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# Civil Engineering Journal

(E-ISSN: 2476-3055; ISSN: 2676-6957)

Vol. 8, No. 08, August, 2022


# The Impact of Coal Quality on Reduction of Environmental Pollution Researched Through Statistical Analysis

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Received 13 April 2022; Revised 10 July 2022; Accepted 16 July 2022; Published 01 August 2022

**Abstract**

Today, the region in general but also Kosovo faces a lack of electricity on the one hand and environmental pollution on the other hand from existing power plants where electricity is produced for the community in general in thermo-plants Kosovo A and Kosovo B. The purpose and importance of this paper is that for the samples taken through the layers (floors) of coal by drilling to extract the calorific values of coal (ETU) and the percentage of ash, whose parameters were analysed in the laboratory of geo-mechanics according to the standards (ISO 9001) in order to eliminate the weak part of coal that would have a positive impact on increasing electricity production but also on reducing environmental pollution within the allowed values according to European Union standards. To carry out this work, a large number of drillings were performed from which 91 samples were taken at different depths, these samples were analysed and, at the same time, statistical processing was done in order to find the average caloric value of (ETU) and the content of ash with the lowest value, these parameters will help us to determine the method to be applied during the exploitation in order to create better conditions for the transport process to the power plants by means of conveyor belts and, at the same time raising the quantity of energy production and reduction of carbon dioxide ($CO_2$).

*Keywords:* Soil Samples; Environmental Pollution; Statistical Processing; Quality of Coal; Ash.

## 1. Introduction

Energy as the driving force of life in any society can be provided in different ways and methods. Currently, human society provides most of its energy needs from the coal mining industry. On the other hand, energy sources from hydrocarbons have also led to the development of the world economy with a more positive trend than in the last century. This trend will continue into the next century too. Kosovo has sufficient reserves of lignite, while there is a lack of water resources or other resources, therefore the exploitation of lignite coal for the production of electricity for the needs of the country and beyond, adapting to the latest technology for the preservation of environmental pollution, remains the main alternative.

Geological reserves of coal in Kosovo are estimated at 12.5 billion tons [1] in the coal basin of Kosovo, which is the largest basin. The coal in this basin is of the lignite type and is mainly used for electricity generation (about 98% of it is provided by the coal industry) and a very small part for heating. The use of coal from the Kosovo basin is exploited by the open sky method, where, in addition to the positive sides, it is associated with a significant impact on the natural environment, being reflected in the lithosphere, hydrosphere and especially the atmosphere.

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http://dx.doi.org/10.28991/CEJ-2022-08-08-05

The increase in the degree of environmental pollution, of course, negatively affects the surrounding environment due to the low calorific value of coal and the presence of a high percentage of ash [2-7], and the presence of $CO_2$ based on the latest research from Kadriu et al. [8] (Figures 1 and 2). The results are presented in Table 1 where the statistical processing according to Surfer V21 guideline [9]. By comparing the caloric values, we obtained satisfactory results where the percentage of ash was higher due to the autoignition of coal, the caloric values were lower and the presence of $CO_2$ was higher. Therefore, with the intervention of firefighting, the environmental pollution has been reduced, then based on the results obtained from the drillings done for this research, we will reduce the environmental pollution from gases, but at the same time, the energy production capacities will be increased with the use of coal with higher caloric values. The results which are presented in this research taking as a basis the recommendations of the European Community according to the allowed standards.

**Figure 1. Coal fire in old underground structures**

**Figure 2. Active coal mine where samples are taken for analysis**

## 2. Research Methodology

### 2.1. Study Area

The coal mine study area is located at the 6th kilometer from Pristina according to Figure 3, which has an average altitude quota of 650 meters (Figures 4 and 5). The slope of these hills lies at an angle of 4 to 10 degrees with a general decline in the direction from southeast to southwest. The sampling location is presented in the map given in Figure 3, in that area geological – geo-mechanical drilling was performed [8], sampling was performed using drilling set of Type EK-650 with diameter 145/101 with rotating receiving core. The thickness of the coal layer on average is 59.50 m (maximum 93.10 m). The minimum caloric value in contact with green clay ranges from 2000 to 9982 kJ/kg, while the geological average is calculated at 7773.824 kJ/kg (calculated with 45% water), taking into account the possible percentage of interferences and the partially high percentage of water. The overburden thickness varies from 50 to 125 m with the lowest values near the northern boundary of the existing mines (Figure 6).

