

Investigation for Environmental Effects and Evaluation of Fine Tailings from Tunçbilek Coal Processing Plant/Turkey

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Abstract: In energy production, coal still keeps its importance despite many environmental problems. Although Turkey is fortunate in terms of coal reserves, it is not possible to say the same for their quality. Unfortunately, most of the coal reserves in Turkey are of low quality. Therefore, they have high ash, moisture and sulphur contents. Increasing environmental concerns and the demands of new generation technologies make it necessary to clean the coal. Coals can be enriched at every stage as large, fine and slime, and are referred to by the same names in the tailings. Coarse and fine tailings can be stored dry, while coal in very fine size (-0.1 mm) is fed to the dams after not being enriched and dewatered at certain rates in Turkey. These residues are produced at Tunçbilek coal processing plant of Western Lignite Corporation (WLC), which is one of the oldest and most important coal preparation plants in Turkey, and during which the gravity processes are applied. The most important environmental problem here is that the ultra-fine slime, which is not enriched with high calorific values (kcal/kg), is charged to previously mined open pit holes. In addition, there are two ponds and an open pit hole in the vicinity of the plant where these remains were stocked in previous years. Tailing charging is still going on for another open pit hole at the plant. In this case, both the economic losses and the environmental problems are continuing as the coal is not recovered from these tailings. For this reason, it is necessary to completely dehydrate and store or enrich these tailings.

Keywords: Environmental effects, evaluation, fine tailings, coal processing.

Introduction

Coal from organic sedimentary rocks contains mostly inorganic materials consisting of minerals and combustible organic materials in the maceral structure. Coal is heterogeneous at certain levels. At its simplest level, it is a mixture of organic and inorganic phases, but the mineral material is composed of inorganic constituents, which have different structures and liberation characters carried from the inorganic constituents of the plant, other organic substances and coal beds (Meyers, et al., 2001).

A widely used method in order to identify coal employs rank, humidity, inorganic material, and calorific value ranging from about 9 to 35 MJ/kg (4000 to about 15,000 Btu/lb). The percentages of humidity and inorganic material typically range from 1% to 30% and 5% to 50%, respectively (Smoot, et al., 2001).

In the preparation of coal, the aim is to increase its value by reducing the content of impurities (inorganic matter) from raw coal. The most common criterion for process quality is the complete removal of the ash during the washing process. However, during this process which is not possible physically, the particles with lower content of inorganic matter are separated from those with higher content of inorganic matter (Meyers, et al., 2001).

Mineral and mineral wastes from ore preparation and coal washing plants, which are established for the

purification from gangue minerals, also require the use of appropriate lands and cause damages to the environment over time. In order to prevent land use for storing purpose and deterioration of the nature of the landscape, the most suitable solution to avoid harming the environment is to charge the tailings that cannot be used and evaluated back into the environment from which they extracted (Kafadar, 1992).

The tailings separated from coal are blended on arable land and the acid waters that leak from them can be harmful to the land. Moreover, since the waters used in the washing facilities are given back again to the nearest rivers, lakes and seas, they cause damages that cannot be compensated for.

The effects of the coal industry on the environment can be examined in two main groups, although they are seen at various stages such as coal mining, coal preparation, coal transportation, coal burning, tailings storage and tailings disposal.

1. Environmental impacts during coal mining: It is seen that the degradation of soil cover, contamination of surface and ground water and drinking water resources, deterioration of water and soil habitat and air quality are affected negatively.

2. Environmental impacts during coal washing and preparation: The resultant tailings formed as a result of coal washing activities have a different character than the wastes described in Article 1. Coarse tailings in

coal mines are generally stored in open stacks, while the fine-grained slimes are transported or filtered to waste dams. In general, although all residues from all stages of coal processing have different characteristics and effects, they are often collectively called coal tailings. These wastes naturally contain radioactive substances. They can also lead to the formation of acidic water in the case of pyrite presence. If a variety of chemicals are used in the coal preparation, flotation and flocculation stages, there may also be contaminants which may be harmful to the environment

If the adequate measures are not taken, all of the mining activities may cause the degradation of river, lake and surface waters as well as affecting the hydrology and quality of groundwater.

