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An Assessment of Cutoff Grade Parameters: A Case Study of Coal Deposit

S. Yerel¹

¹*Civil Engineering Department, Bilecik University, Bilecik, Turkey*

One of the most important aspects of coal deposits is to examine the cutoff grade parameters. The bivariate lognormal distribution model with two uncorrelated samples will serve as an important tool for analysis of these parameters. In this article, the Seyitomer coal deposit in Kutahya (Turkey) parameters, such as moisture and ash, were assessed by a bivariate lognormal distribution model with two uncorrelated samples. Through the results from the model, it was determined that there are tonnage rate, mean of moisture, and mean of ash, which involve the identification of cutoff moisture and cutoff ash. Thus, this study shows the usefulness of a bivariate lognormal distribution model with two uncorrelated samples for analysis and interpretation in the cutoff grade parameters.

Keywords: ash, bivariate lognormal distribution model, coal, cutoff grade parameters, moisture, Turkey

1. INTRODUCTION

Coal resources are those parts of potential for which sufficient information is available to enable a prefeasibility study and for which such planning has been undertaken. Calculations of coal resources and overburden refer to estimates for tonnage and averages of coal quality parameters (moisture, ash, etc.) as well as overburden ratio over an entire coal deposit. Such calculations are useful in making decisions about opening up new coal mines or in planning future investment for operating mines (Tercan and Karayigit, 2001).

Despite developments in renewable energy technologies, such as nuclear, solar, wind energies, and so on, fossil fuels seem to be the primary source of energy in the world for the near future. For this reason, fossil fuel investigations, including determination of the properties and classification, are important (Varol and Ercanoglu, 2006).

One of the most important aspects of coal deposit is deciding what material in a deposit is worth mining and processing versus what material should be considered a waste. This decision is summarized by the cutoff grade policy (Bascetin and Nieto, 2007). Choosing the best cutoff grades has been a major topic of research since the 1960s and many researchers have made contributions in devising various methods and algorithms (Wang et al., 2008). In the literature, there are many studies based on cutoff grade theories developed by Lane (1964), which is applicable to multiple ore deposits. Some studies conducted in multiple ore deposits by using cutoff grade theories are as follows: Cetin and Dowd (2002) describe the general problem of cutoff grade optimization for multi-mineral deposits and outline the use of genetic algorithms for optimal cutoff grade schedules for deposits with up to three constituent minerals. Ataei and Osanloo (2003) presented

Address correspondence to Dr. Suheyra Yerel, Civil Engineering Department, Bilecik University, Bilecik, Turkey.
E-mail: syerel@gmail.com

an optimum cutoff grade of multiple ore deposits by using the golden section search method. Asad (2005) presented the ease of operation, for the second case becomes a reason of choice for the development of the cutoff grade optimization algorithm with a stockpiling option for deposits of two economic minerals.

In coal deposits, moisture and ash are important cutoff grade parameters. In this study, first a bivariate lognormal distribution model with two uncorrelated samples was introduced. Next, a case study describing the bivariate lognormal distribution model with two uncorrelated samples was applied to the northwest of the Seyitomer basin in Kutahya (Turkey).

2. METHODOLOGY

2.1. Bivariate Lognormal Distribution Model with Two Uncorrelated Samples

A positive random variable x is said to be lognormally distributed with mean (μ) and standard deviation (σ) if $y = \log(x)$ is normally distributed with μ and σ . The distribution of the random variable x is given by:

$$f(x) = \frac{1}{x\sigma_y\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{\log(x) - \mu_y}{\sigma_y}\right)^2\right] \quad x > 0, \tag{1}$$

where μ_y and σ_y are the mean and standard deviation of y , respectively.

If two uncorrelated continuous random variables x_1 and x_2 are lognormally distributed with different mean and standard deviations, the joint distribution of these variables are represented by the bivariate lognormal distribution with two uncorrelated samples. The probability density function of the bivariate lognormal distribution is given by:

$$f(x_1, x_2) = \frac{1}{2.\pi.x_1.x_2.\sigma_{y_1}.\sigma_{y_2}} \left(\exp\left(-\frac{1}{2} \cdot \left[\left(\frac{\log(x_1) - \mu_{y_1}}{\sigma_{y_1}}\right)^2 + \left(\frac{\log(x_2) - \mu_{y_2}}{\sigma_{y_2}}\right)^2 \right] \right) \right), \tag{2}$$

where μ_{y_i} and σ_{y_i} are mean and standard deviation of y_i ($i = 1, 2$) and they can be derived using the following formulae:

$$\mu_{y_i} = \log(\mu_{x_i}) - \left(\frac{\sigma_{x_i}^2}{2}\right), \tag{3}$$

$$\sigma_{y_i} = \left[\log\left(1 + \frac{\sigma_{x_i}^2}{\mu_{x_i}^2}\right) \right]^{\frac{1}{2}}. \tag{4}$$

