EVALUATION OF KOLUBARA LIGNITE CARBON EMISSION CHARACTERISTICS

by

Predrag Lj. STEFANOVIĆ, Zoran J. MARKOVIĆ** *, **Vukman V. BAKIĆ, Dejan B. CVETINOVIĆ, Vuk D. SPASOJEVIĆ, and Nikola V. ŽIVKOVIĆ

Laboratory for Thermal Engineering and Energy, Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

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The revised Intergovernmental Panel on Climate Change guidelines for national greenhouse gas inventories recommends that more comprehensive and thus more reliable characteristics of the local fossil fuels should be used for the national greenhouse gas inventory calculations. This paper deal with the carbon emission characteristics of low-calorific lignite recovered from the Kolubara open-pit mine. The samples of coal were carefully selected in order to cover the net calorific value, ash and water content of the broad spectrum of the quality of the raw lignite supplied to the Serbian thermal power plants. Correlation analysis of the laboratory analysis data gave a linear dependency of the net calorific value on the combustible content in the coal samples. Also, linear correlation between the carbon content and the net calorific value was found. The regression analysis of experimentally determined coal characteristics implies that the carbon emission factor is dependent on the net calorific value. For the subset of raw lignite samples with the net calorific value Q_d^r *= 6-10 MJ/kg, that is most representative for current and near future use for power generation in Serbian thermal power plants, the linear dependency* CEF^r *(tC/TJ) = 34.407 – 0.5891·*Q_d^r *MJ/kg was proposed. Regarding the net calorific ranges of samples examined, the raw Kolubara lignite carbon emission factor is considerably higher than those recommended by Intergovernmental Panel on Climate Change Tier 1 method of 27.6 tC/TJ.*

Key words: *greenhouse gases inventory preparation, Kolubara mine low-calorific lignite, carbon emission factor estimation*

Introduction

The problem of climate change as a result of increased concentration of greenhouse gases (GHG) in the atmosphere due to anthropogenic activities, could become very serious in this century if the energy emission of GHG and tropical deforestation will not be limited and decreased in the near future. A recent report of the Intergovernmental Panel on Climate Change (IPPC) [1] predicts, according to the worst-case scenario, an increase in the average air temperature ranging from 1.1 to 6.4 °C in this century which has the potential to cause irreversible impact on ecosystems, biodiversity, water supply, food and energy industries, economic development and global stability.

* Corresponding author; e-mail: zoda_mark@vinca.rs

United Nations Framework Convention on Climate Change (UNFCCC) adopted in Rio de Janeiro in 1992 [2] defined the principles of global action against the climate change while Kyoto Protocol to the Convection defined the obligations of developed (Annex I Parties) and developing countries (Non Annex I Parties) in the period up to 2012. Having ratified the Kyoto Protocol [3], Serbia as a developing country (Non Annex I Party) has committed to the international co-operation in the field of climate research with the obligation of reporting National Communications to the UNFCCC, but without obligations to reduce GHG emission. The European Union (EU) with Member States (as Annex I Parties of the Kyoto Protocol) have realised lot of significant measures to reduce GHG emission. Besides others, implementation of the Directive 2003/87/EC *i. e.* European Emission Trading Schema (ETS) is one of the most cost-effective measures for the realisation of the committed GHG reduction obligations. Based on positive example [4-7] it is clear that Serbia as a candidate for the EU membership will have much to improve of its capacity (to prepare legislation and institutions) for the full implementation of the EU energy-climate package [8] including implementation of the new ETS Directive 2009/29/EC. Therefore, precise annual inventory of the GHG emissions, especially in the energy sector become one of the Serbia's major objectives on its path to EU membership.