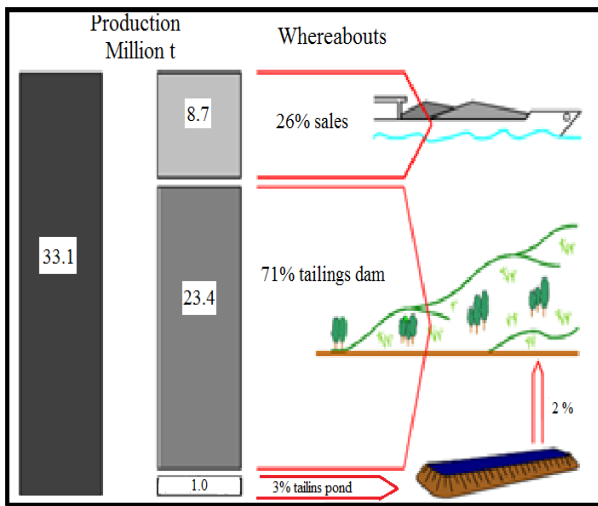


Fig. 1 Mineral exploitation and disposal methods from the coal mines in the Ruhr, Saar and Ibbenbüren regions in Germany (European Commission, 2009).

Coal tailings in some cases reach very large quantities. For example, in Germany it is reported that 24 million tonnes of coal are produced annually from underground coal mines and that the mine waste is almost equal to the produced coal. As seen in Figure 1, some of the tailings are offered for sale, a large proportion is stored, and a small proportion is fed to the tailings dam.

Coal washing sludge is mostly liquid and usually stored in a tailings dam near the coal mine. Tailings dams have a sedimentation pond that allows the solid part to collapse, where they are filtered by water drainage systems

Today, the economic and environmental benefits provided by coal enrichment activities can be listed as follows (DTI, 2001):

- Sellable coal with high quality and commercial value,
- Increase in yield and production,

- Reduction of negative environmental impact of coal preparation plants by emission of SO₂, CO₂ and small size particles,
- Decrease in the amount of ash in the residue.

Clean coal technology uses new techniques which are designed to improve efficiency and environmental suitability in coal production, preparation and use. These technologies help in reducing gas emissions and wastes from one side and increase the energy from unit coal from the other side. On a global basis, the coal industry's main focus in recent years is upon increasing the efficiency of coal-based thermal power plants and reducing CO₂ emissions from these plants (TKI, 2014).

The most important problem that has risen in efforts to reduce the content of ash and pyritic sulphur in the coal of Turkey is the release of ash and pyritic sulphur in coal, usually in fine grain sizes. Gravity methods used to remove gangue from very fine grain sizes have generally low productivity, necessity of flotation method and absolute briquetting of cleaned coal has prevented these studies from being carried out in detail. The development of gravity devices capable of enriching fine grain sizes over the last few years is important for the cleaning of problematic coal in Turkey. This opportunity will make it possible to reduce the dependence on the country's economy and energy by clearing the ash and pyritic sulphur of the large coal reserves and briquetting. As in every country, the energy and therefore the energy materials are also of high importance for the development of Turkey.

In today's world, especially in the last few years, the elimination of the environmental and air pollution problems that grow parallel to rapid industrialization is an important topic, and raw material production which poses no harm to human and environmental health has come to this agenda as well as the improvement of applied technological methods. In addition, a detailed standardization was carried out in the determination of the qualities of the mentioned raw materials; in particular the standards promulgated in advanced industrialized countries which brought legal sanctions. In order to be able to realize the same situation, in the industrialization of Turkey especially in recent years, the reorganization of the technologies affecting the human and environmental health and the increase of the raw material quality have been started and legal arrangements have been put into operation. In this context, the Ministry of Environment, the Turkish Standard Institution, the local governments and universities continue to work on reducing the impacts of low quality coals on air pollution in particular (Semerkant, et al., 1992).

Contaminated water and slimes discharged from Tunçbilek Coal Preparation Plant to Kocaçay Stream and surrounding area caused great damage and Apolyont Lake fed by Kocaçay Stream was filled up with these slimes for years. There are also similar

cases in Soma and Zonguldak, which have coal washing facilities. Of course, it is not only the coal washing and preparation facilities that give harm to the environment. There are similar types of harmful wastes in establishments related to other types of mines.

