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# Characterisation of Tufanbeyli (Adana) Lignite Ashes

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## Abstract

The mineralogical, physical and chemical properties of three different type ashes from Tufanbeyli (Adana) coalfield are investigated in this study. The mineral matter in the ashes, determined by means of X-ray diffraction, is dominated mainly by anhydrite, lime, and quartz. The low-calcium ash sample has the typical crystalline phase quartz. The medium and high-calcium ash samples have the complex assemblage of crystalline phases. The presence of anhydrite in all samples indicates that the high activity of calcium not only promotes the formation of sulphates from calcite, but also the dehydration of gypsum during and after combustion. Chemical analysis of the ashes showed that they were mainly composed of CaO, $SiO_2$ and $Al_2O_3$. It is very important to understand the interaction of ash with water. The tests show that the all the type of Tufanbeyli/Adana ashes can be conditioned with water to permit dust and fume free transport back to the dumping area.

**Keywords:** Tufanbeyli power plant, Ash, Humidification; Ash handling

## Tufanbeyli (Adana) Linyit Küllerinin Karekterizasyonu

## Öz

Bu çalışmada, Tufanbeyli (Adana) kömür havzasından alınan üç farklı kül içeriğine sahip linyit örneklerinin mineralojik, fiziksel ve kimyasal özellikleri araştırılmıştır. X-ray difraksiyon analizine göre; kül numuneleri anhidrit, kireç ve kuvars minerallerinden oluştuğu belirlenmiştir. Düşük kalsiyum içeriğine sahip kül numuneleri kristallin yapıda kuvars minerallerine sahiptir. Orta ve yüksek kalsiyum içeriğine sahip kül numuneleri ise kompleks kristalin yapıya sahiptir. Numunelerin içerdiği anhidrit mineralinin varlığı kalsit minerallerinin sülfat formuna dönüşmesinin yanı sıra, yanma işlemi sonucunda jips minerallerinin dehidrasyona işaret etmektedir. Kimyasal analiz sonuçlarından kül numuneleri CaO, $SiO_2$ ve $Al_2O_3$ elementlerinden oluştuğu belirlenmiştir. Yanma sonrası elde edilen külün su ile etkileşimi çok önemlidir. Yapılan deneylerden elde edilen sonuçlar, Tufanbeyli linyitlerinin yanması sonucunda oluşan küllerin su ile taşınabileceğini ortaya koymuştur.

**Anahtar Kelimeler:** Tufanbeyli termik santrali, Kül, Nemlendirme, Kül taşıma

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## 1. INTRODUCTION

It has been estimated that Turkey's electrical energy demand, which at present is approximately 80.000 GWh, will exceed 150,000 GWh in ten years' time [1]. The full potential of both fossil fuel and hydroelectric resources will have to be exploited to sustain such fast development. The known lignite reserves of Turkey are 7.300.000.000 t, and the Tufanbeyli (Adana) basin contains 300.000.000 t the total reserve. Within the coming ten years and thereafter a boom in lignite production has to be expected.

The Tufanbeyli (Adana) lignite is best suited to use in thermal power generation and are capable of supplying 2 X 300 MW power stations. The Mineral Research and Exploration Institute (MTA) of Turkey first investigated the area in 1986 [2]. Exploratory drilling started from in 1989 and is still underway [3].

This study is carried out by the data supplied from core samples drill holes numbered Z11 that had been drilled vertically from the surface down to the lignite. It is intended of this study to show how widely Tufanbeyli (Adana) lignite ashes vary in their physical, chemical and mineralogical properties. Knowledge of the physical and chemical properties of ash is consider necessary for identifying and preventing problems concerning the construction of power station planned to install at Tufanbeyli (Adana).

## 2. MATERIAL AND METHOD

Approximately 60 kg of the sample used in this study was collected from Tufanbeyli coalfield, Adana.

X-ray diffraction (XRD) analyses were performed on a Shimadzu XRD-6000 type diffractometer employing Cu $K_\alpha$ radiation in the range 2θ=0°-60° at a goniometer rate of 2θ=2°/min. Particle size measurement of ash sample was carried out by sieving technique.

A pycnometer was used to determine the specific gravities of ash samples. Development of pH in suspensions of each ash in water was monitored by a universal glass pH probe and pH meter. Ash samples of weigh 2 g were suspended in 100 mL of deionized water by continuous stirring. The immediate pH of the solution and pH values each hour thereafter for a period of 24 h was recorded.

Elemental analysis of samples, named H-L4, H-M21 and H-H36, taken from the plant scale humidification tests were carried out by X-ray fluorescence (XRF) spectrometry technique.

