Immission of carbon monoxide and carbon dioxide during combustion of fine wood wastes

Vladimir Tomov, Anelia Nenova, Lyubomir Vladimirov

Immission of carbon monoxide and carbon dioxide during combustion of fine wood wastes: *The study aims to determine the dependencies of the imission of carbon monoxide and carbon dioxide in the firing works process. A methodology is made. There have been immission burning of fine woods. Experimental data were processed statistically and dependencies were obtained of immission control factors The risk of air pollution is sssessed.*

Key words: *risk , pollution, carbon monoxide, fire- works , wood wastes.*

The wood wastes are widely used as a solid fuel. They are used to limit the dispersion of oil materials , fuels, solvents , chemicals and other fluids . Except within the wood processing industries they are generated at construction sites and in carrying out the works. They are fire hazard, which requires compliance with specific rules for handling and storage. From their burning the atmospheric air is polluted. Wood wastes are the subject to our studies [1, 2, 3] related to determination of the risk from ignition and air pollution against fire. The laws in combustion of mixed wood wastes are established. The object of this study is air pollution caused by burning of fine wood wastes, having different behavior in ignition and combustion. The paper studies the immission of carbon monoxide and dioxide. The aim of the study is to establish the dependencies of imission of carbon monoxide change. Tasks to be solved are: 1. Development of methodology of the study; 2. Determination the imission of carbon monoxide and carbon dioxide in the combustion of fine wood wastes; 3. Output models, reflecting the dependence of the immission of controllable experimental factors; 4. Risk assessment of air pollution.

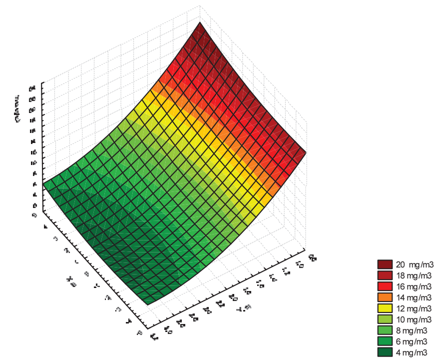


Figure 1. Dynamics of carbon monoxide immission as a function of the point of the combustion

Based on our experimental experience [1, 2, 3, 4, 5, 6], the method of modeling was applied. The experimental system, described in [1, 4] is used in creating the system to follow the idea of simulating the situations of ignition and burning caused by fire works . This class of fire ignitions are regarded as unintentional accidental initiation of ignition. Additional wood wastes are intentional, deliberaty fired. The aim was to compare two methods of initiating ignition, as in the experiments [2, 3] was identified a significant difference in the combustion of wastes.

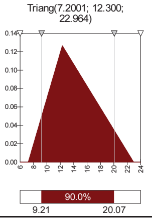
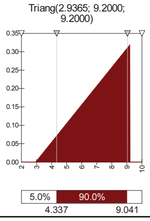
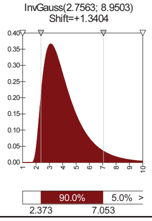
To achieve the objective of the study it was accepted a model that is applied to study the combustion of mixed wood wastes [2].

The controlling factors methodically were divided into two groups. The first group is of technological factors. It includes the typical indicators for technological operations. For inadvertent ignition of oxyacetylene cutting the factors are thickness, plain and cutting height, sheet size, pressure of oxygen, presence of reflective surfaces, cutting material. Arc welding ignition's controllable factors are welded details, angles, angles to the sheet metal, welding plane - horizontal and vertical, type of weld - front and overlap, length of the weld, the welding direction, type of the electrode, diameter of the electrode, current, high welding [1, 2, 3, 4]. The second group are the indicators of wood wastes. Such are the dispersion up to 3 mm, surface distribution of wastes 4, 6 and 8 kg/m^2, additional wetting of the spent and fresh engine oil in 100, 150 and 200 ml/kg waste, relative humidity of the waste - 35-40 %, and 45-52 %. The fractions with such dispersion is obtained by a mechanical sieve selection and the relative humidity in EN 384:2010.

Controllable factors of the experiment are: temperature T_v, relative humidity φ_v and the air velocity V_v. During the study T_v they were varied from 18.6 to 32.4 ^{0}C, and φ_v from 62.6 to 89.3 %. They were measured with Asmann type psyhrometer. Average speed V_v is of 1,8 to 4,6 *m/s*. utput parameters of the experiment are: 1) risk factors of pollution - carbon monoxide CO and carbon dioxide CO_2, 2) imissions $Izam_{CO}$ of carbon monoxide and carbon dioxide - $Izam_{CO2}$, 3) *Pпр* probability of exceeding the limits; 4) the time *Tпр* of the exceedings. Immission were measured at a height of 1,5 *m*, which was chosen to be the height corresponds to the respiration of humans. Measurements were performed by colorimetric method. Indicator tubes of Castec Co. Ltd were used.