The aim of the present study is to reveal the storage forms of the fine tailings up till now, their environmental effects and their potential for evaluation formed in the Tunçbilek Coal Preparation Plant owned by WLC and operated by a private company.

Tuncbilek Coal Preparation Plant

The raw coals with high ash content produced from open and underground pits in Tunçbilek are subjected to preparation and washing processes in Tunçbilek and Omerler Plants of WLC in order to obtain certain ash, calorific and size values suitable for industry and market demand.

Tunçbilek Plant has an installed capacity of 700 tons/h and is trying to get the cleaned coal in three circuits as coarse coal (18-150 mm), fine coal (0.5-18 mm) and slime (0.1-0.5 mm). In addition, there is a thickener cycle (-0.1 mm) in which water is recovered, and there is a tailings dam where the fine wastes are discharged (Fig. 2).

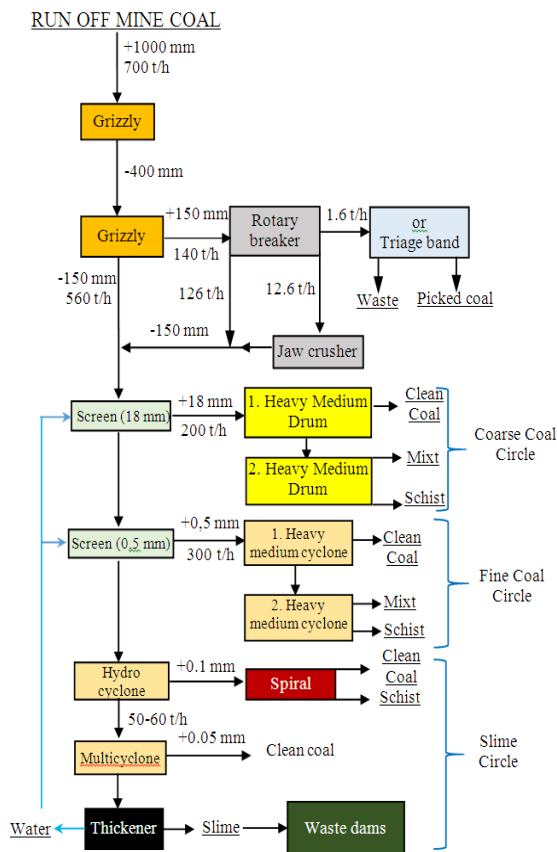


Fig. 2 Tunçbilek plant's simplified process diagram and solid balance.

Coal Feeding; Run-off mine coals coming from underground and open pit operations by trucks were

dumped onto silos with fixed grids of 400x400 mm sieve openings. The raw coal, passed under 400 mm, is hauled to the conveyor belts with the under-silo feeders and fed to the grizzly with a 150 mm span. The particles passing under -150 mm are fed to the plants run-on conveyor belt. The coarse pieces remaining on the sieve are crushed under 150 mm by feeding rotary crusher, and the crusher under belt conveyor is fed. The large coal and marl fragments coming from the rotary crusher outlet are broken under 150 mm in the jaw crusher in front of the rotary crusher. The coals passing under the crusher and the raw coals passing under the grizzly are together fed to group belt conveyors A and B with magnetic metal piece holders.

The -150 mm raw coal fed to the belt conveyor from run-off mine coal is subjected to a sluice treatment with a sieve of 18 mm. The 18 mm run-off mine coal passing under the sieve is fed to the fine coal washing cycle while the run-off mine coal remaining on the sieve is diverged to the large coal wash cycle.

a) Coarse Coal Cleaning Circle: Two heavy media washing drums with 2x200 tons/h raw coal capacity are used for this purpose. The washing drums operate at a heavy media density of 1700 gr/l obtained with magnetite-water mixture. The floating coal and sinking schist of the raw coal (18-150 mm) fed to the drums are then fed to the washing screens separately. In the washing screens, magnetite adhering to the schist and enriched coal particles are collected in the tank by washing and given to the magnetic separators by the pump. Magnetite is recovered and the loss of magnetite is reduced to a minimum level. The schist from the washing screens is thrown into the silos by means of a band conveyor. Coal is sorted and classified according to the size of the pieces (10-18 and +18 mm). The clean coal, which is sorted and classified, is poured separately into silos by means of sorting bands and sent to the market for heating and industrial use.

