Problems Faced on the Exploration and Exploitation of Lignite Deposits for Thermal Power Plants near Jayamkondacholapuram, Tamil Nadu, India

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Abstract

Jayamkondacholapuram lignite deposit may be mined by open cut quarrying and it can be utilized for electric power generation in order to reduce power-shortage. The lignite occurs in Cuddalore Sandstone Formation of Mio-Pliocene age. Lignite seams occur with varying thickness from 1.5 – 24.8 m at depths varying from 54 -135 m below the groud surface from NW to SE. The reserve estimated by drilling of 62 bore-holes in an area covering 52 km^2 yield almost 360 million tons. Groundwater potential is very similar to adjacent Neyveli Lignite Mine. Initial mine-cut may be initiated 1 km south of Melur village which is located NW side of the area investigated. The lignite is intercalated with films, platelets, nuggets and pods of marcasite along its bedding planes and other weak planes. Separation of marcasite is essential before lignite washing and briquetting. The disposal of fly-ash slurry is another major problem. A thermal power plant of 1600 MW capacity may be installed by using 9 million tons of raw lignite per annum for 40 years longevity. Acquisition of land for mining is the major unsolved problem remained for the past 20 years.

1. Introduction

Electrical energy is required in almost limitless set of applications which include industrial manufacturing, transport, heating, lighting, communications and computations. In a thermal plant electric power is generated by electro-mechanical generators driven by steam produced from fossil fuel combustion. In order to meet electric power shortage, Tamil Nadu Government has permitted installation of 25 thermal power plants in various parts of Tamil Nadu State with total installation capacity of 15532.5 MW [1]. Neyveli Lignite Corporation is planned to set up a thermal power plant of 1600 MW capacity in Udayarpalayam village near Jayamkonda-cholapuram Town (also called shortly as Jayamkondam) using lignite deposit [2-5] available in the site [1].

2. Geology

The lignite deposit occurs in Cuddalore Sandstone Formation. The sandstone formation is intercalated 2 to 3 m thick red, buff, grey and white coloured ferruginous, arenaceous and argillaceous layers [2-5]. The general strike of the formation trends NNE-SSW direction and it dips with a regional gradient ranging from 1:50 to 1:1000 and more gentle towards south-east. From top 2 to 3 m depth dry lateritic cap of reddish brown or yellow coloured hard rock or soil cover is found. Below this level, yellow, pale-pink, red, reddish brown, yellow, dirty white, grey coloured ferruginous shale and sandstone beds are seen alternatively. The colour of the Cuddalore Sandstone Formation indicates conditions of its depositional environment. Brow, red, pink and yellow colours of the rocks indicate that they were formed under oxidizing condition. While, grey and black colour of argillaceous rocks were formed under reducing environmental deposition (Table 1).The lignite beds exposed at depth at depths generally dips 5 to 10^o towards ESE direction. Up to a depth of 150 m below the ground level (bgl), three cycles of formations of oxidation and reducing environments are seen after the deposition of lignite seams which itself was formed under anaerobic condition.

The grain size, thickness of clay and other admixtures of impurities of the sandstone beds vary widely. Mottled texture of the shale and sandstone formations have been caused by the mixture of clayey and sandy materials during depositional environment. Intermittent weathering and oxidation during depositional break would also cause such variations. Below white shale / clay, lignite seam occurs with varying thickness from 1.25 to 24.80 m . The bore-hole located south of Angarayanallur has encountered the maximum thickness of lignite seam for 24.80 m at about 90 m bgl. In some places the lignite seam splits into 2 to 3 layers with intervening carbonaceous clay or sandy beds. Among 62 bore-holes drilled, it is found that the lignite seams occur at depths varying from 54 to 130 bgl. Within the lignite seams, granules, plates and concretions of marcasite occurs from 0.01 to 1.50% by volume. It also occurs at the contacts between lignite seams and carbonaceous clay. The recovery percentage of lignite core varies from 80 to 100%. The maximum core loss is only 25% in the lignite mixed with some sandy formations occurring in Jayamkondacholapuram area. Generalized bore-hole logging data reveal presence of 3 stages of anaerobic and oxidation conditions after deposition of lignite. Table 1 show the early Ist stage of anaerobic environmental conditions was prevailed at a depth of 92 m bgl. The next stage of anaerobic condition took place above 65 m (bgl) and continued up to the end of oxidation environment just 30 m bgl. The last stage of anaerobic condition started on sedimentation above 30 m bgl and ended with an oxidation environment at 0 m bgl with exposure of lateritized Cuddalore Sandstone Formation. Speckled and mottled structure of pods of argillaceous material is due to weathering of early formed rocks, transported and deposited at different places.

