly exposure to high levels of noise, then the duration of work, and finally the age of the workers. In a current study, it was emphasized that forest workers exposed to noise levels less than 90 dBA generally do not have hearing loss and do not require special precautions. In addition, it was said that workers exposed to noise levels higher than 90 dBA experienced significant hearing loss at 4000 Hz frequency. On the other hand, it was stated that there was a positive correlation between working hours and hearing loss. It has been stated that chainsaw operators can protect themselves from noise with simple precautions to be taken (Tunay and Melemez, 2008). When chainsaws are used intensively during tree felling activities, it can be very noisy work environment. Excessive noise causes psychological and physiological disturbances on the chainsaw operators. Therefore, determining the noise effect on workers will be an important step in investigating the effects on worker health (Serin and Akay, 2018).

2.2. Particulate Matter

Particulate matter is expressed as solid particles that can hang in the air and tend to collapse over time due to their weight. The large particulate matter with a higher density can collapse quickly, while particulate matter with a low density may remain suspended in the air for a long time. Particulate matter in the range of 0.5-10 microns can enter the body through the respiratory tract. The negative effects of particulate matter on human health are related to their size. Generally, the ones smaller than 2.5 microns (PM2.5) and 10 microns (PM10) are considered (Taş and Akay, 2019). These are called fine and coarse particulate matter, respectively. While the part of the particulate matter larger than 10 microns is kept in the upper respiratory tract, the smaller part such as PM10 and PM2.5 can reach the alveoli. Therefore, particulate matter smaller than 10 microns causes serious health problem. While particulate matter smaller than 10 microns collect in the bronchi, those with a diameter of 1-2 microns in the alveoli, those with a diameter of 0.1 microns pass from the alveoli to the capillaries. Particulate matter may causes a decrease in lung functions, asthma attacks, irritation in the airway, shortness of breath, premature death and heart attacks in those with heart or lung diseases (Zencirci and Işıklı, 2017). Particulate matter causes occupational diseases, but also reduces work efficiency, damages machines and products, and complicates working conditions. Air Quality Index of the Environmental Protection Agency of USA is indicated in Table 3.

Table 3. USA Environmental Protection Agency Air Quality Index (Url-1, 2022)

Index Values	Category	PM2.5 (μg/m3)	PM10 (μg/m3)
0-50	Good	0-15.4	0-54
51-100	Moderate	15.5-40.4	55-154
101-150	Unhealthy for sensitive groups	40.5-65.4	155-254
151-200	Unhealthy	65.5-150.4	255-354
201-300	Very unhealthy	150.5-250.4	355-424
>300	Hazardous	>250.4	>424

The World Health Organization (WHO) estimates that 800,000 deaths occur each year due to particulate matter exposure (WHO, 2002). In terms of the relations between particulate matter and worker health, there are many studies conducted in the past. A study conducted in 19 European cities estimated that a reduction in PM10 concentrations of only 5 μg/m3 would prevent 3300 to 7700 deaths per year (Medina et al., 2004). Most of the epidemiological literature has found an association between increased fine particulate air pollution (PM2.5) and acute and chronic deaths. In a study conducted in the USA, annual city-specific PM2.5 concentrations were measured between 1979 and 1988 and estimated from publicly available data for subsequent years. Mortality rates were estimated with the Cox proportional hazards model used for individual risk factors. An increase in overall deaths was found associated with every 10 μg/m3 increase in PM2.5, modeled as the overall mean or year of death exposure. PM2.5 exposure has been associated with lung cancer and cardiovascular deaths. It was observed that with decreasing PM2.5 concentrations, the risk of death was also reduced. The study states that, in contrast to what was observed in the mid-1970s and mid-1980s, the reduction in PM2.5-related mortality in the 1990s was mainly due to reductions in environmental concentrations of PM2.5 (Laden et al., 2006). These results suggest that the effect of PM2.5 on mortality may be due to acute rather than chronic exposure.

Long-term exposure to air pollution from fine particulate matter (PM) has been associated with common causes of death. Vital status, risk factor, and cause of death data collected by the American Cancer Society as part of the Cancer Prevention II study were found to correlate with air pollution data from United States metropolitan areas (Pope III et al., 2004). Long-term exposures to PM have been strongly associated with ischemic heart disease, arrhythmia, heart failure, and death from cardiac arrest. For these cardiovascular causes of death, an increase in fine PM of 10 μg/m3 was associated with an 8% to 18% increase in risk of death, and similar or greater risks were observed for smokers compared to non-smokers. Air pollution from fine particulate matter is a risk factor for cardiovascular disease deaths. Although smoking is a much greater risk factor for cardiovascular disease deaths; exposure to fine particulate matter produces effects that appear to be at least additive, if not synergistic with smoking (Pope III et al., 2004). An increase of 10 μg/m3 in PM10 was reported to show increases of 3.5% and 4.1% in total death and cardiovascular deaths, respectively.

Researchers note that cardiovascular deaths are increased even at low particulate matter levels (Pönkä et al., 1998).