b) Fine Coal Cleaning Circle: -18 mm raw coal is sieved at 0.5 mm in raw coal sieves. -0.5 mm coal is then directed to the slime pond. 0.5-18 mm raw coal is mixed with heavy media liquid in heavy medium tank and forwarded to 1st heavy medium cyclone circle by a motor pump. Quality coal is produced by washing at a density of 1500 gr/l in 1st heavy medium cyclone cycle. The subsequent sinking part is subjected to a separation at a density of 1800 gr/l in 2nd heavy medium cyclone cycle to obtain an intermediate product. The clean coal obtained from the enrichment process is purified from magnetite and sieved by a sieve of 8 mm opening. The product of 8-18 mm is directly forwarded to the market (heating, industry or coal fired power plant) according to the demand while the remaining part of 0.5-8 mm is dried by a centrifugal dryer to obtain a humidity value of maximum 20%.

c) Slime Cleaning Circle: In 1984, the treatment plants were taken into operation to prevent harm to the

environment and to obtain the flammable part of the waste waters. With the amendment made in 2001, -0.5 mm slime coals and all the run-off waters of the coal washing plant were collected in a large pool, and they were pumped by a pump to 4 pieces of 24-inch diameter cyclones. The product below 0.1 mm is taken as waste water from above the cyclone and sent to the thickener tank which was commissioned in 1996. The particles in the -0.5 + 0.1 mm fractions under the cyclone are fed to the spiral circulation as water with coal. The clean coal from the spiral circulation is fed to the dewatering screen and from there to the centrifuge dryer. The resulting product with an average moisture of 22% is then presented to the market or coal fired thermal plant. The schist from the spiral is fed to the schist band after it is dewatered.

The amendment was made in April 2001 to stop the coal from mixing in the groundwater runoff and to prevent contaminated water leaks to the environment from time to time. Thus, both coal leaks are reduced to a minimum and polluted water discharge from the coal cleaning plant is prevented.

Specifications of Tunçbilek Coal Cleaning Plant:

Plant capacity	: 700 t/h
Feed size for the plant	: 150 mm
Electricity consumption	: 3623.53 kWh/t
Magnetite consumption	: 800 gr/ton
Water consumption	: 1000 t/h
Flocculent consumption	: 7.5 gr/t
Pulp quantity fed to the thickener	: 1000 t/h
Diameter and height of the thickener	: 18 m and 5 m

Product specifications are given in Table 1.

Table 1 Short analysis values of the coal enriched in Tunçbilek Plant (GLI, 2017).

Particle size of coal (mm)	Dried ash (%)	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Lower calorific value (kcal/kg)	Upper calorific value (kcal/kg)	Total sulphur (%)
+18	21,98	13,22	38,24	35,09	5006	6139	2,51
10-18	16,80	15,29	39,61	36,91	5243	6507	2,21
0,5-18	17,54	17,49	39,29	35,56	5048	6470	2,18
0,1-0,5	42,97	24,75	32,70	--	2811 (org.)	3800 (orj.)	1,11
-0,1	53,08	28,65	29,50	--	2016(org.)	3000 (orj.)	1,27

d) Thickener Circle: 1000 tons/hour of water is used for washing the coal in Tunçbilek Coal Cleaning Plant. In 1996, when the wastewater from the previous years was discharged into Adranos Stream (Kocaçay), the thickener system related to the treatment of Tunçbilek wastewater was used to prevent the pollution caused by the wastewater. Wastewater with 6% solid content resulting from the washing of the coal in the coal washing plant is directed to the thickener tank with a capacity of 1000 t/s from the upper stream of the cyclone circuit. The solid in the slurry is precipitated

by means of flocculent (anionic polymer) and subjected to solid-liquid separation. The result of the precipitation is 30% solids content and is subjected to natural sedimentation by pumping into the holes of open pits previously worked out with the help of 200-250 t/h capacity motor pumps. Approximately 200 t/h of water is pumped from Adranos Stream to the plant to compensate for the loss of the water content of the schist-weighted tailings discharged into the holes of previously mined areas as much as the moisture remaining on the coal and tailings. The clean water overflowing from the thickener tank (750-800 t/s) is used as washing water in the plant again by circulation, thus saving the energy costs as well as preventing pollution of the environment.