Low calorific, open-pit mined lignite is the basic energy source of the Republic of Serbia, with a share of nearly 50% in the total primary energy consumption and over 70% in the power generation. Emissions of CO_2 from lignite combustion have a dominant share of more than 40% in total emission of GHG from anthropogenic sources in Serbia [9]. The biggest lignite consumer at national level, the TPP "Nikola Tesla" of the Public enterprise "Electric Power Industry of Serbia" (PE EPS) are not equipped with adequate on-line CO_2 emission measuring systems. For calculation method of the annual emission of CO_2 besides lignite consumption and its net calorific value, data on carbon content, *i.e.* carbon emission and oxidation factor *i. e.* actual combustion conditions are necessary. According to the internationally recommended methodology [10-12], first order estimation (Tier 1 method) of the CO_2 emissions by fuel combustion is calculated as the product of the fuel consumption, recommended net calorific value and the default carbon emission and oxidation factor (or default CO_2 emission factor) for each fuel type (commercial fuels, bituminous coal, sub-bituminous coal, lignite, *etc.*) which could be acceptable method for most developing countries. But recommended net calorific values for the same coal rank vary between countries. The greatest differences are observed for lignite, where recommended values range from 4.19 MJ/kg (Israel), 5.74 MJ/kg (Greece), 8.89 MJ/kg (the ex-Yugoslavia) to 14.25 MJ/kg (Canada), 14.65 MJ/kg (Russia, Ukraine, Kazakhstan, and Kyrgyzstan), 17.17 MJ/kg (Chile), and 17.94 MJ/kg (France) [10, 11]. However, the recommended value of carbon emission factor (*CEF*) for lignite is the same for all countries: 27.6 tC/TJ. It is obvious that such a concept of general values, although much simpler and thus more suitable for GHG inventories, could lead to fallacy concerning CO_2 emission, especially in the case of Serbia [13, 14]. Lignite types from the central and south-eastern Europe open-pit mines are also characterized by the significant divergence from recommended values [15-17]. To overcome such problems, all international guidelines suggest using higher Tier estimation based on country-specific or even district-specific *CEF* values for coal, if appropriate information is available.

This paper presents first results of the raw lignite samples from Kolubara open pit--mine emission characteristics evaluation which should be systematically recorded in the future according to EU legislative [12]. The linear correlations between the lignite characteristics: net calorific value, hydrogen content, carbon content, and the combustible matter content was experimentally determined, based on laboratory analyses of representative lignite samples prepared as a reference base for the on-line coal quality system implementation [18, 19]. The linear correlation between the carbon content and the net calorific value of the representative raw and dry lignite samples was also experimentally determined. Based on these data the carbon emission factor – net calorific value correlation for the Kolubara lignite was determined and compared with literature data for the similar coal qualities [15, 17].

Kolubara lignite *CEF* evaluation

Three open-pit lignite mines have been in service in Serbia: Kolubara (with production up to 30 million tons per annum) [11], Kostolac (up to 9 million tons), and Kosovo (up to 8.5 million tons). The biggest coal basin is the Kolubara with a total share on the national level of near 64%. The lignite from the open-pit mines is predominantly (as much as 90% of the total annual production) used as a fuel in domestic heat and power generation. Total electric power of thermal power plants within PE EPS, that use raw lignite from Kolubara basin, exceeds 3000 MW with annual power generation up to 20 TWh.

Comprehensive studies of the raw lignite characteristics, from open-pit mines of Kolubara, Kostolac, and Kosovo basin, were made on several occasions during the past 50 years. In general, the Kolubara basin lignite is characterized by the low level of carbonization (at the stadium of the soft brown coal) that is unevenly widespread among the coal fields. Evaluation of the carbon emission characteristics of Kolubara basin lignite presented in this paper, are based on laboratory data from one of the newest studies [18]. Namely, problem of lignite quality oscillations due to complex geological coal profile in Kolubara basin [14] and used high productive mining equipment based on bucket wheel excavators, have to be solved by selective excavation followed by homogenization. For the implementation of modern coal quality system in Kolubara open-pit mine, on-line lignite characterisation (at least moister and ash content determination) is needed. For the on-line coal quality system implementation, 30 representative lignite samples were taken with specific care to the coal sampling in order to ensure the simulation of wide spectra of the lignite qualities that are combusted in the TPP "Nikola Tesla", Obrenovac, Serbia. Samples extraction and selection from the area were lignite will be excavated in at least next 10 years, was based on data from previous geological investigations. Sampling and preparation of the representative samples according to ISO 5069 and ISO 1988 standards was done during the period July-August 2007 from the two largest parts of the Kolubara basin: the western part "Tamnava west field" (20 samples) and from the eastern part "Field D'' (10 samples) and characterised in the accredited (according to ISO/IEC 17025) laboratories of the Vinča Institute of Nuclear Sciences, Belgrade. Besides complete proximate and ultimate analysis of the coal samples, complete chemical analysis of the ash (including macro and micro heavy metals content), ash fusion characteristics and natural radioactive characteristics of the coal samples were determined according to appropriate standards [18].