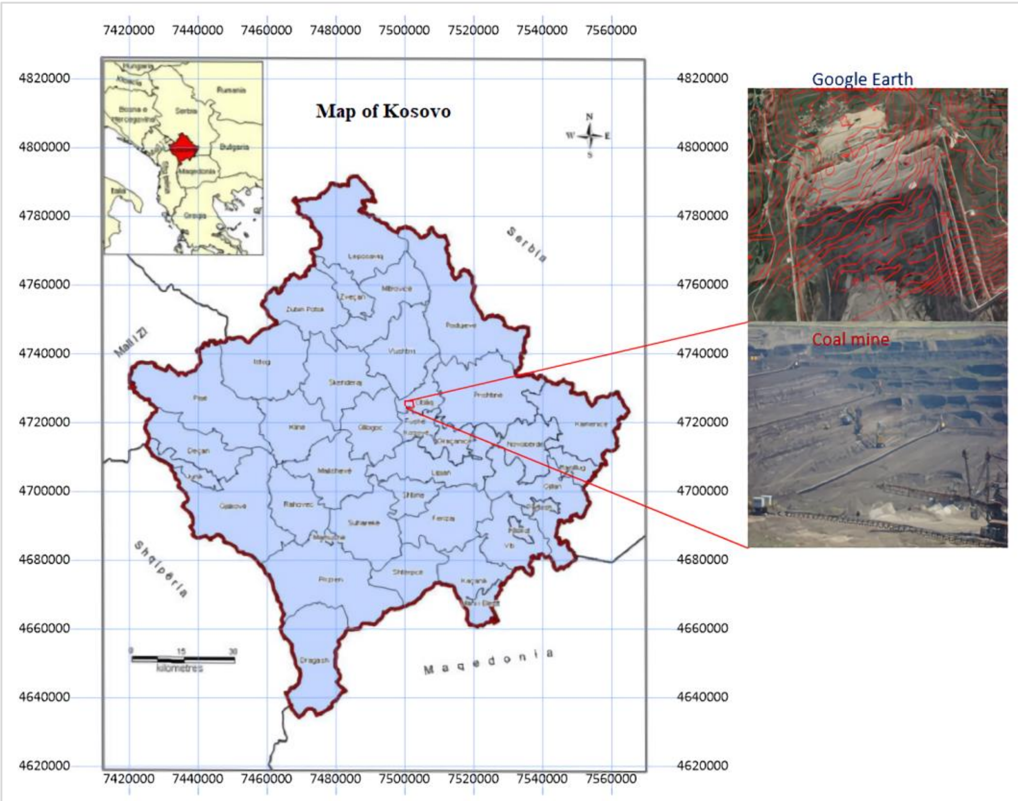


**Figure 3. Map with the geographical position of the surface coal mine**

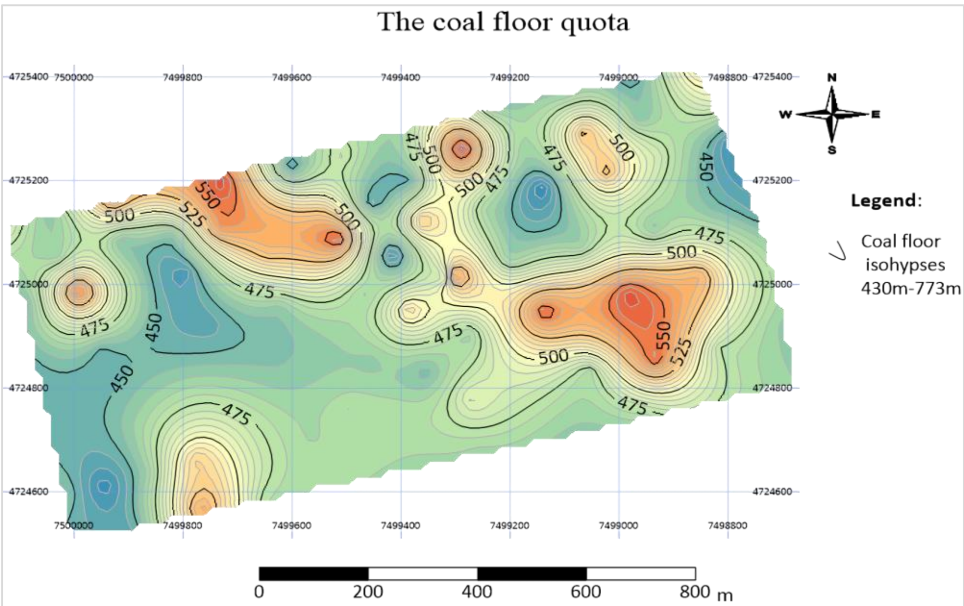


**Figure 4. The coal floor quota**

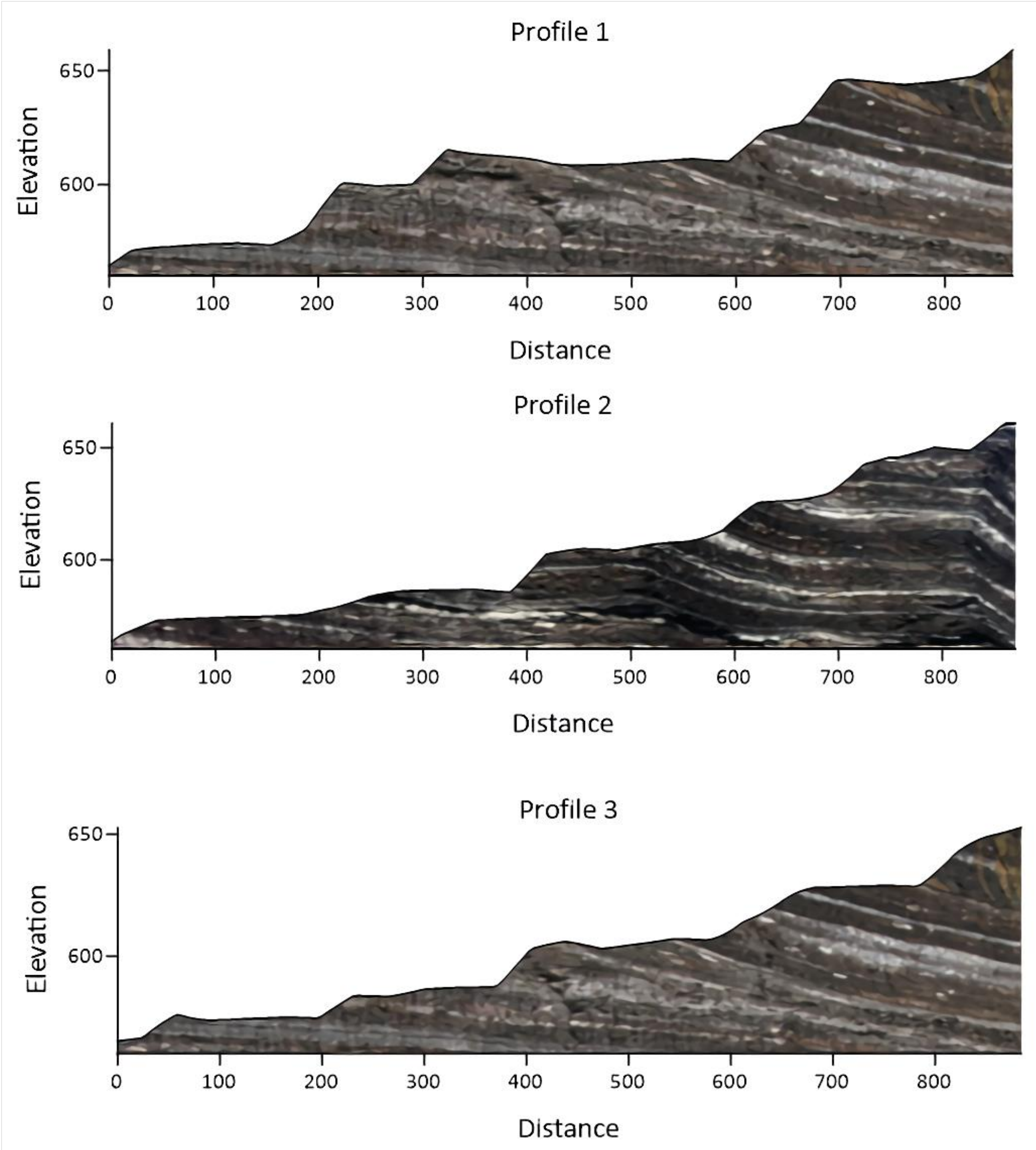


**Figure 5. Longitudinal coal profiles**

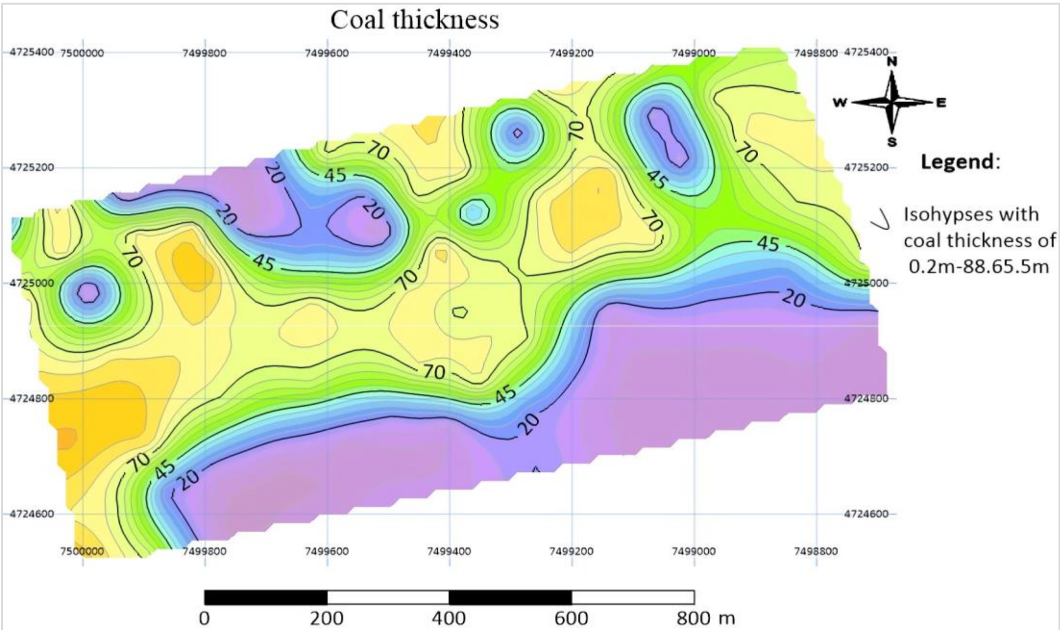


**Figure 6. Coal thickness**

In this research we have relied on a clear and specific methodology. This methodology is generally based on 91 samples of coal extracted from drilling [10, 11] according to Figure 7 which directly affect the determination of the calorific value of coal (ETU) and the percentage of dust mass insertion from geo-mechanical investigation [12, 13].

During the methodology, the drilling network with distance (75 ×75 m) was used to determine the maximum caloric values of coal and ash content with lower values to reduce environmental pollution and increase electricity production for the needs of the country and beyond.