The coal that can be recovered from the slime is considered to be 2% of the raw coal fed into the plant.

As a slime pond, 6-C Panel old working hole at a distance of 1000 m from the plant was used.

The flow diagram of the water balance to be used during the treatment at the plant is given in Figure 3.

3. Storage, Environmental Effects and Evaluation Potential of Tailings

With the appropriate strategy and evaluation methods, it is possible to recover the tailings from the coal preparation plants as much as possible and to prevent the environmental pollution. Tunçbilek coal cleaning plant's tailings that have been formed since the foundation of the plant in 1967, were given to Adranos Stream until 1982 and since then 6 different areas of various sizes have been used for storage (Fig. 4).

Two ponds with soil banks were formed in 1982 in

order to precipitate solids in wastewaters discharged from Tunçbilek plant so that cleaned water could be directed to Kocaçay.

No. 1 pond from these sludge ponds located next to the neighbourhood of miners were partly evacuated. The soil was then poured onto it and planted with poplar trees.

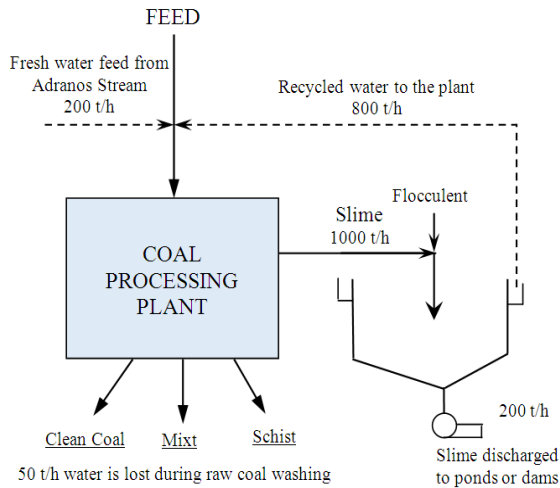


Fig. 3 Water balance of Tunçbilek coal cleaning plant.

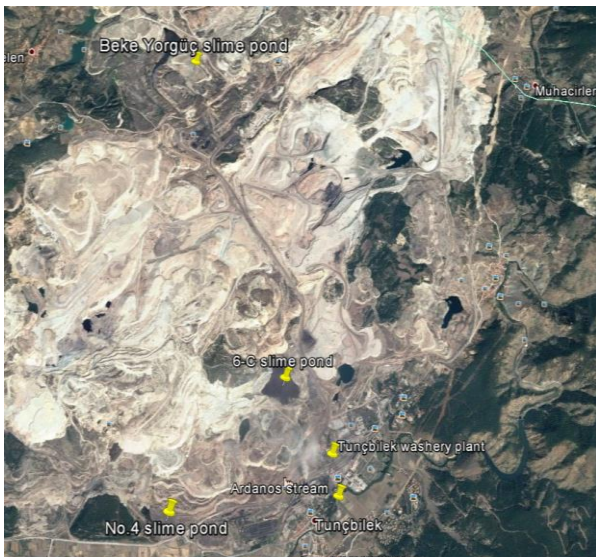


Fig. 4 Mined out areas where the plant wastes were stored (Beke open pit, Number 4 pit and 6-C panel) and the location of Tunçbilek Coal Cleaning Plant.

No. 2 pond is another pond next to former dynamite warehouse and is presently filled up with the settled solid material.