According to the results of the proximate analysis, the wide range of the water content (W^r = 31-52%), the ash content (A^r = 6.9-48.2%), fixed carbon content ($C_{fix}{}^r$ = 5.8--20.4%), volatile content (V^r = 14.6-24.5%), combustible (20.9-42.6%), gross calorific value ($Q_g{}^r$ = 3813-11594 kJ/kg), and the net calorific value ($Q^r{}_d$ = 2847-9939 kJ/kg) levels were established. Accordingly, ultimate analysis revealed the wide range of carbon (C^r = 10.28-

-28.57%), hydrogen (H^r = 1.23-2.52%) and combustible sulphur ($S_S{}^r$ = 0.06-1.04%) content in the raw coal samples. Results of proximate and ultimate analysis for thirty raw lignite representative samples are summarized in tab. 1.

Table 1. Results of proximate and ultimate analysis of Kolubara basin lignite samples

Parameter	Proximate analysis							Ultimate analysis			
	W^r	A^r	$C_{fix}{}^r$	V^r	Combustible	$Q_g{}^r$	$Q_d{}^r$	C^r	H^r	$S_s{}^r$	N^r+O^r
	[%]	[%]	[%]	[%]	[%]	[kJkg^{-1}]	[kJkg^{-1}]	[%]	[%]	[%]	[%]
Sample #											
1	43.81	28.94	10.58	16.68	27.25	6808	5464	16.73	1.63	0.25	8.64
2	46.56	27.37	9.35	16.72	26.07	6134	4744	15.61	1.56	0.15	8.75
3	43.22	30.76	9.79	16.23	26.02	5903	4605	15.29	1.46	0.28	8.99
4	50.35	22.40	10.62	16.63	27.25	6749	5259	16.77	1.60	0.14	8.74
5	49.66	19.42	10.53	20.39	30.92	7859	6339	19.59	1.83	0.13	9.37
6	45.45	22.16	14.35	18.04	32.39	8261	6812	20.97	1.95	0.20	9.27
7	49.99	18.80	11.70	19.51	31.21	7771	6243	19.28	1.83	0.25	9.85
8	51.23	11.58	14.63	22.56	37.19	9889	8261	24.63	2.17	0.15	10.24
9	50.34	12.06	14.80	22.80	37.60	9948	8336	24.61	2.20	0.13	10.66
10	42.83	34.46	8.07	14.64	22.71	5116	3848	13.23	1.36	0.18	7.94
11	37.44	37.70	9.02	15.79	24.86	5748	4580	14.26	1.49	0.31	8.80
12	44.83	27.30	10.80	17.07	27.87	6703	5317	16.96	1.71	0.22	8.98
13	47.03	20.81	13.39	18.77	32.16	8219	6745	20.55	1.90	0.18	9.53
14	48.95	19.98	11.40	19.67	31.07	7854	6347	19.64	1.85	0.11	9.47
15	45.47	19.38	13.77	21.38	35.15	8851	7396	22.01	2.11	0.25	10.78
16	50.24	13.89	13.50	22.37	35.87	9395	7808	23.22	2.11	0.24	10.30
17	48.97	17.01	14.47	19.55	34.02	8880	7331	22.10	2.05	0.14	9.73
18	51.70	14.67	14.72	18.91	33.63	8696	7097	21.59	1.99	0.20	9.85
19	46.28	19.58	13.37	20.77	34.14	8759	7281	21.86	2.00	0.21	10.07
20	45.29	19.26	13.14	22.31	35.45	8947	7465	22.18	2.13	0.11	11.03
21	40.30	26.64	12.73	20.33	33.06	8367	7031	21.03	1.99	0.06	9.98
22	44.80	24.98	12.88	17.34	30.22	7761	6366	19.52	1.77	0.40	8.53
23	40.30	25.45	13.97	20.28	34.25	8893	7539	22.29	2.08	0.22	9.66
24	45.70	18.12	14.63	21.55	36.18	9458	7960	23.56	2.18	0.07	10.37
25	47.90	15.28	17.56	19.26	36.82	9652	8105	23.93	2.16	0.36	10.37
26	47.30	20.65	14.10	17.95	32.05	8204	6725	20.45	1.90	1.04	8.66
27	49.50	7.88	20.38	22.24	42.62	11594	9939	28.57	2.51	0.35	11.19
28	50.70	6.92	17.92	24.46	42.38	11587	9901	28.53	2.52	0.11	11.22
29	42.80	20.36	15.37	21.47	36.84	9596	8160	23.90	2.19	0.13	10.62
30	31.00	48.15	5.82	15.03	20.85	3813	2847	10.28	1.23	0.57	8.77

According to standard procedures, reproducibility of determination of the coal upper heating value is defined as a difference between two serial measurements with results lower than 120 kJ/kg under same conditions, which are conducted by same operator using the same apparatus. Regarding the whole set of samples, reproducibility of $Q_g{}^r$ determination was 97 kJ/kg, while standard deviation of the certified reference coal sample upper heating value determination is σ = 62.96 kJ/kg. The values of the reproducibility required by the governing standard, reproducibility achieved for each measured value and standard deviation of the certified reference coal sample laboratory measurements are presented in tab. 2.