XRD and XRF analysis were carried out at the laboratories of The Scientific and Technical Research Council of Turkey (TUBITAK), Marmara Research Center (MRC). In order to determine free CaO content 1 g sample was mixed intensively in 1 liter of deionized water for an hour using the agitator. After the precipitate was settled, 100 mL of the clear solution was drawn with a pipette then titrated potentiometrically with 0.05 N HCl until pH 7 is obtained.

For the wet quenching curve analysis, ash sample of weigh 500 g placed into a Dewar flask, and cold tap water of weigh 600 g was added in ash sample of weigh 500 g by continuous stirring. Stirrer speed was set to 350 rpm. The temperature was recorded every minute for the first ten minutes, then at intervals of about 5 minutes for a period of one hour.

## 3. RESULTS AND DISCUSSION

### 3.1. Elemental Composition

Analysis results of total CaO, free CaO and $SO_3$ contents of the ash samples are presented in Table 1. Total CaO content of samples varies from 6.20% to 74.12%. The ash samples are classified to three categories referring to their total CaO content.

The total CaO content of low, medium and high-calcium ashes range from 6% to 20%, 21% to 49% and 50% to 75, respectively. The chemical analysis results of the samples named H-L4, H-M21 and

H-H36, taken from the plant scale humidification tests, are presented in Table 2. There is a positive relationship between total and free CaO content (Figure 1). The chloride contents were between 0.01% and 0.06%. These values are too low for corrosion.

**Table 1.** Total CaO, free CaO and $SO_3$ contents of the ash samples

| Sample No | Total CaO (wt%) | Free CaO (wt%) | $SO_3$ (wt%) | Ash Type |
|---|---|---|---|---|
| L1 | 6.20 | 3.50 | 4.26 | Low-calcium |
| L2 | 8.90 | 4.20 | 7.88 | Low-calcium |
| L3 | 14.06 | 5.10 | 12.44 | Low-calcium |
| H-L4 | 14.16 | 4.20 | 12.05 | Low-calcium |
| L5 | 15.70 | 5.90 | 14.62 | Low-calcium |
| L6 | 16.70 | 7.30 | 11.80 | Low-calcium |
| L7 | 16.72 | 7.50 | 3.75 | Low-calcium |
| L8 | 17.92 | 9.50 | 12.86 | Low-calcium |
| L9 | 19.20 | 9.60 | 18.55 | Low-calcium |
| L10 | 19.60 | 10.35 | 14.70 | Low-calcium |
| M11 | 21.64 | 13.70 | 15.66 | Med-calcium |
| M12 | 22.51 | 12.70 | 18.63 | Med-calcium |
| M13 | 23.91 | 9.60 | 15.82 | Med-calcium |
| M14 | 25.72 | 14.20 | 13.69 | Med-calcium |
| M15 | 26.00 | 14.50 | 16.38 | Med-calcium |
| M16 | 27.66 | 15.30 | 15.82 | Med-calcium |
| M17 | 29.54 | 15.90 | 19.47 | Med-calcium |
| M18 | 30.26 | 14.80 | 14.05 | Med-calcium |
| M19 | 32.59 | 17.10 | 15.94 | Med-calcium |
| M20 | 34.16 | 17.60 | 12.16 | Med-calcium |
| H-M21 | 35.43 | 21.50 | 19.30 | Med-calcium |
| M22 | 37.32 | 20.30 | 17.03 | Med-calcium |
| M23 | 41.87 | 22.10 | 19.10 | Med-calcium |
| M24 | 42.00 | 20.00 | 24.20 | Med-calcium |
| M25 | 43.62 | 29.3 | 21.64 | Med-calcium |
| M26 | 44.36 | 25.00 | 18.12 | Med-calcium |
| M27 | 46.68 | 30.50 | 15.20 | Med-calcium |
| M28 | 46.87 | 28.00 | 15.36 | Med-calcium |
| M29 | 47.32 | 30.00 | 19.46 | Med-calcium |
| M30 | 48.30 | 33.10 | 15.38 | Med-calcium |
| M31 | 49.73 | 32.60 | 14.63 | Med-calcium |
| H32 | 50.49 | 34.05 | 12.12 | High-calcium |
| H33 | 53.00 | 35.00 | 19.00 | High-calcium |
| H34 | 56.23 | 38.50 | 18.65 | High-calcium |
| H35 | 61.71 | 44.20 | 12.86 | High-calcium |
| H-H36 | 62.20 | 51.30 | 12.40 | High-calcium |
| H37 | 67.10 | 58.10 | 15.00 | High-calcium |
| H38 | 70.97 | 52.60 | 9.86 | High-calcium |
| H39 | 71.19 | 60.50 | 11.07 | High-calcium |
| H40 | 72.05 | 48.80 | 9.10 | High-calcium |
| H41 | 73.72 | 59.50 | 10.03 | High-calcium |
| H42 | 74.12 | 61.50 | 9.02 | High-calcium |

