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EXAMINING THE CHANGES IN THE AMOUNTS OF $PM_{2.5}$, PM_{10} AND CO_2 IN THE ENVIRONMENT IN DEBARKING OPERATIONS

ISPITIVANJE PROMJENA U KOLIČINAMA $PM_{2,5}$, PM_{10} I CO_2 U OKOLIŠU TIJEKOM POSTUPKA OTKORAVANJA

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SUMMARY

One of the most time-consuming stages in the production of coniferous trees is debarking of the logs. During debarking with a chainsaw apparatus, many air pollutants such as bark residues, dust, sawdust, fuel material, etc. are released into the environment. This situation reduces the air quality for the workers. This study aims to investigate the impact of the debarking process on worker health and environmental impacts in coastal pine plantations in Sarıyer region. The air pollution parameters $PM_{2.5}$, PM_{10}, CO_2 and HCHO levels during the debarking process were measured using a Temtop M2000 air quality meter. The results showed that when comparing these values to standard air quality metrics, it is clear that the peak values of $PM_{2.5}$, PM_{10}, and CO_2 (247 µg/m3, 411 µg/m3, and 2549 ppm, respectively) result in a "Very Unhealthy" environment. The average values for all three parameters (83.91 µg/m3, 121.69 µg/m3, and 614.19 ppm, respectively) are classified as "Unhealthy" for $PM_{2.5}$, and "Moderate" for PM_{10} and CO_2. The study results emphasize that the log debarking process is associated with bark volume, CO_2 release and $PM_{2.5}$ levels. Therefore, it is vital that workers in harvesting use maximum protective equipment, especially respirators. There is also a need to raise awareness and provide training for forest workers on the use of protective equipment. These findings may contribute to the development of effective policies on the health of workers in wood production and environmental air quality.

KEY WORDS: debarking, air quality, debarking tool, timber, Temtop M2000

INTRODUCTION
UVOD

Raw wood material production is one of the most time-consuming forestry activities and consists of different stages with different characteristics. These stages include felling, delimbing, crosscutting, extraction, stacking, loading, transportation, and unloading. In Türkiye, all these stages are carried out with the help of human and machine power. Animal power used in splitting has become almost non-existent in wood production activities in recent years. In wood production activities, tree felling, branch and top removal, and lengthening activities are carried out with the help of chainsaws (Gülci et al. 2017), while debarking in coniferous forests is carried out with debarking shovels, debarking hoes, debarking knives, axes, and debarking apparatus attached to chainsaws. In addition, bark stripping operations are carried out with the help of some chemicals and also with water pressure and friction techniques (Gürtan 1969; Eker et al. 2011; Çağlar 2021).

The transition to mechanized forestry work also brings some health risks to the workers working in wood production. These factors, which pose a risk to human health and

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are mostly encountered by workers working in the forest, can be diversified as noise, waste gases, particulate matter, vibration, etc. (Taş and Akay 2022). Debarking processes vary depending on tree species, age, ecological conditions, and debarking techniques (Eker et al. 2011). In the debarking operations carried out with the apparatus attached to the chainsaw, intense dust, organic matter, and gas emerge. This intensity has been observed especially in products with high bark thickness. Operators working in debarking operations are exposed to this dense mixture when they do not use protective equipment. Exposure to wood dust in long-term work can cause asthma, lung cancer, skin and eye irritations, runny nose (Gülci et al. 2018), upper respiratory and lower respiratory tract disorders (Bishop 2021), poisoning, and allergies in the respiratory system (Arslan et al. 2010).

Particulate matter (PM), a common air pollutant, is a mixture of solid and liquid organic and inorganic matter suspended in the air. Particles vary in origin, chemical composition, and size. Size is defined as aerodynamic diameter and ranges from 0.001 to 100 µm. Particles are generally characterized as coarse (2.5-10 µm), fine (0.1-2.5 µm), and ultrafine (≤0.1 µm) (Gao et al., 2015). Coarse particles are referred to as PM_{10}, fine particles as $PM_{2.5}$, and ultrafine particles as PM_1. Particles referred to as PM_{10} can reach the upper respiratory tract in humans, while particles referred to as $PM_{2.5}$ can affect human health by reaching the lower respiratory tract (Arslan et al. 2010). There are limit values arranged in tables for air quality, which is very important for human health. When these limit values are exceeded, permanent problems for human health may arise. These limit values are shown in Table 1 (Flores et al., 2020).