Defining the percentage of the combustible content in the raw coal sample as:

$$\text{Combustible} = 100 - A^r - W^r \tag{1}$$

the regression analysis, for the data set of Kolubara lignite representative samples, gave linear correlation between the net calorific value and content of combustible matter in the coal samples (fig. 1), with coefficient of correlation $R^2 = 0.9929$:

$$Q_\mathrm{d}^\mathrm{r} = 297.8 \text{ combustible} - 2829.6 \tag{2}$$

Table 2. Achieved reproducibility of measured values

Parameter unit	Reproducibility[1] [%]	Achieved reproducibility[2] [%]	Standard deviation[3] [%]
W^r	0.2	0.13	0.080
A^r	0.2	0.11	0.094
$C_\mathrm{fix}{}^\mathrm{r}$	0.5	0.39	–
$S_\mathrm{u}{}^\mathrm{r}$	0.1	0.07	0.043
C^r	0.25	0.21	0.117
H^r	0.12	0.09	–

[1] Required by standard; [2] Achieved for each measured value of samples analysed; [3] Of the certified reference coal sample laboratory testing measurements

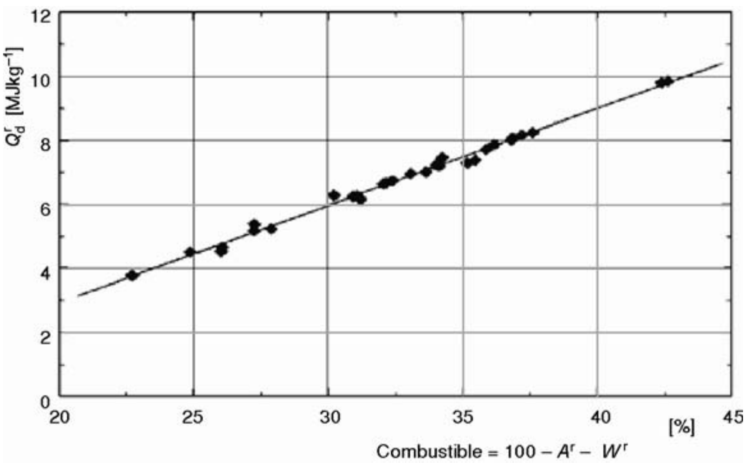

Figure 1. Correlation between the net calorific value, Q_d^r and the combustible matter content in the raw lignite sample from Kolubara basin

Linear correlation obtained is valid for coal samples from both the eastern and the western area of the Kolubara basin and accordingly could be applied to the mixture of these coals. The standard deviation of coal samples lover heating values regarding linear correlation (2) is of value 159.95 kJ/kg, resulting in relative 2σ bandwidth of ±4.76%.

The regression analysis gave linear correlation of hydrogen content in the raw lignite sample to the content of combustible matter: $H^\mathrm{r} = 0.0594$ combustible, with coefficient of correlation $R^2 = 0.9897$ and relative 2σ bandwidth of ±2.96% for this set of samples (fig. 2).

The regression analysis gave linear dependence (coefficient of correlation $R^2 = 0.9935$) between the content of the carbon and the content of the combustible matter in the Kolubara raw lignite samples (fig. 3):

$$C^\mathrm{r} = 0.7785 \text{ combustible} - 4.6405 \tag{3}$$

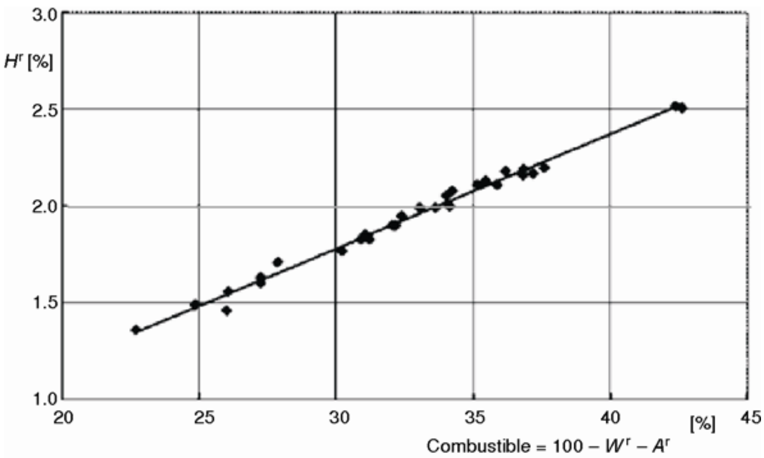

Figure 2. Correlation between the hydrogen content H^r and the combustible matter content in the raw lignite sample from Kolubara basin