Table 1 Generalized drill-hole logging data

Bgl m	Stage Environ	Lithological characteristics
0-2		Yellowish sandy lateritic clay
2-5		Reddish brown laterite
5-10		Pale yellowish white unconsolidated clay
10-19		Arenaceous grey coloured shale
19-27		Mottled pods of yellow , red and white argillaceous materials in grey shale
27-30	III	Yellowish white argillaceous sandstone
30--36		Mottled pods of yellow, white and red coloured argillaceous matter in pink sandstone of medium to coarse grained rock
36-40		Brown coloured argillaceous sandstone
40-48		Pink coloured arenaceous shale
48-56		Dark reddish brown argillaceous sandstone
56-61		Yellowish argillaceous shale with pods of reddish brown grit
61-65		Yellowish fine-grained sandstone with pods of pink argillaceous materials
65-67	II	White shale with pods of yellow shale
67-72		Pink argillaceous shale with yellowish and reddish argillaceous pods
72-76		White shale with thi layers of grey shale
76-92		Lignite
92-93	I	Carbonaceous clay (unconsolidated)
93-95		Carbonaceous sand fine to medium grained (unconsolidated)
95-110		Medium to coarse-grained sand (unconsolidated) aquifer

3. Structure

Jayamkondacholapuram lignite deposit is bounds by NE-SW trending rift and graben structures in this area. The NE-SW trending Great Boundary Fault separates Archaean rocks from sedimentary rocks and is exposed just 20 km west of the Jayamkondacholapuram. The rift and graben structures are also cross-cut by E-W trending rift systems and acquire major source for groundwater supply from artesian aquifer systems lying below the lignite seams. Besides this, the lignite basins are comprised with accretion of numerous minor basins with their diameters varying from <1 km o >19.5 km. They are overturned basins. Sedimentary layers in the SW portions of these basins dip approximately 30^o towards NE and the NE layers dip 40^o towards NE. The south eastern and central portions of these basins appear to be covered with younger beds. On the other hand, the NW layers dip 40^o towards NW and the SE layers dip 50^o towards NW. Thus they constitute overturned basin structures. These structural features and intersections of fault systems also favour the formation of artesian pressures below the lignite seams. A net-work of shallow groundwater aquifers with deep confined aquifers at depth forming universal piezometric surface and the area is enriched with groundwater potential. The lignite might have been deposited under shallow water lacustrine environment by sedimentation of organic materials from the siliceous material by non-wetting and wetting properties created during lignite depositions under anaerobic environment enriched with H_2S activities (Fig. 1). The lignite in the adjacent Srimushnam area [4] was also formed similar environmental condition and it is promising area for mining after exploitation of lignite from Jayamkondacholapuram.

4. Lignite Deposit

The isopach map of the lignite deposit (Fig. 2) shows that Melur (11^{o}15’04”N-79^{o}20’34”E) is the promising site for the first mine-cutin this area where an average thickness of lignite exceeds over 15 m and teh lignite seams occur at 54 m bgl. However, before opening first mine-cut, more number of boreholes are necessary to confirm the fact. Tamil Nadu State Department of Geology and Mining has made only 62 boreholes with minimum grid intervals of 400 m, in an area of investigation around 70 km^2. Using the isopach map, the total reserve estimated in the Jayamkonda-cholapuram area is 364 million tons within the coverage of promising 53 km^2 (Table 2). Lignite mining is economical if the thickness of lignite just exceeds over 5 m thickness where the lignite overburden thickness ratios not less than 1:10. The zone where the lignite / overburden ratio less than 1:15