Table 1

Theoretical models of the distribution from imissions of carbon monoxide from wood wastes having dispersion up to 3 mm burning at a surface distribution of 4 kg/m^2 without additional wetting

Y	1m	2m	3m
Model			
	Triangel distribution	Triangel distribution	Gauss ivariant distribution
Parameters	7.2001; 12.300; 22.964	2.9365; 9.2000; 9.2000	2.7563; 8.9503
Left	9.21	4.337	7.053
Left	95.00%	5.00%	95.00%
Right	20.07	9.041	7.053
Right	95.00%	95.00%	95.00%
Range	20.07	4.7043	7.053
Range	90.00%	90.00%	90.00%
Min value	7.2001	2.9365	1.3404
Max value	22.964	9.2000	+Infinity
Average	14.155	7.1122	4.0967
Mode	12.300	9.2000	3.1033
Median	13.796	7.3655	3.7350
Dispersion	3.2840	1.4763	1.5296
Вариация	10.785	2.1795	2.3396
Асиметрия	0.3209	-0.5657	1.6648
Ексцес	2.4000	2.4000	7.6193

A conditional network of rectangles with size of 1 *m*, covering an area measuring 8x8 *m* is adopted. Transverse axis is *X* and *Y*. is the longitudinal one In the central square are placed wood wastes, and over them an inadvertent ignition process is implemented. In this quadrant is deliberated the ignition. Immissions measurements are performed in the remaining squares in the combustion of waste woods.

Immission were tested as random variables. For theoretical models from the imission of pollution with carbon monoxide and dioxide statistical laws of distribution were received. Through the program Risk 4.5 of *Palisade Corporation* the following hypotheses were tested: a) discrete distributions - Poisson distribution, binomial distribution, negative - binomial, geometric, log - logistic and hypergeometric distribution, b) indiscrete law distributions: flat probability; Gamma; Normal, Triangular, Beta, Log - normal, Exponential and Logistic distribution, Weibull distribution, Relay, of Pearson, Gingel , Erlangen and Wald. Discrete distributions are used to determine the probability of wastes ignition and the indiscrete for the immissions.

The criteria for risk assessment of air pollution are: 1) the probability of contamination P_K in the range $Izam_{sr} \pm \sigma(Izam)$, where $Izam_{sr}$ is the average immission of pollutants, and $\sigma(Izam)$ is the standard deviation; 2) The number *N* of exceedances of the TLV; 3) Probability *Рпр* of exceedings the TLV in the range $Izam_{sr} \pm \sigma(Izam)$, where $Izam_{sr}$ is the average number of exceedances and $\sigma(Izam)$ - the deviation; 4) The time *Тпр* of the TLV exceedances; 5) the probability $Рпр_T$ for the time of exceeding in the range $E[T] \pm \sigma(T)$, where $E[T]$ is the average value *Тпр* of the time exceedances of TLV and $\sigma(T)$ - the deviation. The probability P_K characterizes the content of pollutants in the air. *Рпр* and $Рпр_T$ determine the level of criticalities. These criteria reflect the differential risks of exceeding the TLV.

The integral risk *Rzam* for air pollution is calculated by the product

$Rzam = Рпр.Рпр_T$,

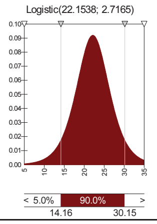
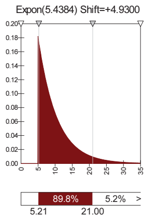
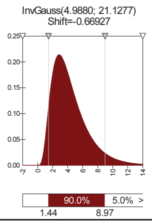
where *Рпр* is the probability of exceeding the TLV;

$Рпр_T$ is the probability of exceeding the time during the experiment.

To determine the probabilities P_K, *Рпр*, $Рпр_T$ a check on the assumption of the statistical law of distribution is made. After establishing its appearance through the Risk 4.5 probabilities are determined by the program *Razpredelenie*. The results of the study of air pollution under the above conditions of combustion of the material showed distinct patterns. Part of the results are set out in Figure 1.

Table 2

Theoretical models of the distribution from imissions of carbon dioxide from moxed wood wastes having dispersion up to 3 mm burning at a surface distribution of 6 kg/m² without additional processing

Y	1m	2m	3m
Model			
	Logistic distribution	Exponential distribution	Gauss invariantdistribution
Parameters	22.1538; 2.7165	5.4384	4.9880; 21.1277
Min value	-Infinity	4.9300	-0.66927
Max value	+Infinity	+Infinity	+Infinity
Average	22.1538	10.3685	4.3188
Mode	22.1538	4.9300	2.8559
Median	22.1538	8.6997	3.7994
Dispersion	4.9273	5.4384	2.4236
Variance	24.2780	29.5766	5.8740
Asymmetry	0.0000	2.0000	1.4577
Kurtosis	4.2000	9.0000	6.5413
Left X	14.16	5.21	1.44
Left P	5.00%	5.00%	5.00%
RIght X	30.15	21.00	8.97
RIght P	95.00%	94.79%	95.00%
Range X	15.9974	15.7910	7.5253
Range P	90.00%	89.79%	90.00%

In table 1 and 2 is represented a sample of distribution laws of immissions. It is noy able to make definitive conclusions about the prevailing laws of distribution. In immission of carbon monoxide are established Gamma, Normal, Triangular, Exponential distribution, Logistic distribution, Weibull distribution Similar are the distributions from imissions of carbon dioxide. Among them may be noted as prevalent Weibull distribution, Normal distribution, Triangular and Logistics distribution.