Standard deviation of carbon content values in this set of samples regarding linear correlation (3) is of value 0.38%, resulting in relative 2σ bandwidth of ±3.72 %.

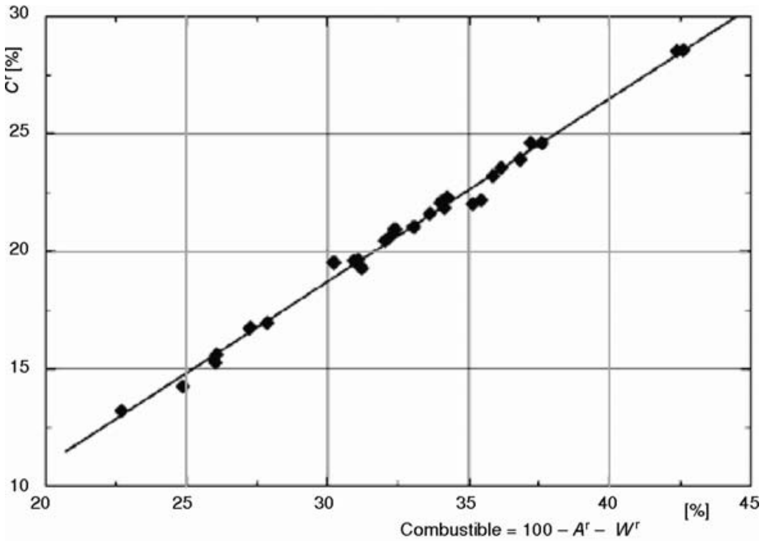

Figure 3 Linear dependency between the carbon content C^r and the combustible matter in the raw lignite from the Kolubara basin

The experimentally determined dependence between the carbon content and the net calorific value of the representative raw and dry lignite samples (which is more suitable for *CEF* determination [15, 17]) from the Kolubara basin is shown in fig. 4. The linear regression line (with coefficient of correlation R^2 = 0.9969) describing the carbon content versus net calorific value is of the form:

$$C = 2.3718\ Q_d + 4.2637 \tag{4}$$

This correlation is in good agreement with the linear correlations obtained by regression analysis of the numerous data for Czech coals of different quality (ranging from lignite to bituminous coal) [15, 16]:

$$\text{Series A,}\ C = 2.333\ Q_d + 5.511 \tag{5}$$

$$\text{Series B,}\ C = 2.344\ Q_d + 5.056 \tag{6}$$

$$\text{Series C,}\ C = 2.4\ Q_d + 4.123 \tag{7}$$

$$\text{Series E,}\ C = 2.334\ Q_d + 5.786 \tag{8}$$

The correlation (8) for series E, also recommended by the authors for use for all European coals, is obtained from averaged values Q_d and *CEF* for coals used in selected power stations in 11 European countries.

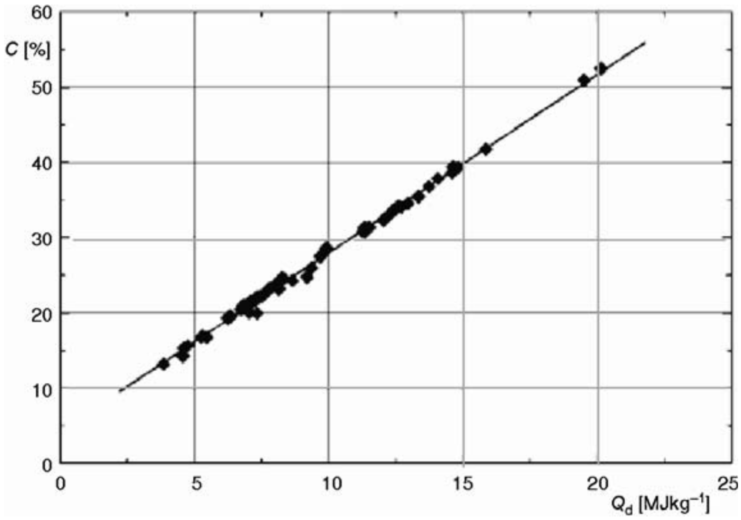

Figure 4. Dependence between the carbon content end the net calorific value for raw and dried lignite from Kolubara basin