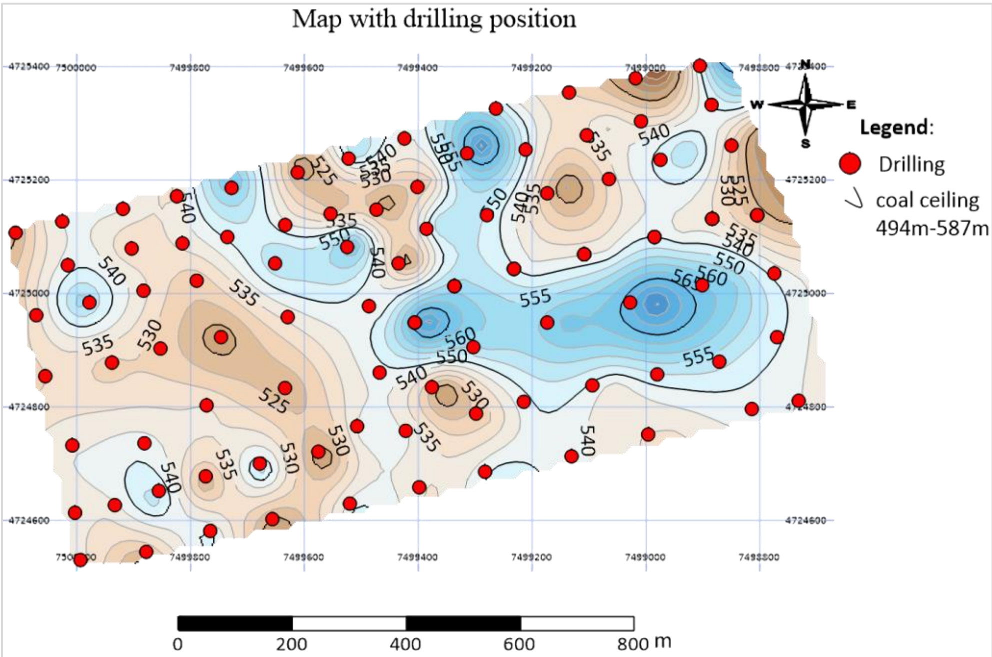


**Figure 7. Map with drilling position for coal sampling**

## 3. Results and Discussion

Based on the data taken from investigation, 91 samples were analyzed for accurate definition of caloric values of coal, in this paper statistical processing was used [15-18], according to Equations 1 to 7 to define the highest caloric values of coal and the percentage of dust mass as small as possible. Samples for analysis were taken from Table 1 while the results are presented in Table 2 for the caloric value of coal and ash content. The representation of the correlation of these two parameters is done according to Equations 8 to 11 [19-22]:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{2}$$

***Variance:***

$$V = \frac{\sum(x_i - \bar{x})^2}{n} \tag{3}$$

***Standard Deviation:***

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n}} \tag{4}$$

***Coefficient of Variation:***

$$CV = \frac{\sigma}{\bar{x}} \cdot 100\% \tag{5}$$

$$Kurtosis = \frac{\sum(x_i - \bar{x})^4}{(n-1)\,\sigma^4} \tag{6}$$

$$Skewness = \frac{\sum(x_i - \bar{x})^3}{(n-1)\,\sigma^3} \tag{7}$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} = \frac{S_{xx}}{\sqrt{S_{xx} \cdot S_{yy}}} \tag{8}$$

$$S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = n\, s^{-2}\, x \tag{9}$$

$$S_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2 = n\, s^{-2}\, y \tag{10}$$

$$S_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = \sum_{i=1}^{n} x_i\, y_i - n\bar{x}\,\bar{y} \tag{11}$$

**Table 1. Analysis of coal samples according to caloric value and percentage of ash**

| **Xi - ETU** | **Caloric values of coal samples** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7285 | 8604 | 8361 | 4200 | 7005 | 5179 | 3200 | 9906 |
| | 2000 | 8988 | 8113 | 4350 | 8231 | 2500 | 5308 | 4869 |
| | 9982 | 9747 | 5800 | 9149 | 9613 | 7403 | 7256 | 4356 |
| | 8332 | 2500 | 9683 | 8321 | 5250 | 9088 | 9380 | 8515 |
| | 6325 | 8117 | 9103 | 7525 | 8573 | 8683 | 8718 | 8659 |
| | 8657 | 9077 | 8345 | 8690 | 9476 | 8332 | 9336 | 9683 |
| | 8321 | 9479 | 9088 | 9380 | 8515 | 9244 | 8117 | 9103 |
| | 7525 | 8573 | 8683 | 8718 | 8659 | 8657 | 9077 | 8345 |
| | 8690 | 6894 | 6988 | 8835 | 7083 | 7941 | 6937 | 7749 |
| | 7285 | 7639 | 7248 | 7264 | 6664 | 7719 | 9049 | 9229 |
| | 2000 | 9125 | 5862 | | | | | |
| **Yi - Ash** | **Coal samples with ash content in [%]** | | | | | | | |
| | 17.80 | 13.60 | 14.38 | 26.50 | 18.69 | 24.50 | 28.00 | 9.45 |
| | 30.31 | 12.37 | 15.50 | 27.05 | 14.79 | 25.00 | 24.10 | 19.50 |
| | 10.01 | 11.07 | 23.40 | 12.81 | 18.80 | 17.37 | 17.89 | 23.50 |
| | 16.23 | 29.50 | 11.29 | 15.89 | 22.50 | 13.45 | 12.25 | 14.47 |
| | 21.50 | 15.14 | 12.83 | 18.59 | 14.93 | 13.87 | 14.81 | 13.92 |
| | 13.80 | 13.31 | 15.29 | 14.39 | 16.65 | 19.22 | 17.20 | 17.87 |
| | 19.70 | 18.10 | 15.54 | 13.03 | 14.58 | 12.65 | 14.61 | 13.05 |
| | 16.65 | 13.69 | 14.51 | 13.70 | 13.91 | 11.92 | 13.51 | 16.15 |
| | 13.51 | 16.03 | 15.20 | 14.68 | 13.45 | 14.64 | 14.45 | 14.63 |
| | 15.41 | 14.11 | 13.75 | 13.22 | 15.55 | 14.68 | 14.08 | 13.83 |
| | 12.56 | 13.69 | 18.95 | | | | | |