The number of exceedings of the TVL, is subject to the law of Poisson. With an average of exceedances greater than 9, they are an essential part of the cases то become normal law. Exceptions are established when burning wood wastes wetted with used and fresh engine oil. For them except the Poisson distribution were derived instances of binomial distribution, negative binomial, and geometric distribution. With increasing the distance from the point of combustion the immissions reduce which can be seen in Figure 1. For analytical determination of the regularities are derived mathematical models of the immissions. The program Statistika 7 is used.

The following models were obtained:

1. Inadvertent technological ignition:

- dry wood wastes :

$Izam_{CO}$ = 29.6437+0.3295X-16.0987Y+0.0515X^2-0.0809XY+2.4867Y^2;

$Izam_{CO2}$ = 47.243+0.0608X-26.0756Y-0.1406X^{2}*+0.1055XY+4.139Y$^{2;}$

- wetted wood wastes with used motor oil:

$Izam_{CO}$ = 32.1426+0.4015X-13.2877Y+0.0371X^2-0.0617XY+1.6217Y^2;

$Izam_{CO2}$ = 54.7118+0.07310X-21.8233Y-0.1891X^{2}*+0.1701XY+2.8801Y$^{2;}$;

- wetted wood wastes with fresh motor oil:

$Izam_{CO}$ = 35.8823+0.3491X-13.5177Y+0.0291X^2-0.0380XY+1.6691Y^2;

$Izam_{CO2}$ = 44.9288+0.0426X-22.7129Y-0.11037X^{2}*+0.1271XY+3.0271Y$^{2;}$;

2. Deliberated ignition:

- dry wood wastes :

$Izam_{CO}$ = 41.6117+0.3472X-17.7281Y+0.1827X^2-0.1272XY+2.2201Y^2;

$Izam_{CO2}$ = 48.8222+0.1982X-22.8827Y-0.1928X^{2}*+0.1591XY+4.0651Y$^{2;}$

- wetted wood wastes with used motor oil:

$Izam_{CO}$ = 31.2762+0.3517X-14.2341Y+0.0291X^2-0.0452XY+2.2061Y^2;

$Izam_{CO2}$ = 44.9102+0.08911X-25.1226Y-0.1672X^{2}*+0.1701XY+2.0181Y$^{2;}$;

- wetted wood wastes with fresh motor oil:

$Izam_{CO}$ = 34.2214+0.4171X-15.7122Y+0.0891X^2-0.1102XY+1.8271Y^2;

$Izam_{CO2}$ = 49.8971+0.0921X-21.0817Y-0.1102X^{2}*+0.1301XY+5.0281Y$^{2;}$;

It has been found that the immission of the carbon monoxide are increased by 1.6 to 2.7 times with larger amounts of the surface distribution of the wastes. Carbon dioxide is affected to a lesser extent, from 0.8 to 1.4 times. In intentional combustion the ingnition is more intensive and the immissions are greater. It is found to be more intense effect of wetting with oil. Comparing the results with previous studies, it is noteworthy that the finely dispersed wastes receive smaller amounts of immissions, but for a long time. Burning is slower. Burning time varies depending on the mode of the ignition. It can not be precisely established. It is not possible to determine the influence of the weather conditions in natural experiments, as their only parameters are controllable factors. Technological factors strongly influence the ignition of the wastes, as it is more risky for oxyacetylene cutting.

Differential risk of exceeding *Рпр* (Table 3) was higher for contamination with carbon monoxide until the differential risk $Рпр_T$ has a higher value at the carbon dioxide. Integral risk of carbon dioxide is higher. Compared with mixed wood wastes the risks at fine wastes is higher, which can be explained by differences in the combustion process.

Table 3

Risks of burning of fine wood wastes

Pollutant	Differential risk		Integral risk
	Рпр	$Рпр_T$	*Rzam*
Dry wood wastes			
Carbon oxide	0,6347	0,2783	0.1766
Carbon dioxide	0,5618	0,5715	0.3210
Wood wastes, wetted with fresh macine oil			
Carbon oxide	0,6917	0,4261	0.2947
Carbon dioxide	0,6302	0,6702	0.4223

The above shows the following conclusions.

There have been immission of carbon monoxide and carbon dioxide through a method that allows control of the main experimental factors. Mathematical models are derived from the imissions as a function of the distance. They allow determining the safety margin to implement offsite protection and individual protection. Through the differential and integral risks it is able to determine the degree of security in the combustion zone of fine wood wastes and the environmental impact. Risks allow sufficient reliable evaluation of the contamination process. It is necessary to examine the entire spectrum of contreollable factors that would allow to create regulations for risk management against fire works.

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Contacts:

Professor, DSc. Vladimir Tomov, Varna Free University, tel +359 888 555 628, e-mail: tomovvlado@abv.bg.

Associate professor, DSc. Lyubomir Vladimirov, Ruse University, tel +359 82 888 481, e-mail: lvvladimirov@uni-ruse.bg.

The report was reviewed.