PM_{10} (≤10 µm) from dust and construction cause respiratory irritation; $PM_{2.5}$ (≤2.5 µm) from vehicle exhaust and wildfires penetrate deep into the lungs; PM_1 (≤1 µm) from similar sources as $PM_{2.5}$, infiltrate cells and pose severe health risks (California Air Resources Board, 2024). Different substances such as gas, vapor, smoke, and fog pollute the air of the working environment. When these substances reach high concentrations, they become harmful to human health (Taş and Akay 2022). Carbon dioxide (CO_2), whose rate in the air is quite low compared to other gases, is currently around 400 ppm in the atmosphere. However, CO_2 levels in the atmosphere tend to increase rapidly due to the greenhouse effect (Müezzinoglu, 2000). It is a non-flammable, colorless, and odorless substance which is a result of from natural inhalation and combustion. CO_2 gas, which can be released into the air as a result of the combustion reaction of all kinds of organic matter, is present in the content of waste gases released into the air by domestic heating, exhaust gases, industrial plants, and power plants. Although CO_2 is non-toxic, it reduces the amount of available oxygen in the environment and causes suffocation due to lack of oxygen. When the CO_2 level in the environment exceeds 3500 ppm, negative health effects are observed on the nervous system, along with breathing difficulties (Menteşe and Çotuker 2021).

In this study, the amounts of $PM_{2.5}$, PM_{10}, and CO_2 in the debarking process of coniferous trees in wood production studies were measured. As a result of these measurements, the change in the amount of $PM_{2.5}$, PM_{10}, and CO_2 in the environment during debarking operations was revealed. The studies and recommendations to be carried out according to air quality changes in the working environment during debarking operations were presented.

MATERIAL AND METHOD
MATERIJALI I METODE

Study area – *Područje istraživanja*

This study was carried out in compartment number 9 located within the boundaries of Sarıyer Forest Management Directorate of Istanbul Regional Directorate of Forestry in Türkiye. Sarıyer Forest Management Directorate covers a total area of 10,543.8 ha, including 5,214.6 ha of forested area, 374.5 ha of unproductive area, 3,962.9 ha of open area, and 991.8 ha of private forests. Forest volume amounts to 217,291 m³, and the total wealth of the coppice forest volume is 49,055 m³. The total increment of the plan unit's forest is 10,646 m³, and the total increment of the coppice forest is 3,887 m³. The region is located between 41°08'13"-41°15'54" north latitude and 28°56'01"-29°06'59" east longitude (GDF 2023) (Figure 1). The size of compartment number 9, where the study was conducted, is 34.1 ha. The area cut within the compartment is a maritime pine (*Pinus maritima* Lam.) plantation.

Table 1. Air quality limit values
Tablica 1. Granične vrijednosti kvalitete zraka

$PM_{2.5}$ µg/m³	PM_{10} µg/m³	CO_2 ppm	Status	HCHO mg/m³	TVOC mg/m³	Status
0.0-12.0	0-54	0-700	Good	0-0.1	0-0.5	Safe
12.1-35.4	55-154	701-1000	Moderate			
35.5-55.4	155-254	1001-1500	Unhealthy for sensitive groups			
55.5-150.4	255-354	1501-2500	Unhealthy			
150.5-250.4	355-424	2501-5000	Very unhealthy	>0.1	>0.5	Unsafe
>250.4	>424	>5000	Hazardous			