2.3. Carbon Monoxide (CO)

Different substances such as gas, steam, smoke and fog pollute the air of the working environment. When these substances reach high concentrations, they become harmful to human health (Aksüt et al., 2020). The main gases polluting the air include carbon monoxide (CO), sulfur oxides, hydrocarbons and nitrogen oxides. Pollutant resulting from combustion; fuel type and amount, combustion system characteristics and meteorological conditions. Gases such as CO and nitrous oxide are often mixed into the air from the waste exhaust gases. CO is very dangerous especially because of its rapid mixing with the blood. The binding speed of CO gas to hemoglobin in the blood is 200 times faster than oxygen. In case of high CO concentration in the blood, the distribution of oxygen throughout the body is prevented (Aytaç and İlkılıç, 2019). Therefore, although the first effect is seen in the blood, the internal organs are also affected. The effects of CO gas on human health are given in Table 4.

As a result of CO exposure, milder cardiovascular and neurobehavioral effects can be seen at low concentrations, and different health effects can be seen at higher CO concentrations, ranging from unconsciousness and death after acute or chronic exposure. Early symptoms of CO poisoning can be listed as headache, dizziness, weakness, nausea, confusion, disorientation and visual disturbances. It has been stated that sudden deaths are most likely of cardiac origin because myocardial tissues are highly sensitive to the hypoxic effects of CO. On the other hand, perhaps the most insidious effect of CO poisoning was explained as the development of neuropsychiatric disorder occurring within 2-28 days after poisoning and the slow resolution of neurobehavioral consequences. CO poisoning occurs frequently and has serious consequences, including sudden death (Raub et al., 2000).

Table 4. Effects of CO levels on human health (Kök, 2020)

CO (ppm)	Symptoms
35	It is the maximum limit value allowed by OSHA in 8-hour shifts and does not cause any health problems. This value is accepted as 10 ppm by WHO.
200	When exposed for 2-3 hours, it causes mild headache, weakness, nausea and dizziness, drowsiness.
400	Severe intense headache and other symptoms appear more severe after 1-2 hours of exposure, and life-threatening after 3 hours.
800	Weakness, nausea, shaking, convulsions after 45 minutes of exposure, loss of consciousness and consciousness after 2 hours of exposure, death after 3 hours of exposure.
1600	Headache, weakness, nausea within 20 minutes. Death within 1 hour.
3200	Headache, weakness and nausea after 5-10 minutes of exposure, death within 1 hour.
6400	Headache, weakness and nausea within 1-2 minutes, death within 5-30 minutes.
12800	Danger of death after 1-3 minutes of exposure.

Carbon monoxide gas is a risk factor that can be encountered during forestry work. In forestry works where chainsaw or machine use is intense, carbon monoxide resulting from exhaust waste can be dangerous. Hooper et al. (2017) measured the CO concentration in the breathing zone of their operators during chainsaw operations and investigated potential effects on CO exposure levels. Operators who have been exposed to CO at different working stages have been examined and it has been reported that in some cases, CO has reached concentrations that will seriously affect human health.

3. Risk Assessment Method

Within the scope of the study, Fine Kinney method, one of the well-known risk assessment methods, was discussed. The Fine Kinney method is a quantitative risk assessment method developed by Kinney and Wiruth (1976). In this method, three parameters (probability, frequency, severity) are taken into account for each detected hazard. Then, these parameters are multiplied to obtain the “Risk Score” as shown in Equation 1 (Kinney and Wiruth, 1976). The evaluation tables of the parameters used to calculate the risk score are shown in Table 5-7. The risk score table is given in Table 8.

$$Risk\ Score = Probability \times Frequency \times Severity \quad (1)$$

Table 5. Probability Scale of Fine-Kinney Method (Kinney and Wiruth, 1976)

Probability	Value
Virtually impossible	0.1
Practically impossible	0.2
Conceivable but very unlikely	0.5
Only remotely possible	1
Unusual but possible	3
Quite possible	6
Might well be expected	10

Table 6. Frequency Scale of Fine-Kinney Method (Kinney and Wiruth, 1976)

Frequency	Value
Very rare	0.5
Rare	1
Unusual	2
Occasional	3
Frequent	6
Continuous	10

Table 7. Severity Scale of Fine-Kinney Method (Kinney and Wiruth, 1976)

Severity	Value
Noticeable	1
Important	3
Serious	7
Very serious	15
Disaster	40
Catastrophe	100

Table 8. Risk Scale of Fine-Kinney Method (Kinney and Wiruth, 1976)

Risk Scale	Risk Value
<20	Risk; perhaps acceptable
20-70	Possible risk; attention indicated
70-200	Substantial risk; correction needed
200-400	High risk; immediate correction required
>400	Very high risk; consider discontinuing operation

Possible risk outcomes are graded by the Fine Kinney method. In case of detecting a danger, the severity of the damage or damage to the human, workplace and environment is evaluated. It is a common and practical to implement this method. Then, the urgency of the measures to be taken can be determined by looking at the high risk value and the order of importance can be determined according to the risk level.