Table 2 Reserve estimation of Jayamkondacholapuram lignite deposit

Isop-ach	Area of influence km^2	Lignite reserve in million tons	Cumulative	
			Area influence in sq.km	Reserve million tons
>20m	0.096	20*0.096*0.8= 1.536	0.096	1.536
>15	5.768	15*5.768*0.8=69.216	5.864	70.752
>10	26.752	10*26.752*0.8=214.016	32.616	284.076
>5	19.676	5*19.696*0.8=78.784	52.312	363.552

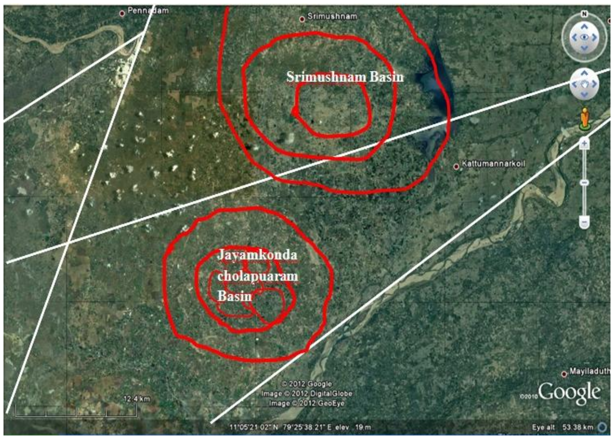

Figure 1. Structural features of Lignite deposits

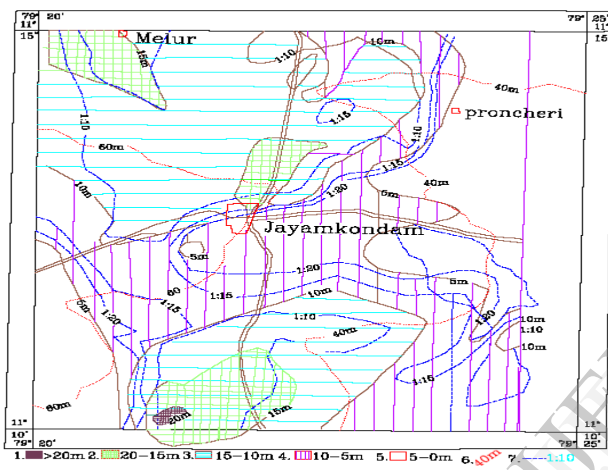

Figure 2. Isopach map of lignite deposit of Jayamkondacholapuram

and lignite seams at greater depths of over 100 m bgl is also uneconomical . However, by power crisis and development of mining technology, such deposit in this area yield marginal benefits. The coloured portions can be economically mined by step by step development of mine from shallow to deeper levels. Below the lignite seams, white silica sand with varying particles size from 4 mm to 0.05 mm are found for about 100 m thickness [4] with artesian water pressure heads. It is necessary to reduce the artesian pressure before mining the lignite seams, similar to the mining method adopted in Neyveli area.

Table 3 Proximate analyses of Lignite samples

S.No	Bore	Depth	FC	Ash	VM	LOI	C.V.
37	OF	89.3	36.28	8.48	28.24	46.58	5638
46	OF	101.10	34.23	13.40	52.36	47.35	5380
61	SD6	125.5	37.96	4.29	57.75	43.67	5750
64	SF11	119.0	31.35	10.23	58.42	53.02	5670
85	SF11	143.0	23.79	7.96	68.25	49.63	5707
89	SF13	117.0	37.13	5.87	57.00	50.68	5407
90	SF13	118.0	40.39	5.60	54.01	54.67	5996
91	SF13	119.0	35.03	5.80	59.17	50.89	6039
98	SF13	125.0	25.13	6.47	71.40	49.17	62.08
119	SF7	104.5	39.45	5.86	54.70	52.73	5975
124	SF7	109.0	36.28	4.68	59.04	50.42	6202
129	SF7	114.0	29.12	8.54	62.34	47.46	6304
136	SD3	105.5	32.46	6.36	61.18	49.28	5809
138	SD3	108.5	34.26	4.04	61.76	47.91	6365
47	OF	112.5	8.66	24.51	66.83	42.49	4614
87	SD11	122.0	21.1	16.83	62.06	39.24	5121
88	SD11	123.0	26.4	21.46	52.15	27.96	4189
114	SF3	98.5	19.2	45.13	35.45	46.92	3139

Table 4. Ash analyses of lignite samples.