Based on statistical data of the quality of Velenje lignite used in TPP "Šoštanj", Slovenia, over a period of several years [17], correlations similar to eqs. (5)-(8) was also derived:

$$C^r = 2.2477\ Q_d^r + 5.8216 \tag{9}$$

Additional analyses of thirty representative samples of Velenje lignite [17] derived another linear dependency between the carbon content C^r and the net calorific value Q_d^r:

$$C^r = 2.3878\ Q_d^r + 4.6548 \tag{10}$$

The correlation (4) for both raw and dried Kolubara lignite is in a good agreement with the correlations given in [15], especially with the correlation (7) for series C. The same conclusion stands when comparing correlations given by eqs. (4) and (10).

Experimental data for the samples of raw and dried Kolubara lignite samples, with a wide range of the combustible matter ranging from 20% to 80% including polynomial fit of these data (coefficient of correlation $R^2 = 0.9127$) is given on fig. 5.

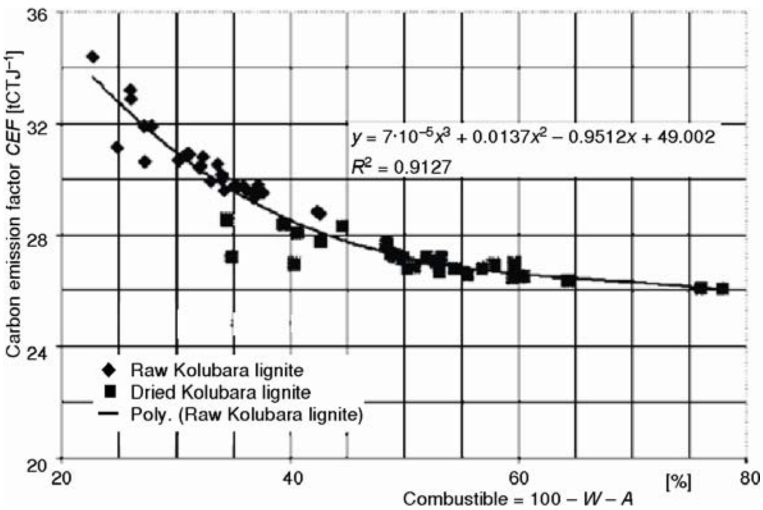

Figure 5. Functional dependencies between laboratory data for the carbon emission factor and the combustible matter for raw and dried Kolubara lignite

Based on the correlation between the carbon content and the net calorific value (4), a dependency between the carbon emission factor and the net calorific value of Kolubara lignite can also be derived:

$$CEF = 10\, C/Q_d = 23.718 + 42.637/Q_d \qquad (11)$$

The dependency (11) is shown on fig. 6, together with the experimental data for 30 representative Kolubara lignite (raw and dry) samples. The carbon emission factor is inversely proportional to the net calorific value. Increasing the coal quality (*i. e.*, increasing the net calorific value), the carbon emission factor gradually decreases and at lower heating value Q_d = 25 MJ/kg has value of 25.42 tC/TJ. This value for *CEF* is a bit lower than standard recommended (25.8 tC/TJ) for bituminous coal (but within wider net calorific value Q_d = = 24.4-28.7 MJ/kg, [10, 11]). In comparison to the international standard recommended value of *CEF* = 26.2 tC/TJ [10, 11] for brown coals derived correlation gives value of 17.18 MJ/kg for the net calorific value.

However, for the raw Kolubara lignite with net calorific value in the range of $6 \leq \leq Q_d^r \leq 10$ MJ/kg, the correlation (11) gives significantly higher values for the carbon emission factor (30.8-28 tC/TJ) compared to the standard recommended *CEF* value for lignite of 27.6 tC/TJ [10-12].

A function derived from eq. (8) for European coals [15] is shown on fig. 6. It is evident that this correlation gives even higher values for the carbon emission factor than the experimentally determined values for Kolubara lignite. The correlation obtained for Velenje lignite lies practically between these two curves.