**Table 2.** Chemical analysis results of the ash samples numbered H-L4, H-M21 and H-L36

| Element Oxide (wt%) | H-L4 | H-M21 | H-H36 |
|---|---|---|---|
| Total CaO | 14.16 | 35.40 | 62.20 |
| Free CaO | 4.20 | 21.50 | 51.30 |
| $TiO_2$ | 0.66 | 0.20 | 0.20 |
| $Al_2O_3$ | 17.10 | 9.55 | 4.60 |
| $Fe_2O_3$ | 8.56 | 4.10 | 5.40 |
| MnO | 0.09 | 0.16 | 0.02 |
| MgO | 2.68 | 3.65 | 2.60 |
| $SiO_2$ | 42.66 | 26.81 | 10.30 |
| $Na_2O$ | 0.71 | 0.20 | 0.20 |
| $K_2O$ | 0.67 | 0.20 | 0.20 |
| $P_2O_5$ | 0.34 | 0.46 | 0.10 |
| $SO_3$ | 12.05 | 19.30 | 12.40 |
| Cl | 0.01 | 0.02 | 0.06 |

### 3.2. Mineralogy

The mineral matter in the ashes is dominated mainly by anhydrite, lime, and quartz. The low-calcium ash sample has the typical crystalline phase quartz. A similar pattern has been identified in some Turkish ashes from Soma, Seyitomer and Catalagzi coal fields [2].

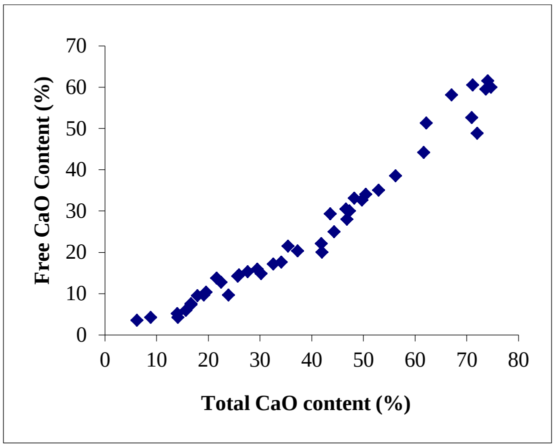


**Figure 1.** Relationship between total and free CaO contents

The medium and high-calcium ash samples have the complex assemblage of crystalline phases. High calcium concentrations in these samples result in the formation of lime (CaO) and anhydrite. The presence of anhydrite in all samples indicates that the high activity of calcium not only promotes the formation of sulphates from calcite (in the presence of sulphur oxygen), but also dehydration of gypsum during and after combustion, which occurs at temperatures greater than 400-500°C [3-4]. It is very important to understand the interaction of ashes with water, in order to determine their optimum humidification level.

For that reason, normative analysis was used to estimate the various amounts of anhydrite and lime based on their oxide percentages [5]. The result of these calculations is presented in Table 3.

**Table 3**. The amount of anhydrite and lime contents of the ash samples

| Type of ash | Anhydrite (wt%) | Lime (wt%) |
|---|---|---|
| Low-Calcium Ash (H-L4) | 20.5 | 5.7 |
| Medium-Calcium Ash (H-M21) | 24.8 | 29.9 |
| High-Calcium Ash (H-H36) | 21.1 | 53.5 |

### 3.3. Fineness Variation

The particle size range for the samples H-L4 and H-M21 show no significant difference, whereas H-L4 is significantly finer. Figure 2 presents the range of the particle size distribution of the Tufanbeyli (Adana) ash samples.

It indicates that the ash contains important proportion of (31 to 68 wt%) clay and silt size. These results agree with this found by Bayat [2], who reported that clay and silt size proportion of four different Turkish coal ashes including Afsin-Elbistan ash vary from 40 to 70 wt%. The fineness of ash reflects its permeability.

### 3.4. pH Development

Data on the development of pH with time of solutions of ashes in water are presented in Figure 3. Ash samples except H-L4 are highly alkaline at around 12.5. In the cases of ashes numbered H-M21, H-H36 and H42, the pH of the solution reached a peak value of 12.5 and 12.8 at 6 h and 13 at 4 h respectively, and then remained at the same level for the period of 24 h. In the case of ash numbered H-L4, the ph value reached a peak value of 9.3 at 2 h and decreased 7.1 at 4 h, and then remained almost constant at approximately 7.