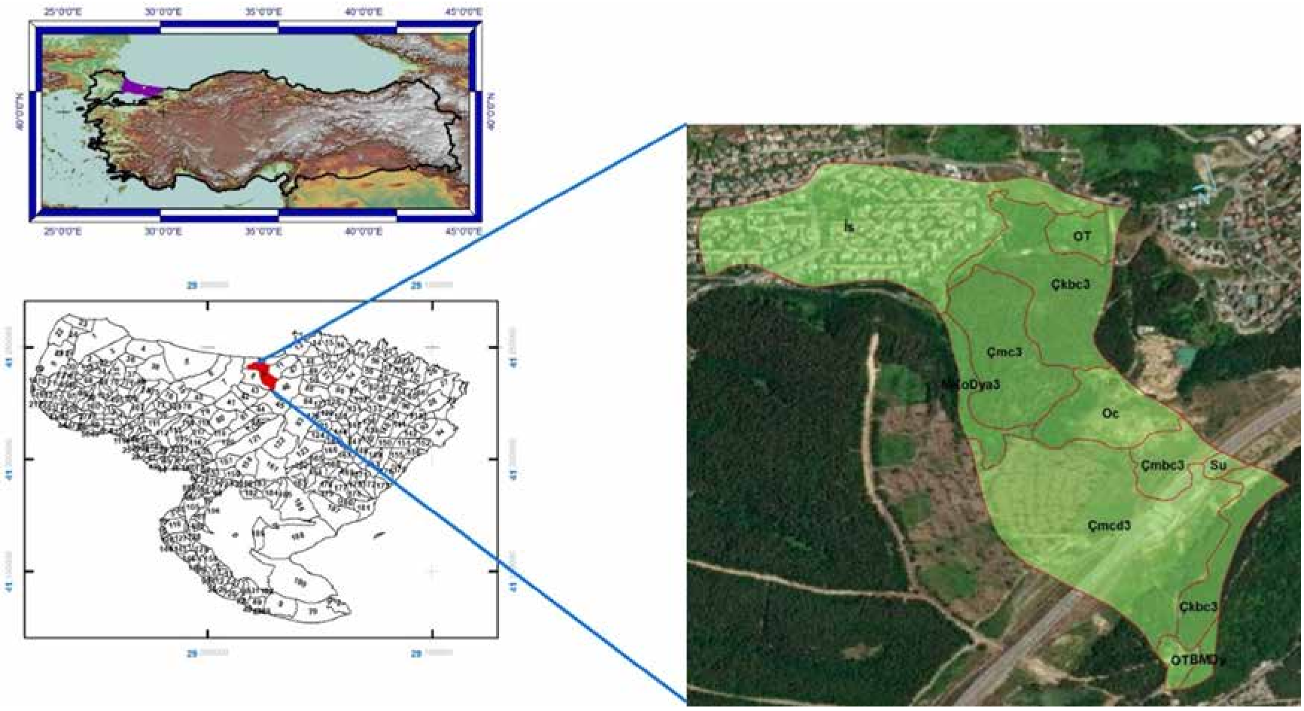

Figure 1. Study area
Slika 1. Područje istraživanja

Table 2. Technical specifications of the Husqvarna 365 chainsaw
Tablica 2. Tehničke karakteristike motorne pile Husqvarna 365

Technical specifications *Tehničke karakteristike*	Unit *Jedinica*	Technical specifications *Tehničke karakteristike*	Unit *Jedinica*
Cylinder volume (cm^3)	65.1	Bar length (min) (cm)	38
Power output (kW)	3.4	Bar length (max) (cm)	70
Tank capacity (l)	0.77	Weight (kg)	6.4
Oil depot (liter)	0.42	Sound pressure level (dB)	102.5
Chain speed (m/h)	20.7	Sound power level (dB)	114
Max. Rotation speed (rpm)	12 500	Equivalent vibration level (m/s^2)	5.7

The study was conducted between June 2023 and July 2023. Two workers were involved in the debarking of the logs. The average slope of the land within the compartment varied between 2-12%. There was a dense ground cover in the cutting compartment. Therefore, the logs were removed from the compartment to the roadside landing with the help of a tractor, and the debarking process was carried out on the roadside. Three (3) m logs and 1.25 m industrial timber were the products produced in the compartment. During the study, the humidity of the air was 65% and the wind speed varied between 0 and 5 km/h. All cut trees were healthy and there were no dead standing trees or rotten trees among the cut trees. All logs on which debarking operations were carried out were produced from healthy trees.

Figure 2. Debarking apparatus
Slika 1. Alat za otkoravanje

Technical specifications of Husqvarna 365 chainsaw and Baseh debarking tool – *Tehničke karakteristike motorne pile Husqvarna 365 i alata za otkoravanje Baseh*

In the study, Baseh apparatus was used as for debarking (Figure 2) by being mounted on Husqvarna 365 chainsaw. The technical specifications of the chainsaw and Baseh debarking tool are shown in Tables 2 and 3 (URL-1; URL-2).

Table 3. Technical specifications of the Baseh debarking apparatus
Tablica 3. Tehničke karakteristike alata za otkoravanje Baseh

Technical specifications *Tehničke karakteristike*	Unit *Jedinica*	Technical specifications *Tehničke karakteristike*	Unit *Jedinica*
Weight (kg)	2.9	Debarking width (mm)	120
Belt protection		Knife width (mm)	30
Short model	0.585	Knife number	4
Long model	0.825	Maximum cycle (rpm)	13,000
Engine power (kW)	1.6	Link rod feature	Steel

Technical specifications of Temtop M2000 air quality meter – *Tehničke specifikacije mjerača kvalitete zraka Temtop M2000*

Temtop M2000 air quality meter (Figure 3) is a $PM_{2.5}$, PM_{10}, formaldehyde, CO_2, humidity, and temperature meter. General technical specifications of the device are shown in Table 4.

Figure 3. Temtop M2000 air quality meter
Slika 3. Mjerač kvalitete zraka Temtop M2000

Table 4. Technical specifications of Temtop M2000 air quality meter
Tablica 4. Tehničke karakteristike mjerača kvalitete zraka Temtop M2000

Technical specifications *Tehničke karakteristike*	Measuring ranges *Mjerni rasponi*
M2000 model	For $PM_{2.5}$;
TFT Color LCD screen	– Measuring range: 0 – 999 µg/m^3
Battery voltage: 3.7 VDC	– Resolution: 0.1 µg/m^3
Dimension: 73.5 x 220 x 37.5 mm	For PM_{10};
Data transfer: USB	– Measuring range: 0 – 999 µg/m^3
Temparature range: 0 – 50 °C	– Resolution: 0.1 µg/m^3
Humidity range: %0-90	For CO_2;
Atmospheric pressure: 1 atm	– Measuring range: 0 – 5000 PPM
Output voltage: 5 VDC	– Resolution: 1 PPM
Output current: 1 A	For Formaldehyde (HCHO);
Rechargeable	– Measuring range: 0 – 5 mg / m^3
	– Resolution: 0.001 mg / m^3