**Table 2. Analysis of coal samples according to caloric value and percentage of ash**

| **Statistical processing according to the caloric values of coal** | | **Statistical processing according to grace values** | |
|---|---|---|---|
| **Number of values** | **91** | **Number of values** | **91** |
| Sum | 707418 | Sum | 1485.76 |
| Minimum | 2000 | Minimum | 9.45 |
| Maximum | 9982 | Maximum | 30.31 |
| Range | 7982 | Range | 20.86 |
| Mean | 7773.82 | Mean | 16.32 |
| Median | 8345 | Median | 14.68 |
| First quartile | 7033.50 | First quartile | 13.65 |
| Interval | 363.53 | Interval | 0.91279 |
| Variance | 3012517.66 | Variance | 18.9928 |
| Average deviation | 1322.18 | Average deviation | 3.321956 |
| Standard deviation | 1735.66 | Standard deviation | 4.3581 |
| Coefficient of variation | 0.22451 | Coefficient of variation | 0.2684 |
| Skew | -1.4915 | Skew | 1.406 |
| Kurtosis | 4.8737 | Kurtosis | 1.618 |

In this case, a graphical representation of all samples was made by applying statistical processing using two variables, the calorific value of coal $X_i$ and samples of ash content $Y_i$, the results show that we have a linear correlation above average, the linear correlation in this case is of negative value which means that with increasing caloric value of coal we have a reduction of ash content (Figure 8). The ratios of calorific values of coal in relation to ash content as allowed values are presented according to Figures 9 to 11.