S.No	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2	P2O5	SO3
37	25.43	30.26	0.40	28.20	7.58	0.44	-			7.83
46	29.16	30.37	6.17	14.71	3.07	0.41	0.42	0.45	0.05	15.21
61	13.57	26.87	0.85	37.72	0.68	0.83				11.84
64	39.23	18.24	1.24	22.59	4.84	0.89	0.17	5.1	0.04	7.66
85	21.02	25.89	1.09	28.9	4.27	0.67	0.18	1.84	0.02	16.11
89	9.06	20.86	2.54	36.90	6.40	0.74	0.12	0.30	0.02	23.15
90	19.72	23.70	0.44	35.59	8.69	0.78				11.14
91	15.68	25.73	0.89	38.34	7.80	0.59				11.34
98	35.61	23.41	1.29	25.43	3.84	0.80				9.73
119	7.36	18.77	4.31	31.86	6.92	3.28	0.35		0.16	26.95
124	5.36	20.48	3.71	43.28	5.44	0.34			0.11	21.13
129	14.32	24.42	2.63	39.06	5.73	0.46		0.70	0.09	12.27
136	15.85	22.52	4.02	36.02	7.4	0.38			0.09	13.74
138	15.65	25.56	4.85	33.13	2.93	0.74		1.75	0.11	15.13
47	34.68	34.09	6.41	9.22	2.11	0.18		7.27	0.09	5.15
87	15.77	16.23	41.48	7.83	3.47	0.41	0.12	1.97	0.09	12.79
88	17.26	14.50	41.67	10.44	1.60	0.37	0.12	2.11	0.07	11.86
114	69.76	16.52	5.91	3.11	1.05	0.43	0.35	1.00	0.10	1.70

The controlling of hydrostatic pressure under lignite seams is very essential for lignite miing. The ferruginous laterite clay beds overlying lignite seams contain large quantities of goethite and gibbsite constituents which incorporate huge quantities of water and flow under liquefaction process. This leads to structural collapse at the mine-site. Open cut mining s the only method suitable for mining of lignite in this area. The ultimate analyses of lignite samples show that an average of fixed carbon FC 30.45% ranging between 24% and 40%. Volatile material is VM 56.81% (~28-68%. Combined water is 14% (~10-32%). Ash content is 11.42% (~4-13%). SO_3 is 1% (~1-27%) Table 3 and 4). Losses on ignition include both combined water and moistures contents. Fixed carbon, ash and volatile matter accounts for 100 per cent. If the three constituents are more than 100 % means, the volatile matter in the sample contains significant amount of combined water and if it is less than 100% means, the volatile matter in the sample might have been evaporated during loss on ignition or the lignite sample might be dried before analysis.

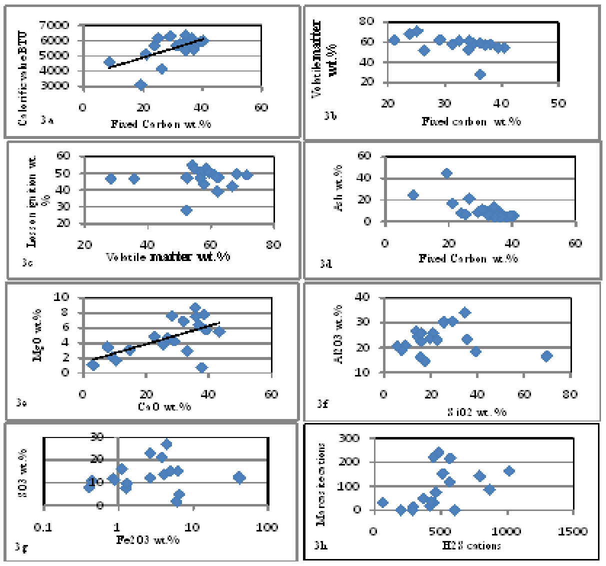

Figure 3 Geochemical variations present in Jayamkonda-cholapuram lignite samples.