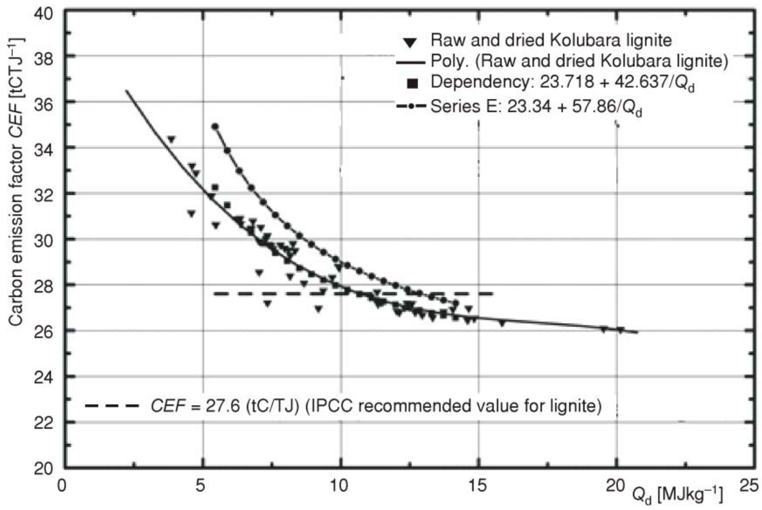

Figure 6. Functional dependency between the carbon emission factor and the net calorific value for raw and dried Kolubara lignite

The survey of data base for Velenje lignite coal quality used for power generation in the TPP "Šoštanj" over a period of several years shows that for the usual values of the net calorific values in the range 6-12 MJ/kg, the above mentioned dependence may be approximated with sufficient accuracy with the straight line:

$$CEF^{r} = 35.242 - 0.6941\, Q_{d}^{r} \tag{12}$$

Another equation was derived based on analysis of 30 representative samples of Velenje lignite [17]:

$$CEF^{r} = 34.454 - 0.5843\, Q_{d}^{r} \tag{13}$$

The experimental values for 30 representative Kolubara lignite samples, the fitted curve for the whole range of Q_d values ($CEF^r = -0.0243\, Q_d^{\,3} + 0.6208\, Q_d^{\,2} - 5.7416\, Q_d +$ $+ 48.288$, $R^2 = 0.8964$) and the fitted linear dependency of the carbon emission factor for the subset of lignite samples with net calorific value in the range of Q_d^r = 6-10 MJ/kg are shown in fig. 7. The regression line that describes carbon emission factor of Kolubara lignite samples with Q_d^r = 6-10 MJ/kg is:

$$CEF^{r} = 34.407 - 0.5891\, Q_{d}^{r} \tag{14}$$

The values of the intercepts and slopes of lines given by eq. (13) and (14) are almost identical, resulting in relative difference of *CEF* calculated using these equations less than 0.35% in the sub-range of Q_d^r = 6-10 MJ/kg. For the same sub range of the net calorific values, the relative difference between results of eq. (14) and standard recommended value (27,6 tC/TJ) remains higher, decreasing from the value of +10.6% for lignite of lowest quality rank (Q_d^r = 6 MJ/kg) to the level of +3.2% for lignite with higher net calorific values (Q_d^r =

= 10 MJ/kg). Relative difference between values calculated using eqs. (14) and (11) vary between 0.2% and 2.3% in the sub range of interest.

According to guidelines [10, 11], standard recommended net calorific value for the lignite from ex-Yugoslav mines is 8.89 MJ/kg, while standard *CEF* value for lignite is 27.6 tC/TJ. The value of CEF^{r} obtained for the Kolubara lignite samples using eq. (11) is 28.52 tC/TJ while the eq. (14) result in 29.17 tC/TJ. Thus, local *CEF* value exceeds the internationally recommended one by 3.2% and 5.69% consequently.

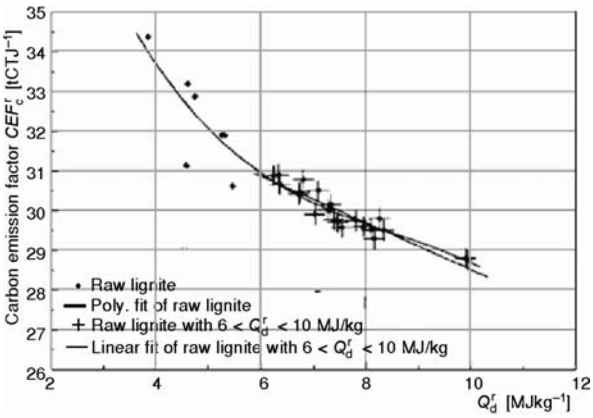

Figure 7. Functional dependency between the carbon emission factor and the net calorific value for raw Kolubara lignite

Averaged lignite quality from the Kolubara open-pit mine combusted in the boilers of TPP "Nikola Tesla", is usually of considerably low heat content (7.0-8.0 MJ/kg). The annually averaged values of Q_{d}^{r} for Kolubara raw lignite and results of CEF^{r} calculation according to eq. (14) (with an uncertainty assessment) are presented in tab. 3. The uncertainty assessment to the values of CEF^{r} calculated and presented in tab. 3 is based on the assumption that measurement capabilities of the testing laboratories, which undertake determination of net calorific values of the raw Kolubara lignite conveyed to TPP "Nikola Tesla" and averaged on yearly basis, are equal to measurement capability of Vinca Institute Testing Laboratory.