METHODS
METODE

Data collection – *Prikupljanje podataka*

The study was carried out in the Sarıyer Forestry Management Directorate in the section numbered 9. Fifty-eight (58) coast pine logs (3 m length) were cut with a chainsaw and a study was carried out to evaluate the parameters affecting the debarking time. The diameter at mid length ($d_{0.5}$) of each timber was measured in centimeters (cm) and the length (l) was measured in meters (m). Huber's formula (2.1) (Carus 2002) was used to calculate the log volume using the mid diameter and log length. The debarking surface area (m^2) S (2.2) and bark thickness (mm) were used to calculate bark volume (2.3) (Eker and Öztürk 2022).

$$V = \frac{\pi}{4} * (d^2{}_{0.5}) * l \quad (2.1)$$

$$S = c * l \quad (2.2)$$

$$B_v = S * Bt \quad (2.3)$$

In the above equations, V is log volume (m^3), $d_{0.5}$ (cm) is diameter at mid length of the log, c is circumference of the bark (m), S is debarking surface area of the log (m^2), Bt is bark thickness (m), Bv is bark volume of the log (m^3) and l is log length (m).

Field work method – *Metoda rada na terenu*

The air quality device was placed on the operator during debarking operations. The device was placed in a pocket on the reflective vest and positioned so as not to interfere with the operator's work (Figure 4). The device, which was continuously switched on during the debarking process, continuously measured the air quality at one-minute intervals. The data collected on Temtop M2000 was then transferred to the computer via a transfer cable and evaluated. During refueling and operator rest time, the device was left on the operator and measurements were continued.

The values found during this study were compared with the air quality limit values in Table 1 in terms of their impact on human health.

Figure 4. Debarking work
Slika 4. Rad na otkoravanju

Data analysis – *Analiza podataka*

Based on the characteristics of the data, the Kolmogorov-Smirnov test was applied. According to the Kolmogorov-Smirnov test results, Debarking time (*sec*) (Dt_{sec}), Work time (*sec*) (Wt_{sec}), Timber volume (V), Bark volume (m^3) (Bv) and the features obtained with Temtop M2000 air quality meter ($PM_{2.5}$: Particulate matter of 2.5 microns and smaller, PM_{10}: Particulate matter of 10 microns and smaller, CO_2: Carbon dioxide, *HCHO*: Formaldehyde) were not normally distributed ($p<0.05$). The correlation between the properties was determined by considering Spearman's correlation coefficient used for non-normally distributed data. Multiple regression models were developed using the backward selection method with the model shown in equation 2.4, where Dt_{sec} and Wt_{sec} were created as dependent variables and other attributes as independent variables. In addition, the assumptions of the regression analysis were examined and the autocorrelation problem of the regression model was determined by the Durbin-Watson (DW) value. DW value varies between 0-4, and if it is close to 2, it indicates that there is no autocorrelation problem (Kalaycı 2006).

$$Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n + \varepsilon \qquad (2.4)$$

Where b_i represent the model coefficients, Y is Dt_{sec} or Wt_{sec}, X_i (i = 1 to n) are texture values (B_v (m^3), $PM_{2.5}$, PM_{10}, CO_2, *HCHO* and ε is the error term.

Data were separated to develop a model and to test the validity of the developed model. The model was developed with 75% of the data (43 of them). The other group comprising 25% of the data (15 of them) was used to test the validation of fitted models. The validity of multiple regression models where all parameter values were significant ($p<0.05$) was tested by the Wilcoxon signed rank test. The nonparametric Wilcoxon signed rank test was applied instead of student's t test because Dt_{sec} and Wt_{sec} were not normally distributed. Correlation analysis was obtained using the "metan" package in the R software program (R Core Team Citation 2019). IBM SPSS Statistics 29 software was used for the time prediction model and other statistical analyses. All tests were conducted at the significance level of $p<0.05$. The prediction success of the regression models was determined using Equation 2.5 Adjusted Coefficient of Determination (R^2_{adj}), Equation 2.6 Mean Absolute Error (*MAE*) and Equation 2.7 Root Mean Square Error (*RMSE*), respectively.

Adjusted Coefficient of Determination (R^2_{adj});

$$R^2_{adj} = 1 - \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 (n-1)}{\sum_{i=1}^{n}\left(Y_i - \bar{Y}_i\right)^2 (n-p)} \qquad (2.5)$$

Mean Absolute Error *(MAE)*;

$$MAE = \frac{\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|}{n} \qquad (2.6)$$

Root Mean Square Error *(RMSE)*;

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{n}} \qquad (2.7)$$

In these equations, Y_i, $\hat{Y}_i$, $\bar{Y}_i$ are the measured, estimated and average values for the time study, n is the number of observations, and p is the number of parameters of the equation.