Here, μ_{x_i} and σ_{x_i} are the mean and standard deviation of x_i . For the standard values corresponding to cutoff, y_2 and y_1 can be derived as Eqs. (5)–(6) (Konuk and Yersel, 1998; Yerel, 2008):

$$z_1 = \frac{\log(x_2) - \mu_{y_2}}{\sigma_{y_2}}, \tag{5}$$

$$z_2 = \frac{\log(x_1) - \mu_{y_1}}{\sigma_{y_1}}, \tag{6}$$

which is the product of dependent probabilities, and gives the total joint probability of cutoff grade parameters that correspond to the tonnage rate (T_c) of coal deposits as given by Eq. (7):

$$T_c = T_{x_1} \cdot T_{x_2}. \quad (7)$$

From the above equation, corresponding T_{x_1} and T_{x_2} are given by cumulative normal probability tables, respectively. The mean of x_1 ($\overline{x_{c_1}}$) and mean of x_2 ($\overline{x_{c_2}}$) of coal deposits under cutoff x_1 and cutoff x_2 can be calculated by Eqs. (8) and (9) (Clark, 2001):

$$\overline{x_{c_1}} = \frac{B}{T_{x_1}} \cdot \overline{x_1}, \quad (8)$$

$$\overline{x_{c_2}} = \frac{B}{T_{x_2}} \cdot \overline{x_2}. \quad (9)$$

From Eqs. (8) and (9), corresponding of the parameter B is calculated by Eq. (10):

$$B = \Phi(z - \sigma_{y_i}). \quad (10)$$

2.2. Stratigraphy of the Seyitomer Basin

Stratigraphy of the Seyitomer Basin is summarized as provided by Bas (1986) and especially the first author's field observations. A generalized stratigraphic sequence of the Seyitomer Basin is presented in Figure 1. The metamorphic and ophiolitic rocks and granites of the Pre-Neogene age form the basement of the basin. The Miocene-Pliocene aged basin fill rests unconformably on the basement rocks, and the first sedimentary system in the basin begins with the fluvial regime of the Egrioz Formation, which consists of conglomerate, trough cross-bedded conglomerate, sandstone, mudstone, and thin coal seam. The conglomerates are much more abundant near the basin margin. The conglomerate, trough cross-bedded conglomerate, and pebbly sandstone units are channel deposits, which incised into a floodplain and horizontally bedded siltstone and mudstone and are interpreted as overbank deposits.

The coal-bearing Seyitomer Formation of the Lower-Middle Miocene age in the basin was conformably underlain by fluvial deposits of the Egrioz Formation and conformably overlain by the Kepez Formation of the Miocene-Pliocene age. The coal-bearing Seyitomer Formation in a lateral-vertical direction was developed in lacustrine facies, and is represented, from the base upwards, by green claystone, lower coal seam, bituminous marl with mudstone and sapropelic coal lenses, upper coal seam, diatomite interbedded with carbonaceous claystone, and fossiliferous marl. The Kepez Formation that developed in the lacustrine, partly fluvial environment, from the base upwards, consists mainly of carbonaceous claystone, tuffite, tuffaceous marl, clayey limestone, and conglomerate-tuffite. The facies units of the Kepez Formation are interpreted as freshwater carbonates, volcanic fall deposits, and river deposits (Celik and Karayigit, 2004).

2.3. Dataset Description

The study area, the lower coal seam, is located to the northwest of the Seyitomer basin (Figure 1). In a coal deposit, moisture and ash have more important parameters. The parameters used in this article were obtained from 231 drillholes, and the drillhole samples were analyzed for moisture and ash. Afterwards, the coal deposit parameters, including moisture and ash, were evaluated by using the bivariate lognormal distribution model with two uncorrelated samples.