The samples were subjected to both proximate and analyses and ash analyses. The lignite in this area has high content of volatile matter (mean 56.81%) and also loss on ignition which constitutes both moisture content and combined water (ranging from 39 to 55%) mean value is 47% prior to detection of FC, ash and VM. In order to increase fuel efficiency, it is necessary to remove the VM by briquetting and carbonation processes after washing and removal of marcasite and other solid wastes. The calorific values are given in British thermal Units (Btu). The lignite samples show (Fig. 3 a) that Btu values are directly proportional to to fixed carbon (FC). If the lignite samples are washed and cleaned with removal of marcasite and other solid wastes the maximum Btu values required for a thermal plat may be obtained. A negative correlation exists with a gentle slope between the distributions (Fig. 3b) of vM and FC. Though loss on ignition LOI and VM are independent to each other's (Fig. 3c), they show positive correlation between them indicating that they are related with each others. On the other hand ash contents of lignite samples show negative correlation with FC (Fig. 3d) indicating that the lignite has inherent ahs content released from combustion. The ash is composed of significant amounts of CaO and MgO, showing positive correlation between them (Fig. 3e). The enrichments of these basic constituents in lignite is very strange and differ from the chemical composition of normal sedimentary rocks of non-carbonate origin. However, it is quite possible, the tree and plants might have utilized these constituents as their nutrients for abundant growth. Similar positive growth is found between the distributions of Al_2O_3 and SiO_2. This feature reveals that the sediments associated with lignite are predominantly composed of siliceous materials and their ratio varies around 1. The lignite is associated with plate-lets, pods, grains and nodules of marcasite with H_2S odour. Almost all iron reported as total FeO content and MnO are utilized for the formation of marcasite and the marcasite is formed under reduced state without any ferric iron. Owing to presence of ilmenite and rutile, notable amount of TiO_2 is seen (Table 4). Striking 3 different positive correlations between total iron and SO_3 (Fig. 3g), indicate that almost all iron and MnO are consumed for the formation of marcasite. The plotted normative proportions of marcasite against H_2S [5,6] show a linear positive correlation that indicates that both marcasite and lignite were formed under oxygen depleted anaerobic lacustrine environment.

5. Exploration

In this area, no lignite outcrops are seen on the land surface. Lignite from Tamil Nadu is discovered by Jambulingha Mudaliyar in early 1950 from the deep borehole samples in Viruthachalam area and reported to the State department of Geology and Mining [8], Government of Tamil Nadu. Geological Survey of India further conducted detailed investigation in 60 km^2 around Neyveli and a large quantity of lignite reserve was estimated for opening up Neyveli Lignite Mine [2]. Preliminary investigations reveal that towards SE, lignite occurs around Mannargudi more than 300 m bgl and further SE in Ramanathapuram District at deeper levels [9]. More exploratory drill holes are essential and lithological units may be identified with borehole geophysical exploratory methods. Geophysical explorations and systematic borehole logging investigations are essential as it is carried out for hydrocarbon investigations for shallow levels. Cross-bore tomographic imaging, resistivity logging, neutron resonance logging are required and they should be carried out logging while drilling. By these methods, it is possible collect more quantity of lithological data with sinking minimum number of boreholes with limited period of investigation. It is necessary to design suitable low cost instruments for this purpose and they can be utilized for groundwater investigations also in these areas. Therefore, exploration of lignite is highly expensive. Drilling in hard compact laterite and in quartz rich argillaceous sandstone are difficult and time consuming even at top-gear rotated drilling operations. On the other hand drilling in quartz poor arenaceous wet-shale is more sticky and difficult to rotated rill-bit and often causes loss of drill-bit at depth and it necessary fishing operation is required to recover the bit from deep hole. Sometimes, drill bit never recovered and abandoned the drill hole with intermittent stopping of drilling operation may be encountered. Along with lignite, groundwater potential for the investigation site is also to be estimated. After estimating proved reserve, probable reserve and possible reserve, it is essential to locate the site of initial mine-cut by carrying out detailed geophysical and drilling investigations. The reserve of associated minerals such as ball clay, kaolinite, silica sand in overlying beds of Cuddalore Sandstone Formation, marcasite associated with lignite and silica sand occurring in underlying lignite seams are to be estimated. One of the objectives of exploration of lignite is to be demarcation of barren lands for installation of thermal power plants, residential sites for township development and to dump overburden materials mined-out. Mie-dump materials are further required to fill-up the quarried of open-cut mines after exploitation of lignite and other valuable minerals for reclamation and plantation.