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

Descriptive statistical information of the measurements values and calculations made with the Temtop M2000 air quality device are given in Table 5.

When the international air quality limit values given in Table 4 are compared with the values found as a result of the measurements, it was found that the maximum values of $PM_{2.5}$, PM_{10} and CO_2 (247 µg/m^3, 411 µg/m^3 and 2549 ppm, respectively) constitute a "Very Unhealthy" environment,

Table 5. Descriptive statistics
Tablica 5. Opisna statistika

Variables *Varijable*	Minimum *Minimum*	Maximum *Maksimum*	Average *Prosjek*	Std. Deviation *Stan. devijacija*
$d_{0.5}$ (cm)	21	46	28.41	5.678
V (m^3)	0.104	0.49	0.198	0.086
c(m)	0.66	1.45	0.89	0.178
S (m^2)	1.98	4.34	2.68	0.535
Bv (m^3)	0.01	0.13	0.03	0.026
$PM_{2.5}$ ($\mu g/m^3$)	26	247	83.91	57.700
PM_{10} ($\mu g/m^3$)	32	411	121.69	95.198
CO_2 (ppm)	309	2549	914.190	463.258
HCHO (mg/m^3)	0.001	0.039	0.0089	0.011
Dt_{sec} (sn)	45	273	97.45	40.138
Wt_{sec} (sn)	45	337	108.81	47.585

$d_{0.5}$: Mid diameter (*cm*), *V*: Timber volume (m^3), *c:* Circumference (*m*), *S*: Debarking surface area (m^2), *Bv*: Bark volume (m^3), $PM_{2.5}$: Particulate matter of 2.5 microns and smaller, PM_{10}: Particulate matter of 10 microns and smaller, CO_2: Carbon dioxide, *HCHO*: Formaldehyde, Dt_{sec}: Debarking time (*sec*), Wt_{sec}: Work time (*sec*)

while the average values for all three values (83.91 µg/m³, 121.69 µg/m³ and 614.19 ppm, respectively) are "Unhealthy" for $PM_{2.5}$ and "Moderate" for PM_{10} and CO_2. The HCHO value was determined to be safe throughout all measurements and it does not pose a risk to human health. The "Very Unhealthy" $PM_{2.5}$ value indicates that forest workers working in debarking operations are in a risky working environment in terms of respiratory diseases. It has been reported in various studies that such high values pose a great risk for problems in the lower respiratory tract (Gülci et al. 2018; Baldauf et al. 2006). In cases where the $PM_{2.5}$ value is high, this value must be reduced (Martins and Graca 2018).

In this study, the debarking time of a timber was measured as Dt_{sec} between 45 and 273 seconds (sec) with a mean of 97.45 sec, and Wt_{sec} between 45 and 337 sec with a mean of 108.81 sec. When Dt_{sec} and Wt_{sec} values and tree characteristics were examined for their conformity to normal distribution by the Kolmogorov-Smirnov test, all values did not show normal distribution at 0.05 significance level, Therefore, Spearman's correlation coefficient was used to determine the correlation coefficient. As a result of the correlation analysis, Dt_{sec} and Wt_{sec} values showed moderate positive correlations with *Bv* (m^3) at 0.05 significance level, while $PM_{2.5}$, PM_{10}, CO_2 and HCHO did not show significant relationships. The significant relationships with Dt_{sec} and Wt_{sec} values respectively displayed were r = 0.604 and r = 0.575. The results are given in Figure 5.

In this study, with the help of backward regression, the parameters of the regression models in which Dt_{sec} and Wt_{sec} were used as dependent and other traits as independent variables were calculated and their prediction success was determined. The parameter equations and Durbin-Watson

Figure 5. Spearman's correlation analysis. Spearman's multiple correlation plot with *R* representing correlation coefficient and *p* the statistical significance (ns > 0.05;*p < 0.05;p < 0.01; ***p < 0.001)**
Slika 5. Spearmanova korelacijska analiza. Spearmanov dijagram višestruke korelacije gdje *R* predstavlja koeficijent korelacije, a *p* statističku značajnost (ns > 0,05;*p < 0,05;**p < 0,01;***p < 0,001)

(DW) test statistic, R^2_{adj}, *MAE* and *RMSE* values and other statistical measures for these equations are presented in Table 6. When Table 6 is analyzed, the goodness of fit of the models is analyzed by *F* test and the significance of the model coefficients is analyzed by *t* test, and all parameters of the models are found to be significant at 0.05 significance level. DW test statistic values for Dt_{sec} and Wt_{sec} models are 1.733 and 1.768, R^2_{adj} values are 0.617 and 0.715, *MAE* values are 16.909 and 13.929, and *RMSE* values are 20.599 and 19.664, respectively.