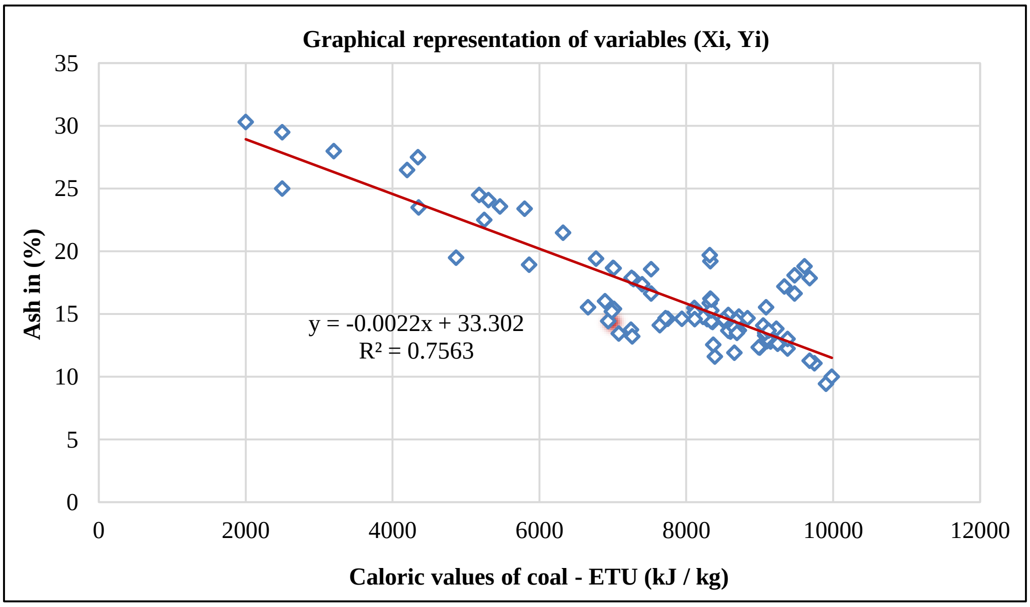


**Figure 3. Linear correlation between the caloric value of coal and the percentage of ash**

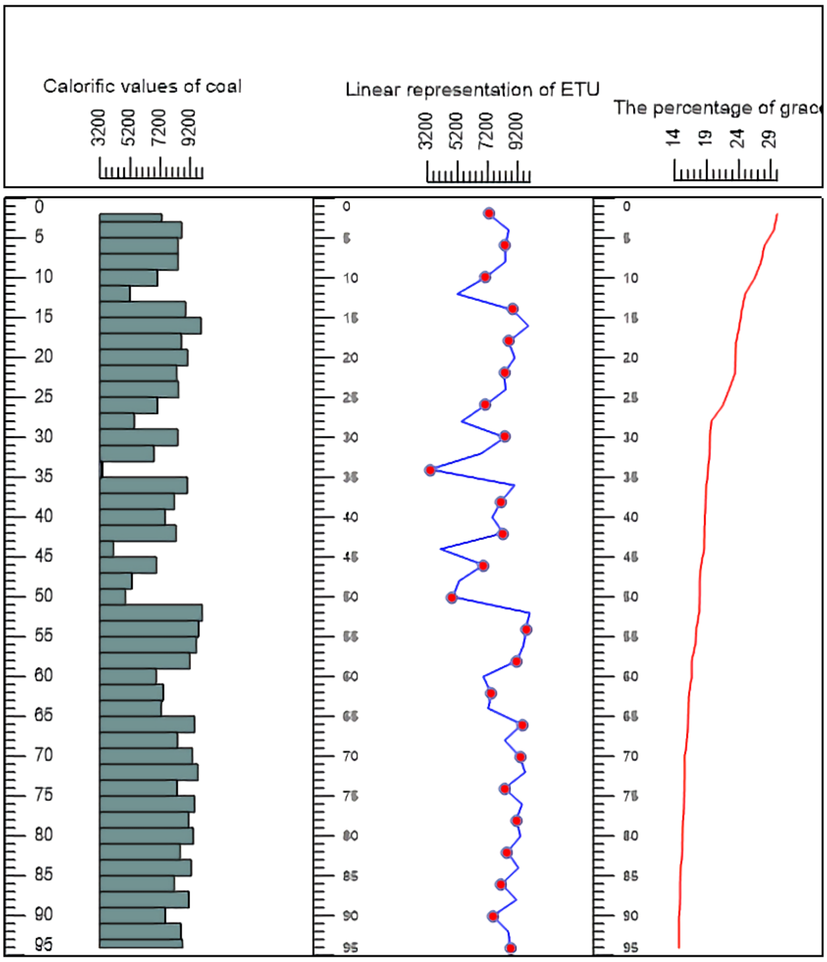


**Figure 9. Presentation of the calorific value of coal and the percentage of ash according to the depth of drilling**

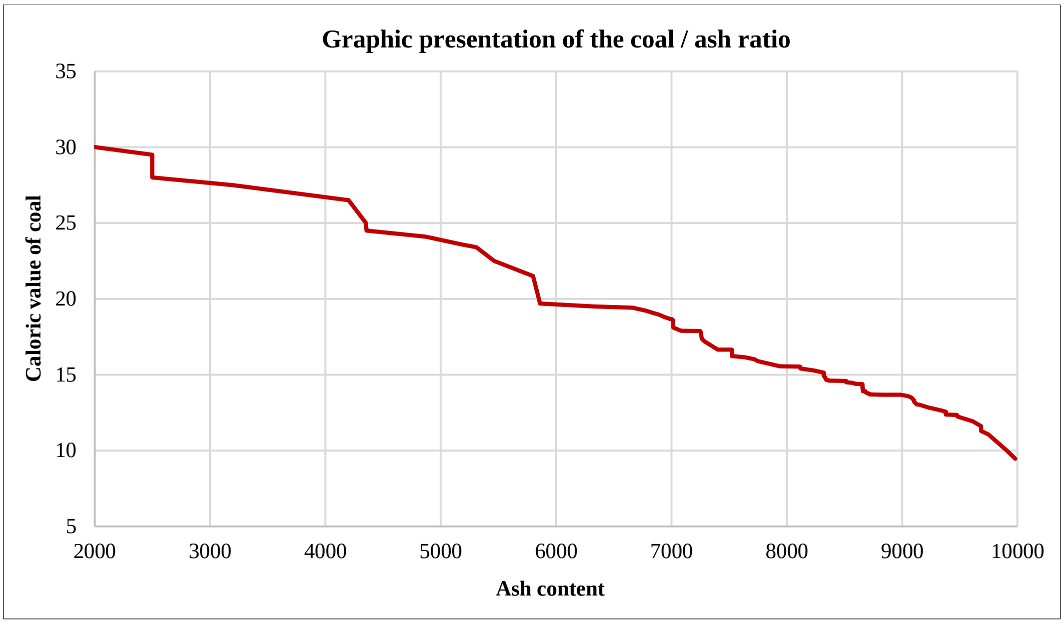


**Figure 10. Caloric values of coal in relation to ash content**

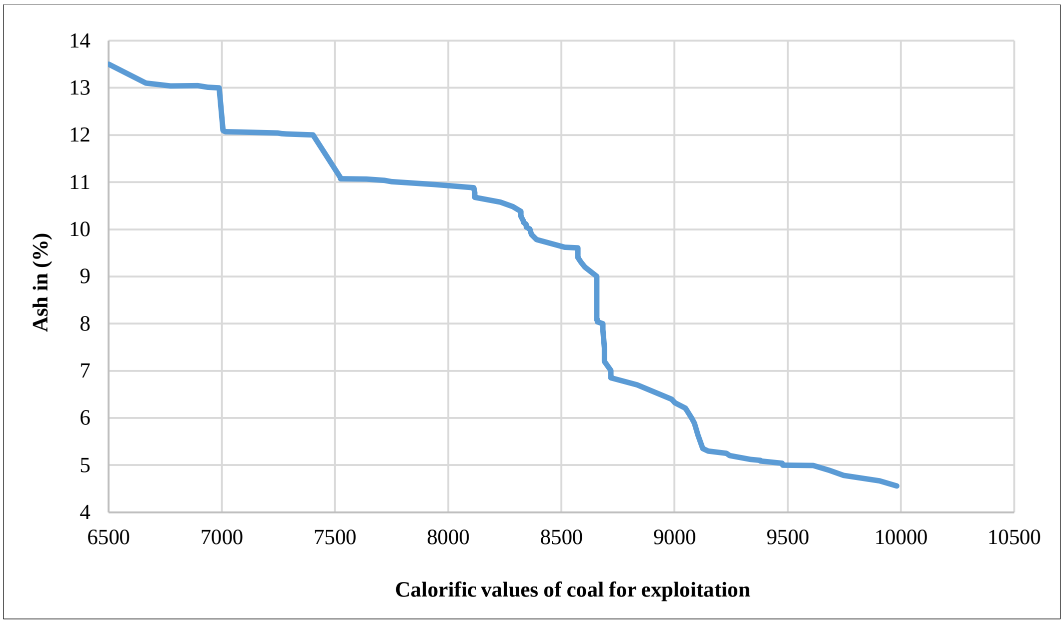


**Figure 11. Allowable values of coal exploitation with the percentage of ash**

## 4. Conclusions

The Kosovo coal basin is considered the largest basin of coal reserves and the main source of electricity supply in our country. The coals of this basin are estimated to be of the lignite type, where their constituent minerals are (*liptinite*, *inertinite*, and *huminite*). Geologically, the main part of the basin is composed of Pliocene deposits represented by yellow clays, poorly bound fine sand clays, unbound (cemented) clays, and coal. From a hydro-geological point of view, the Kosovo coal basin is characterized by complex hydro-geological conditions, conditioned by the good hydraulic