Measurements to the overflow level of No. 2 pond:

Area of pond	: 24 941 m ²
Depth of pond	: 4.25 m
Volume of pond	: 106 000 m ³
Density	: 1.8 t/m ³
Quantity of slurry	: 190 800 t

Analysis results of the specimen taken from the pond on 08.05.2003 are as follows:

<u>Moisture, %</u>	<u>Ash, %</u>	<u>Calorific value, kcal/kg</u>
23.50	62.66	1355

To solve the problem in 1983, The Tunçbilek Waste Water Treatment Plant was taken into operation and the wastewater discharged from the plant was first pumped to Kargapınarı-3 mined out hole. However, this area was used as overburden heap for the K3-HF panel and the waste material was left at the bottom.

Then, the wastewater was discharged into No. 4 mined out hole. The diluted slurry coming into the thickener started working in the first half of 1996 and was precipitated from its solid matter with the addition of flocculent. Therefore, the thickened waste was pumped into the same place until the year 2001 (Figure 5).

Measurements to the overflow level of No. 4 slurry pond:

Area of pond	: 116 000 m ²
Depth of pond	: 40 m
Volume of pond	: 4 640 000 m ³
Density	: 1.8 t/m ³
Quantity of slurry	: 8 352 000 t

Analysis results of the specimen taken from the pond on 08.05.2003 are as follows

<u>Moisture, %</u>	<u>Ash, %</u>	<u>Calorific value, kcal/kg</u>
27.80	71.50	667

The Beke top slurry pond is located on the soil heaps within the old mined out borders of Beke open pit. The keeping level of slurry was also low because the bank was not raised enough in the surrounding area.



Fig. 5 Slurry pond formed in the hole of No 4 mined out pit.

Measurements to the overflow level of slurry pond in concern

Area of pond	: 226 800 m ²
Depth of pond	: 5 00 m
Volume of pond	: 1 134 000 m ³
Density	: 1.8 t/m ³
Quantity of slurry	: 2 041 200 t

Analysis results of the specimen taken from the pond on 08.05.2003 are as follows:

<u>Moisture, %</u>	<u>Ash, %</u>	<u>Calorific value, kcal/kg</u>
27.70	65.94	1049



Fig. 6 Slurry pond formed in the mined out hole of Beke open pit.

The slime of Tunçbilek Coal Cleaning Plant is still deposited in the mined out hole of the 6-C panel (Figure 7). It is not possible to remove the material, which is already in the form of slime, due to topographical conditions.

Analysis of the specimen taken from the outlet of the thickener tank on 08.05.2003 is as follows:

<u>Moisture, %</u>	<u>Ash, %</u>	<u>Calorific value, kcal/kg</u>
25	66	713

Analysis values of original waste are given below:

Solid density, g/cm ³	: 1.9
Solid ratio, %	: 7-12
Particle size, mm	: -0.05
Ash, %	: 71.48
Volatile matter, %	: 20.71
Fixed carbon, %	: 13.13
Upper calorific value, kcal/kg	: 1866
Lower calorific value, kcal/kg	: 1751
Total sulphur, %	: 1.88



Fig. 7 Slime pond formed in the mined out hole of 6-C panel.

In order to carry out the enrichment of coarse coals (+0,1 mm), devices using the differences between the density of organic and inorganic compounds such as heavy media, jig, shaking table, spirals, cyclone, etc. are affectively utilized industrially. However, in these devices, the yield is reduced in fine dimensions; even the recovery is very difficult for the sizes less than 0.1 mm. Gravimetric enrichment methods based on centrifugal forces and flotation are more effective in the acquisition of such fine sized coals (Özbayoğlu and Mamurekli, 1988; Aktaş, 2002; Osborne, 1988).

Despite the fact that fine coal is more economical to be thrown away in the past years, the rapid increase in the activities of mining today necessitates the assessment of the fine fractions. Although it is possible to find many studies using advanced gravity separators in the world, researches on the enrichment of fine size coal in Turkey have been limited (Aslan, 1996; Engin, 2002).

In a project conducted by Sabah (2007), enrichment of the wastes of Tunçbilek Coal Preparation Plant (WLC) under 0.1 mm with a minimum cost was explored together with the investigation of the residues accompanying the coal in the tailings for their usability in brick manufacturing. In the process proposed in this study, clean coal with 19.72% ash, 1.47% total and 1.37% flammable sulphur content and 5696 kCal/Kg of upper calorific value was obtained.