Table 6. Regression analysis results
Tablica 6. Rezultati regresijske analize

No	R^2_{adj}	MAE	RMSE	F	p	b_0	b_1	b_2	b_3
Debarking time model Durbin-Watson = 1.733									
D-1	0.617	16.909	20.599	23.56	0.000	48.32***	1196.67***	-0.261*	0.030**
Work time model Durbin-Watson = 1.768									
D-2	0.715	13.929	19.664	36.09	0.000	56.81***	29080.29***	-0.356***	0.032***

ns: p>0.05, *: p<0.05, **: p<0.01, ***: p< 0.001

In order to check the validity of the models that were found to be successful according to the statistical criteria, with the help of the control data created by separating 15% of the data, the Wilcoxon signed rank test for paired samples (Wilcoxon signed rank test) compared the data obtained from the equations with the actual values and no statistical difference was found at the 0.05 level of significance (Table 7). Thus, it was decided that the established models were usable at 0.05 significance level.

Table 7. Wilcoxon signed rank test results for equations
Tablica 7. Rezultati Wilcoxonova testa ranka za jednadžbe

No	*Z*	*p*
Debarking time model		
D-1	0,738	0.852^{ns}
Work time model		
D-2	0,460	0.394^{ns}

Z: Wilcoxon signed rank test, ns: p>0.05, *: p<0.05, **: p<0.01, ***: p< 0.001

As a result of the regression analysis (Table 6), the usable forms of the statistically successful D-1 and D-2 models are given below:

$$Dt_{sec} = 48.32 + 1196.67 B_v - 0.261 PM_{2.5} + 0.030 CO_2 \quad \text{(D-1)}$$

$$Wt_{sec} = 56.81 + 29080.29 B_v - 0.356 PM_{2.5} + 0.032 CO_2 \quad \text{(D-2)}$$

According to these findings, the debarking time of a timber is affected by the bark volume of the debarking log, CO_2 and $PM_{2.5}$ released during debarking. The temporal variations of $PM_{2.5}$, PM_{10} and CO_2 values and their comparison with international threshold values are given in Figure 6, Figure 7 and Figure 8.

There were two breaks during this study. The first break started at 15.15 and ended at 15.35 (20 minutes), and the second break started at 16.19 and ended at 16.52 (33 minutes). Measurements were taken continuously at one-minute intervals, including rest intervals. Changes were observed in the air quality measurements during the debarking ope-

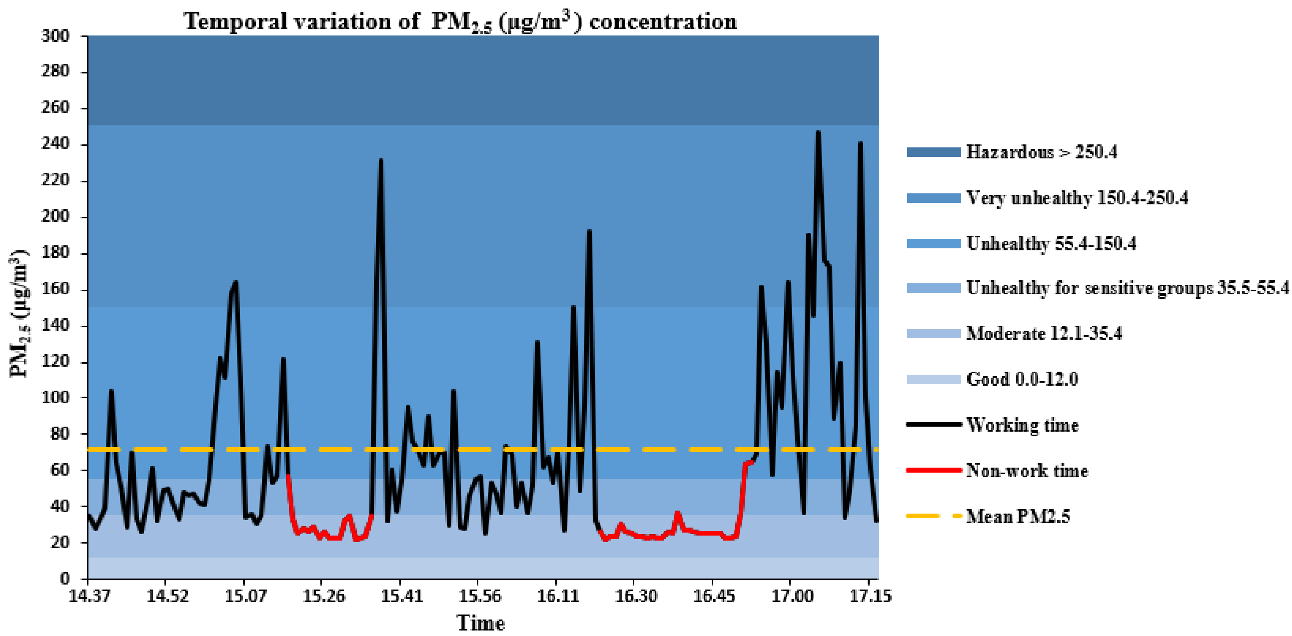

Figure 6. Temporal variation of $PM_{2.5}$ concentration
Slika 6. Vremenska varijacija koncentracije $PM_{2.5}$