connection of the coal package with surface water with developed tectonics and the presence of water-holding layers above the coal package ceiling. The coal exploitation system in the Kosovo Basin is an open skies system with heights of layers and inclination of slopes determined in function of the geo-mechanical characteristics of the coal. Based on the analysis and results of the samples mentioned above, we recommend:

- According to the analysis, coal, which has a calorific value of less than 6500 kJ/kg, should not be used due to its low caloric value because it will reduce the production of electricity, which affects environmental pollution;
- To homogenize the coal at the in-situ work front, applying the technology, in order to achieve the optimal value of the coal >6500 kJ/kg according to the obtained results that are presented in the diagram given in Figure 5;

- During the transportation of coal from the mine to the power plants along the residential areas, water should be used for spraying the coal, especially during the summer, to stop the spread of the masses of dust particles in the residential areas in order to protect the air from pollution within the values allowed.

# 5. Declarations

## 5.1. Author Contributions

Conceptualization, H.A. and A.A.; methodology, H.A. and R.B.; software, R.B.; validation, H.A., A.A. and R.B.; formal analysis, A.A.; investigation, H.A.; resources, H.A.; data curation, H.A.; writing—original draft preparation, H.A.; writing—review and editing, R.B.; visualization, R.B.; supervision, H.A.; project administration, H.A.; funding acquisition, H.A. and R.B. All authors have read and agreed to the published version of the manuscript.

## 5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

## 5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

## 5.4. Acknowledgements

The authors want to express their special gratitude to the specialized institute for geological and geo-mechanical investigations, Institute INKOS SH.A., where the corresponding author worked for many years, and also to Kosovo Energy Corporation J.S.C., whose activities are professionally supported by Institute INKOS SH.A.

## 5.5. Conflicts of Interest

The authors declare no conflict of interest.

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