According to column flotation studies conducted with the slime obtained from lower outlet of the thickener of Tunçbilek coal cleaning plant (Öteyaka, et al., 2008), 20.79% ash content of coal was recovered with a calorific value of 5671.13 Kcal/kg with 64.86% efficiency. In the light of the Jameson cell flotation studies carried out with the same sample by Uçar, et al. (2006), 18.3% ash content of coal was obtained with 90% yield.

Although it is costly to obtain coal from fine tailings, it is important that these tailings should not be discarded due to reasons such as the new techniques for fine particles recovery (centrifugal methods, Jameson flotation, etc.), environmental factors and the use of inorganic tailings to be obtained therefrom. Moreover, due to the fragile structure of the coal, the processes starting from the extraction and washing processes tend to crumble the particles and gradually move to subtle dimensions. That is, this fraction is readily available at every stage of production, and as the coal becomes more liberated, it can be recovered by effective methods.

Results and Discussion

The Tunçbilek washery tailings, which are mostly in the size under 0.1 mm, are pumped on the ponds or waste dams following the dewatering operations carried out in the thickener tanks, together with the wastewater released after the coal preparation operations.

At present, the facility has a capacity of 700 tons/hour and consumes an average of 1.5 cubic meters of water per ton of enriched coal. Prosthetic water loss consists solely of water on products and tailings, as moisture, and together with slime. In order to prevent unnecessary water loss, the water contaminated during the process is purified and reused. Treatment is carried out at thickener tank and approximately 800 t/s of purified water is fed back. Water loss is unavoidable at negligible rates as the plant operates with a completely watery process. Some of this loss is on coal, some on schist, and some on slime as moisture. The difference between the moisture content of the product and the tailings is considered as water loss of the system. In addition, some water is discharged together with the slime. For this reason, additional water is needed in the system. Additional fresh water requirement is about 200 t/h and pumped from Adranos Stream. During the operation of the plant, the amount of lost water is continuously supplemented with new water addition to the system.

Leachate from both solid wastes and waste dams is very acidic in some cases and contains important dissolved metals as well as heavy metals. In uncontrolled conditions, these waters are likely to interfere with surface water or groundwater.

The amount of clay and coal in the waste water of the plant in concern reaches about 400 000 tons per year. Approximately 20-35% of this constitutes coal leaks with the calorific value of around 1000 kcal/kg. These wastes have been accumulated in various ponds and holes of old open pit workings since the installation of the plant and are still being accumulated.

Approximately 3 300 000 tons of coal will be produced if it is thought that about 12 000 000 tons of waste have been stored for about 30 years. This causes both economic loss and increasing environmental problems.

Evaluation of stored wastes;

- The evaluation of this stock is currently unavailable because some of the slime pond 1 has been drained and landfilled and there is no information about the tailings in the pond.
- The material in the slime pond No. 2 located next to the old dynamite warehouse has a calorific value of 1355 kcal/kg, about 190800 tons of slime and has a potential of evaluation.
- There is no information available about the waste discharged into the mined out workings of Kargapınarı-3. Therefore, there is no possibility to evaluate its potential because it is covered with overburden material.
- The calorific value of the material in the No. 4 slime pond is low. However, there is 8352000 tons of material and it has the potential to be evaluated. It is dangerous to enter the pond with a vehicle because of the depth of the pool and the softness of the material, so it may not be safe.

- The material in the Beke top slime pond also has a calorific value of 1049 kcal/kg and 2041200 tons of material. There is a potential for this waste to be evaluated.
- The slime of Tunçbilek Coal Cleaning Plant is still being discharged in the old working space within the 6C panel. It is not possible to remove the material that is still in liquid form due to topographical conditions.

Once the tailings are completely dehydrated, it can be stored with much less harm to the environment.

The residual inorganic fraction that emerges after the tailings coal has been enriched can be the raw material of other sectors (brick, tile, briquette, cement, concrete, etc.).

Fine coals are formed at every stage of the process in the plant and are discarded as slime. In other words, it is the ideal situation that this value which is liberated and ready, which has a high thermal value in short, is to be recovered by effective methods for the economy and the environment.

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