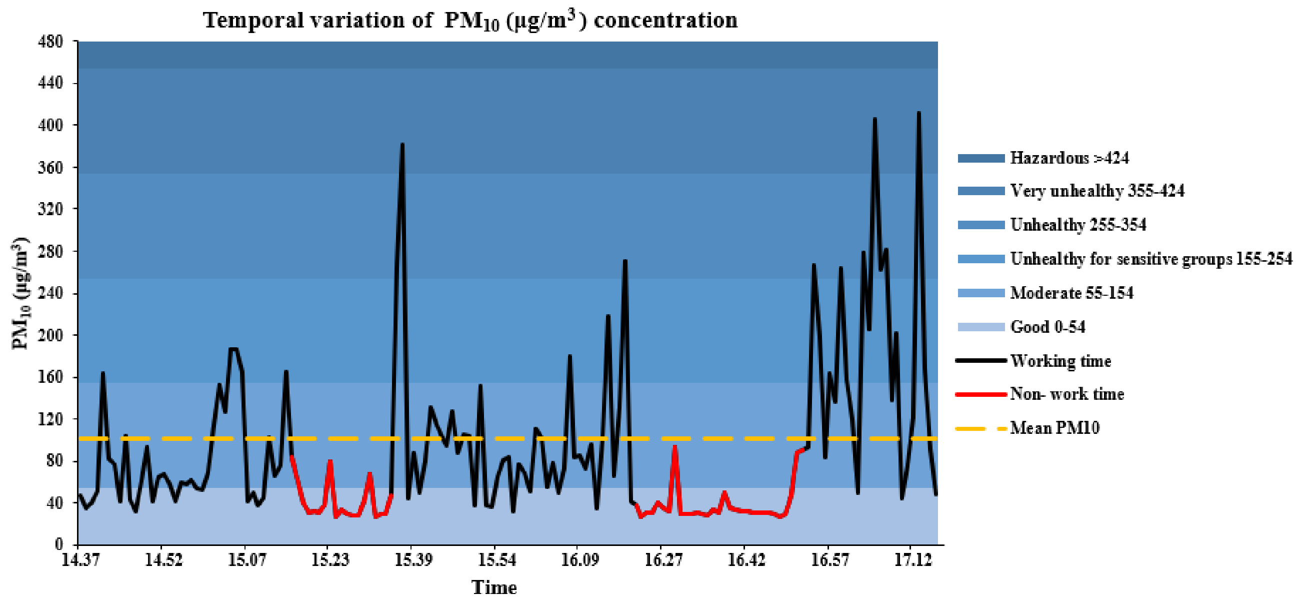

Figure 7. Temporal variation of PM_{10} concentration
Slika 7. Vremenska varijacija koncentracije PM_{10}

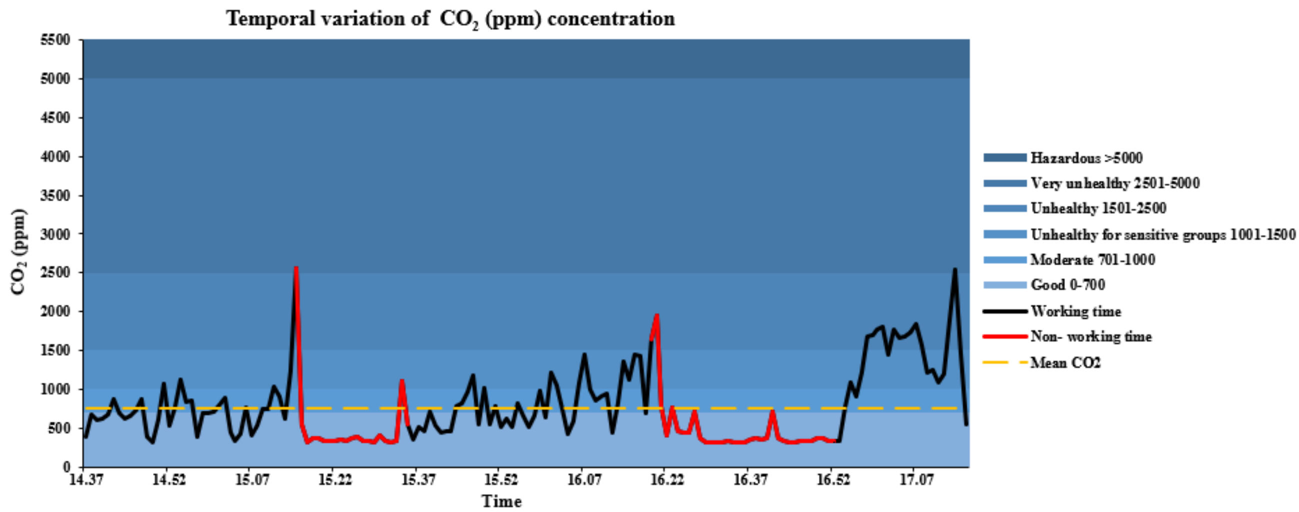

Figure 8. Temporal variation of CO_2 concentration
Slika 8. Vremenska varijacija koncentracije CO_2