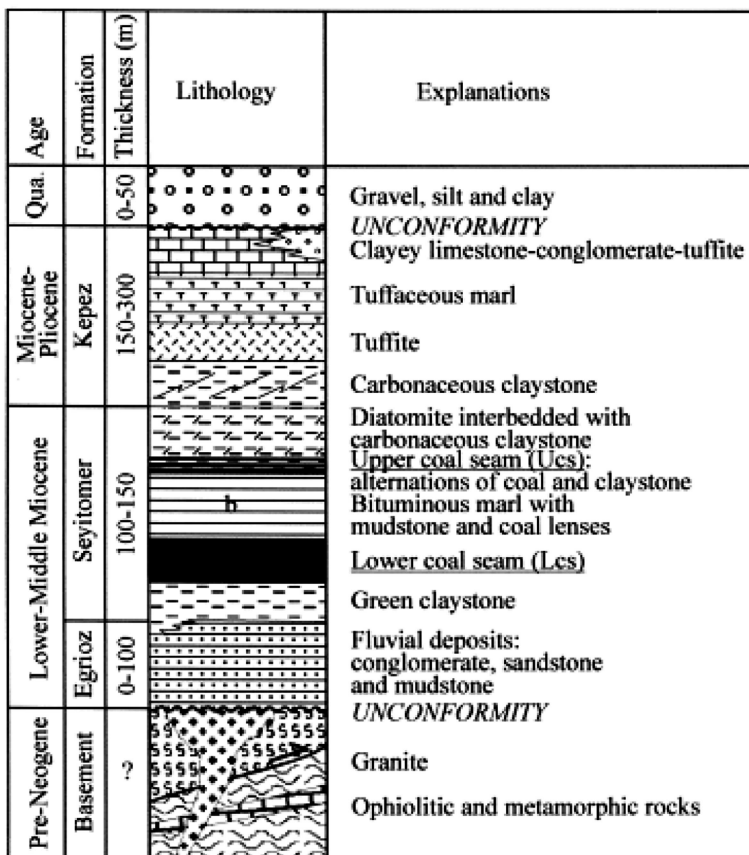


FIGURE 1 Generalized stratigraphic column section of the Seyitomer Basin.

3. RESULTS AND DISCUSSION

The evaluation of cutoff grade parameters for a coal deposit is most significant. The important parameters of a coal deposit are the moisture and ash. The correlation coefficient between moisture and ash were calculated by using regression analysis. The analysis result shows that a value of correlation coefficient close to zero. Thus, it is assumed that moisture and ash are uncorrelated parameters.

In cutoff grade policy, uncorrelated parameters may be estimated by a bivariate lognormal distribution model with two uncorrelated samples. In this article, tonnage rate, mean of moisture, and mean of ash with the Seyitomer coal deposit in Kutahya (Turkey) have been calculated by using the bivariate lognormal distribution model with two uncorrelated samples.

Considering that cutoff moisture and cutoff ash were a bivariate lognormal distribution model with two uncorrelated parameters, tonnage rate was calculated by using Eq. (7). The tonnage rates considering different cutoff moisture and cutoff ash were graphed in Figure 2. The figure shows that cutoff moisture and cutoff ash increases as the tonnage rate increases, but over 30% of cutoff moisture is not a considerable increase in tonnage rate.

The mean of moisture and mean of ash of the deposit was calculated by using Eqs. (8) and (9). These calculations were graphed and presented in Figures 3 and 4. Figure 3 indicates that

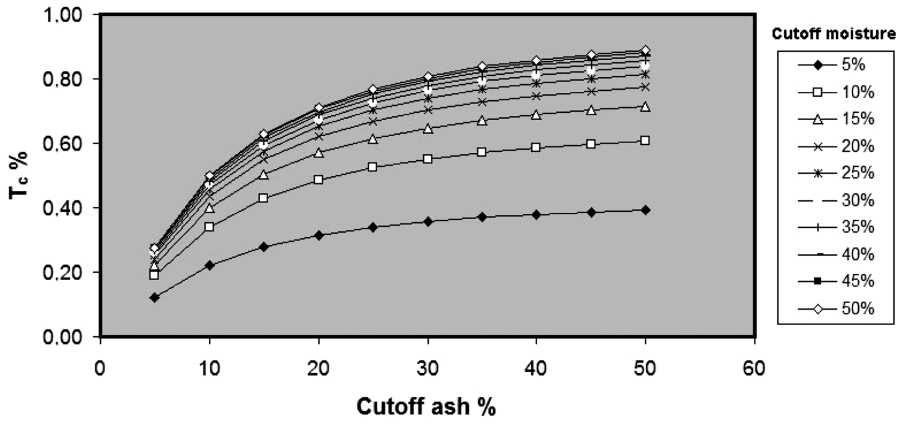


FIGURE 2 Cutoff ash versus Tc.