4. Conclusions

Noise, particulate matter and CO can be shown among important risk factors with serious effects on forest workers health during forest operations. In many studies, these factors that affect people mentally or physically are frequently encountered during forestry production works. The operators or workers should be aware of these factors during the work, and properly use the personal protective equipment against such risk factors. This may require to include risk factors into the occupational education and vocational training of forest workers. In forestry operations, which generally have a high level of danger, other factors affecting worker and operator health apart from accidents and injuries can cause significant health problems for workers in the long run. Thus, people in this occupational group should be checked by a doctor regularly. Besides, education on worker health should be provided along with the necessary vocational training. Finally, forest workers should be encouraged to use personal protective equipment and it should be inspected by the supervisors in the field.

Ethics Committee Approval: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept: İ. T. and A.E.A; Design: A.E.A. and İ.T.; Supervision: A.E.A. and İ.T.; Resources: A.E.A. and İ.T.; Data Collection: İ.T.; Analysis: A.E.A and İ.T.; Literature Search: İ.T..; Writing Manuscript: A.E.A. and İ.T.; Critical Review: A.E.A.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support

Cite this paper as: Taş, İ., Akay A.E., 2022. Evaluation of Various Risk Factors Caused by Mechanized Equipment Used in Forest Operations , *European Journal of Forest Engineering*, 8(1):40-45.

References

Aksüt, G., Eren, T., Tüfekçi, M. 2020. Classification of ergonomic risk factors: a literature review. *Ergonomic,* 3(3): 169-192.

Aytaç, Z., İlkılıç, C. 2019. The Investigation of Decrease Harmful Exhaust Emissions on a Diesel Engines. In 4th International Symposium on Innovative Approaches in Engineering and Natural Sciences. 22-24 November, Samsun, Türkiye.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S. 2014. Auditory and non-auditory effects of noise on health. *The lancet,* 383(9925): 1325-1332.

Güler, Ç., Çobanoğlu, Z. 1994. Noise. Environmental Health Core Resource Series, 19.

Güvercin, Ö., Aybek, A. 2003. Noise Problem in Stone Pulverizing and Sieving Plants. *KSU J. Science and Engineering.* 6(2): 101-107.

Hooper, B., Parker, R., Todoroki, C. 2017. Exploring chainsaw operator occupational exposure to carbon monoxide in forestry. *Journal of occupational and environmental hygiene,* 14(1): D1-D12.

Kinney, G. F., Wiruth, A. D. 1976. Practical risk analysis for safety management. Naval Weapons Center China Lake CA. 21 p.

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.

Laden, F., Schwartz, J., Speizer, F.E., Dockery, D.W. 2006. Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities study. *American journal of respiratory and critical care medicine*, 173(6): 667-672.

Medina, S., Plasencia, A., Ballester, F., Mücke, H. G., Schwartz, J. 2004. Apheis: public health impact of PM10 in 19 European cities. *Journal of Epidemiology & Community Health,* 58(10): 831-836.

Osada, Y. 1988. An overview of health effects on noise. *Journal of sound and vibration*, 127(3): 407-410.

Pope III, C. A., Burnett, R. T., Thurston, G. D., Thun, M. J., Calle, E. E., Krewski, D., Godleski, J. J. 2004. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation*, 109(1): 71-77.

Pönkä, A., Savela, M., Virtanen, M. 1998. Mortality and air pollution in Helsinki. *Archives of Environmental Health: An International Journal,* 53(4): 281-286.

Raub, J. A., Mathieu-Nolf, M., Hampson, N. B., Thom, S. R. 2000. Carbon monoxide poisoning—a public health perspective. *Toxicology,* 145(1): 1-14.

Official newspaper 2013. Regulation on Protection of Employees from Risks Related to Noise. T. C. Official newspaper, 28721, 28 July, 2013.

Serin, H., Akay, A. E. 2018. Analysis of Noise Level During Logging. 14. National Ergonomics Congress, 30 October-1 November, Trabzon, Türkiye.

Taş, İ., Akay, A.E. 2019. Analysis of Dust Exposure during Chainsaw Felling Operations. V. Science Technology and Innovation Congress, 17-21 April, Alanya, Antalya.

Toprak, R., Aktürk, N. 2004. The negative effects of noise on human health. *Turkish Journal of Hygiene and Experimental Biology*. 61(1), 49-58.

Tunay, M., Melemez, K. 2008. Noise induced hearing loss of forest workers in Turkey. *Pakistan Journal of Biological Sciences,* 11(17): 2144-2148.

Url-1 https://aqs.epa.gov/aqsweb/documents/codetables/aqi_breakpoints.html Last Access: 10/06/2022

Watts, G. R. 1995. A comparison of noise measures for assessing vehicle noisiness. *Journal of sound and vibration,* 180(3): 493-512.

World Health Organization. 2002. The world health report 2002: reducing risks, promoting healthy life. World Health Organization. 248 p.

Zencirci, S.A., Işıklı, B. 2017. Air Pollution. *Journal of Public Health of the Turkish World. Application and Research Center.* 2(2): 24-36.