rations (58 units). When the graphs in Figure 5, Figure 6 and Figure 7 are examined, it can be seen that $PM_{2.5}$, PM_{10} and CO_2 values decreased and remained approximately stable during the rest periods shown in red. Especially in the CO_2 graph (Figure 7), where the red line remains approximately straight, the CO_2 rate in the environment is within the health limits. In the $PM_{2.5}$ and PM_{10} graphs, minor peaks were observed at rest times. At the same time, looking at the last parts of the $PM_{2.5}$ and PM_{10} graphs, it can be seen that the particle values are gradually increasing. This means that the particulate matter suspended in the air increases. In a similar study conducted in agricultural fields, Jia et al. (2023) reported that as the hours of operation of agricultural machinery in wheat fields increased, the particulate matter in the field also increased.

CONCLUSIONS
ZAKLJUČCI

During these debarking activities, measurements were made with Temtop M2000 air quality meter. $PM_{2.5}$, PM_{10}, CO_2 and HCHO values were measured throughout the debarking process and various values were found. Considering these values, it was determined that the average value of $PM_{2.5}$ is an "Unhealthy" environment when compared to international threshold values. The average values of PM_{10} and CO_2 were found to be "Moderate" and the average value of HCHO was found to be "Safe". It was observed that the maximum values of $PM_{2.5}$, PM_{10} and CO_2 created a "Very Unhealthy" environment. The high $PM_{2.5}$ value indicates that particles of 1.0-2.5 microns in size are dense in the environment and that these particles may cause various disorders, especially in the lower respiratory tract of working people. It is known that if the PM_{10} value increases from "Moderate" to "Unhealthy", it may cause upper respiratory tract diseases. For this reason, work planning by considering these values is required for intensive debarking works. In the light of this study, the recommendations are listed below:

– Masks, which are best suited to trap $PM_{2.5}$ and PM_{10} particles, must be worn by workers engaged in debarking operations in Türkiye. In addition, these workers should wear protective equipment such as glasses, hard hats, gloves, and protective pants.

– During intensive debarking operations, it is necessary to increase the frequency of rest or rest time for workers. This will allow the particles in the air to disperse and settle to the ground during non-working rest hours.

– It is important for the health of the workers involved in debarking work to undergo periodic medical check-ups and to have the necessary examinations, especially in terms of upper and lower respiratory diseases.

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SAŽETAK

Jedna od najdugotrajnijih faza u proizvodnji crnogoričnog drveća je otkoravanje trupaca. Tijekom otkoravanja s uređajem na bazi motorne pile mnogi zagađivači zraka kao što su ostaci kore, prašina, piljevina, gorivni materijal i drugi ispuštaju se u okoliš, što utječe na smanjenje kvalitete zraka za radnike. Cilj ovog istraživanja je istražiti utjecaj procesa otkoravanja na zdravlje radnika i okoliš u sastojinama primorskog bora u regiji Sarıyer. Parametri onečišćenja zraka $PM_{2,5}$, PM_{10}, CO_2 i HCHO tijekom procesa otkoravanja izmjereni su pomoću mjerača kvalitete zraka Temtop M2000. Rezultati su pokazali da maksimalne razine $PM_{2,5}$, PM_{10} i CO_2 stvaraju „Vrlo nezdravo" okruženje, dok su prosječne vrijednosti bile „Nezdravo" za $PM_{2,5}$ i „Umjereno" za PM_{10} i CO_2. Utvrđeno je da su razine HCHO (formaldehida) prihvatljive za ljudsko zdravlje. Rezultati istraživanja naglašavaju da je proces otkoravanja trupaca povezan s volumenom kore, ispuštanjem CO_2 i razinama $PM_{2,5}$. Važno je da radnici tijekom rada koriste maksimalnu zaštitnu opremu, osobito maske. Potrebno je podići svijest i unaprijediti obuku šumskih radnika za korištenje zaštitne opreme. Rezultati istraživanja doprinijeti će razvoju učinkovitih politika o zdravlju radnika u proizvodnji drva i zaštiti okoliša.

KLJUČNE RIJEČI: otkoravanje, kvaliteta zraka, alat za otkoravanje, drvo, Temtop M2000