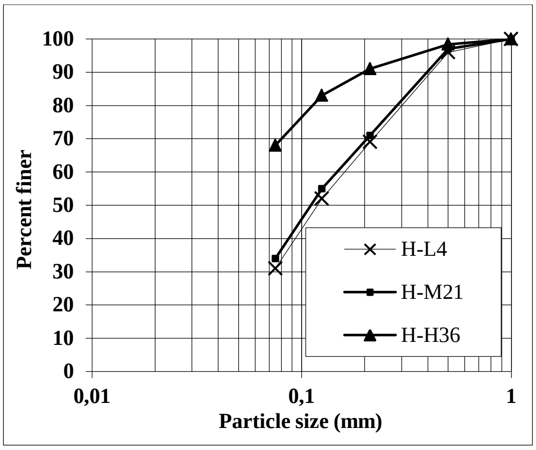


**Figure 2**. Particle size distribution of the Tufanbeyli (Adana) ash samples

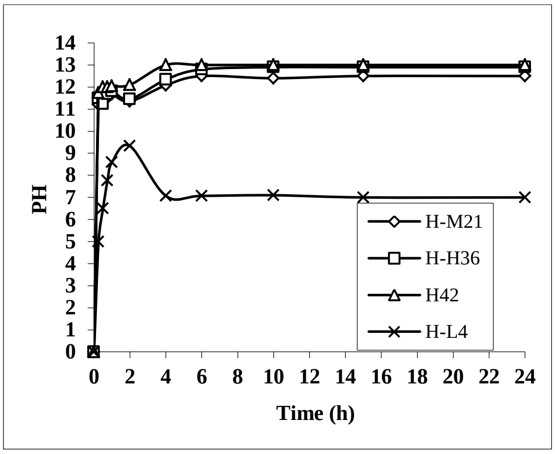


**Figure 3**. pH development of Tufanbeyli (Adana) ashes

### 3.5. Wet Quenching Curve

Wet quenching curve analyses were carried out for the samples H-L4, H-M21 and H-H36. The residual moisture content of 0.3 wt% measured for the samples H-L4 and H-M21 and 0.4 wt% for H-H36 has no bearing on the observations that follow. This confirmed by the existence of a clear gradation of reactivity between the individual ash samples in the wet quenching curves (Figure 4). These wet quenching curves reveal only slight difference between the samples H-L4 and H-M21. In both instance, only a very slight temperature increase from the initial temperature of 17°C to 25°C or 32°C is observed after one hour. A temperature of 55 °C was measured after ten minutes and ultimate temperature of 68 °C after 24 minutes.

### 3.6. Density Distribution

As seen from Table 4, the bulk density of the ash samples ranged from 0.56 to 1.36 g/cm$^3$, and specific gravity ranged from 2.55 to 3.27 g/cm$^3$.

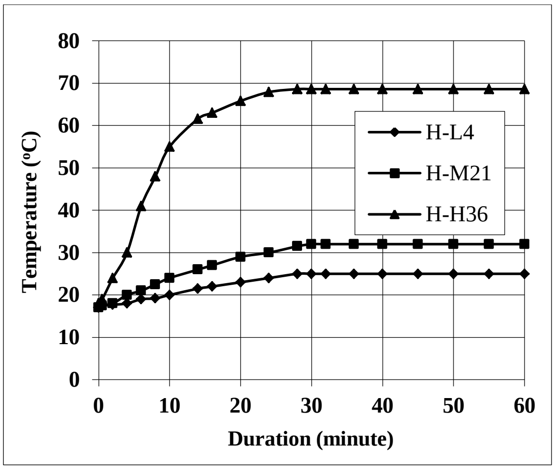


**Figure 4.** Wet quenching curve analyses results

**Table 4**. Density distribution of Tufanbeyli (Adana) ashes

| | Bulk density (g/cm$^3$) | Specific gravity (g/cm$^3$) |
|---|---|---|
| L1 | 1.34 | 3.16 |
| H-L4 | 1.36 | 3.27 |
| M11 | 1.10 | 2.97 |
| H-M21 | 1.07 | 3.03 |
| H32 | 0.81 | 2.84 |
| H-H36 | 0.79 | 2.80 |
| H42 | 0.56 | 2.55 |

It was evident that both bulk density and specific gravity values increase as the particle size and total CaO content of the ash samples decrease. In addition, due to the big range of the density of ash samples, particular attention has to be paid for the design and construction of ash handling system.

## 4. CONCLUSIONS

In this study, the characterisation of Adana/Tufanbeyli lignite ashes was evaluated using chemical analysis, density wet quenching curve, mineralogical elemental composition analyses. It was determined that all the type of Adana/Tufanbeyli ashes can be conditioned with water to permit dust and fume free transport back to the dumping area

## 5. REFERENCES

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