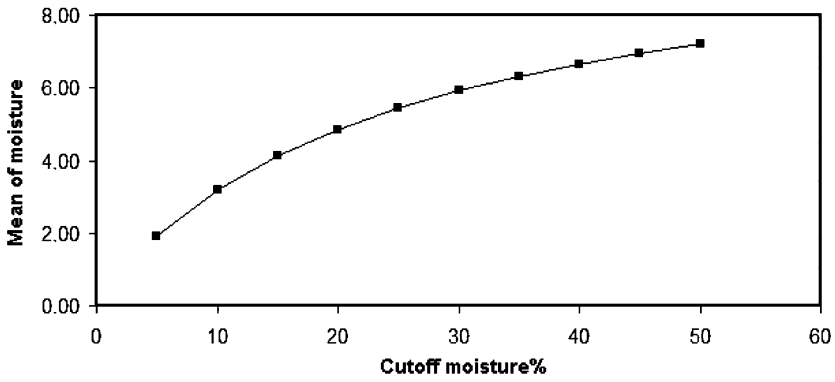


FIGURE 3 Cutoff moisture versus mean of moisture.

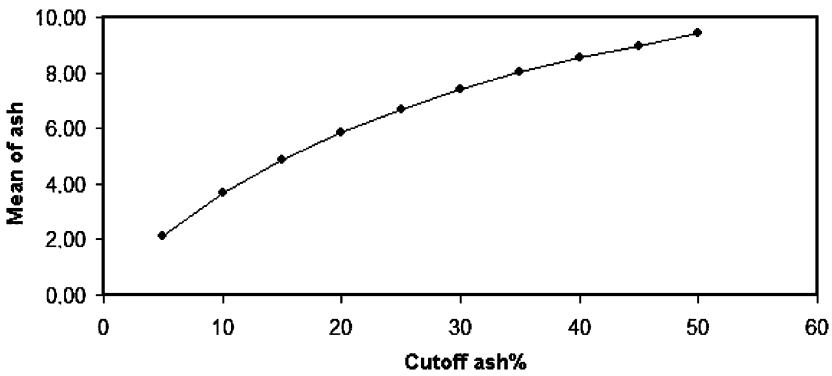


FIGURE 4 Cutoff ash versus mean of ash.

cutoff moisture increases as the mean of moisture increases, but over 40% cutoff moisture not an important variation in the mean of moisture. Similarly, cutoff ash is increased as the mean of ash increases, but over 35% ash not considerable variation in the mean of ash (Figure 4). But, with mean of moisture and mean of ash increasing, the quality of the coal deposits are decreasing. For this reason, the bivariate lognormal distribution model can be considered as an effective tool because of its dynamic calculation feature. That is to say, any user can be adapting parameters to the model for determining the cutoff grade parameters according to the features of the study area. This study should be considered to investigate the applicability of the bivariate lognormal distribution model with two independent samples to examine the cutoff grade parameters, and further improvements should be made for other ore deposits.

4. CONCLUSIONS

One of the most significant parameters of a coal deposit is the moisture and ash. The determination of tonnage rate, mean of moisture, and mean of ash involves the determination of cutoff moisture, and cutoff ash is very important. The bivariate lognormal distribution model with two uncorrelated samples will serve as an important tool for analysis of the moisture and ash.

In the Seyitomer coal deposit, as the cutoff grade parameters increase, tonnage rates of the deposit also increase as determined by using the model. But over 30% of cutoff moisture is not a considerable variation in tonnage rate. In addition, cutoff moisture and cutoff ash are increased as the mean of moisture and mean of ash are increased. However, with mean of moisture and mean of ash increased, the quality of the coal deposit is decreased.

This article shows that a bivariate lognormal distribution model with two uncorrelated samples provides useful information for the cutoff grade parameters in helping them plan their coal deposits. This method is efficient to assist decision makers assessing cutoff grades parameters in order to improve the mining planning.

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