Table 3. The annual average net calorific value of the raw Kolubara lignite conveyed to the TPP "Nikola Tesla" and carbon emission factor according eq. (14)

YEAR	1990	1998	2000	2004	2005	2006	2007	2008
Q_d^r [MJ/kg]	7756	7905	8076	7198	7957	7936	8018	8033
CEF^r [tC/TJ]	29.84 ±0.09	29.75 ±0.09	29.65 ±0.08	29.74 ±0.10	29.72 ±0.08	29.73 ±0.09	29.68 ±0.08	29.68 ±0.08

Application of the obtained results for carbon emission factor (eq. 14) for Kolubara lignite will increase precision and absolute value of calculated emission of CO_2 from TPP "Nikola Tesla" compared to recommended value by Tier 1 method [10-12]. Further verification of these results are expected in the future through frequent sampling (every charge of 20,000 t at least) and characterisation of the lignite quality in the accredited Laboratory according to the prescribed monitoring and verification process for the annual CO_2 emission values from TPP "Nikola Tesla" necessary for the ETS implementation [12].

Conclusions

International recommended methodologies for GHG emission inventories suggest development and application of more precise data base of local fossil fuels emission characteristics, if such data are generated by accredited Laboratories according to international standards. According to that, carbon emission characteristics of the local low-calorific lignite recovered from the Kolubara basin with the highest annual production in Serbia (30 Mt per year, dominantly used for power generation) are evaluated. Thirty representative Kolubara lignite samples selected to represent wide spectra of lignite quality that is presently and will be in the next 10 years combusted in thermal power plants are extracted, sampled and prepared for laboratory analysis according to ISO 5065 and ISO 1988. Performed (according to appropriate international standards) proximate and ultimate laboratory analysis of the representative Kolubara lignite samples reviled expected wide range of lignite quality and generated excellent data base for the regression analyses.

The correlation analysis generated linear regression with high correlation coefficients ($R^2 \geq 0.99$) for: net calorific value, carbon content, and hydrogen content, all as linear functions of combustible matter content in the raw coal samples, which are valid for samples from both the eastern and the western area of Kolubara basin and for their mixtures. The linear regression for the carbon content *vs.* the net calorific value in the representative lignite (raw and dry) samples was derived too. The correlation is found to be in good agreement with the appropriate linear correlations obtained by the regression analysis of numerous data for Czech coals of different quality and Velenje lignite. Based on the correlation between the carbon content and the net calorific value for lignite from Kolubara basin, a dependency between the carbon emission factor (*CEF*) and the net calorific value was defined. The results of the *CEF* evaluation, fig. 6 and eq. 11, indicate that raw lignite from Kolubara basin has significantly lower net calorific value and higher *CEF* value in comparison to those recommended by the IPCC Tier 1 method. For the raw lignite from Kolubara basin with the net calorific value in the range $6 \leq Q_d^r \leq 10$ MJ/kg, linear correlation, fig. 7 and eq. 14, is recommended for corresponded CO_2 emission calculation with high precision. Further verification of these results is expected in the future through frequent sampling and characterisation of the lignite quality in the accredited Laboratory.

Besides lignite quality characterization, experimental determination at the site of the oxidation factor is needed too, as preliminary results at boilers in TPP "Nikola Tesla" indicate much lower value compared to recommended one (0,98 [10, 11]).

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Nomenclature

A – ash, [%]
C – carbon content, [%]
C_{fix} – fixed carbon content, [%]
CEF – carbon emission factor, [tC/TJ]
Q_g – gross calorific value, [kJkg^{-1}]
Q_d – net calorific value, [kJkg^{-1}]
V – volatile content, [%]
W – water content, [%]
R^2 – coefficient of correlation, [–]
S_u – total sulphur content, [%]
S_s – combustible sulphur content, [%]

Superscripts

r – raw lignite sample

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