6. Exploitation

The opening of initial mine-cut depends up on depth lignite: overburden ratio and volume of lignite reserve estimated in the selected for initial mine-cut. The overall lignite / overburden ratio dictates the economy of exploitation of the raw material. The overlying column of Cuddalore Sandstone Formation above the lignite seam is composed of significant amount of goethite, gibbsite, and montmorillonite. These minerals absorb huge quantities of water and subjected to liquefaction and flow. Therefore, the arenaceous shale and argillaceous sandstone comprising of these minerals have low stability under wet-condition. Therefore, underground mining is not possible and roof collapse may happen at critical conditions. Edges of bench widths required to be strengthened. Initial mine-cut may be made where thick lignite seams occur t shallow levels. The high qualities of silica sand, ball clay and marcasite are to be mined and processed for utilization or marketing as by-products. It is proposed to install a thermal plant of 1600 MW capacity in this area in between Jayamkondacholapuram and Udaiyarpalayam towns [1]. Since the lignite is composed of more than 50% of water, about 12 million tons of raw lignite is to be mined per annum [7]. Again water required for this plant is $57.23*10^6$ m^3 per annum [7]. However, the excessive water pumped from the aquifer underlying the lignite seams may be utilized for agricultural purpose in the adjoin regions. Before mining of lignite seams, the hydrostatic head in the artesian aquifer lying below the lignite seams should be greatly reduced as that is in Neyveli Lignite Mines.

7. Processing

The lignite sample is mixed with clay and sandy materials ad has high specific gravities and ash cotent with mixtures of marcasite. Lignite washing is essential to remove such impurities and to increase calorific values and to reduce SO_3 emission from thermal power plant. Crushing, screening with electromagnetic separation of marcasite granules, it is necessary to wash the lignite before carbonization to make briquettes. The raw wet lignite has low calorific value (Table 1). The conversion factor from Btu to kcal/kg is multiplication with the factor 0.5556. Raw lignite has gross calorific value ranging between 1744 and 3502 kcal/kg. Manufactured carbonized briquettes improve the calorific value and these briquettes can be directly used for increasing thermal efficiency of the plant.

8. Thermal Power Plant

In a thermal power plant water is heated into steam and spins a steam turbine which drives an electrical generator. The scarcity of electric power supply and demand has forced an installation 1600 MW thermal power plant in this area. In the area adjacent to the road leading to Jayamkondacholapuram and Udaiyarpalayam, the lignite has rarely 2 m thick lignite seams at depth exceeding over 80 m bgl and therefore site for the installation of thermal plant and township was proposed. Moreover, the site is hardly 5 km south of the initial mine-cut proposed near Melur village. For setting upa power plant of 1600 MW per day capacity about $8000*10^6$ INR is required [7]. It was estimated that the plant will consume 128 MW per day for its operation and the net output electricity is 1472 MW may be supplied per day from the plant. The annual lignite consumption for the plant is $7.01*10^6$ tons, but owing to its water content and poor grade quality about $9*10^6$ tons of raw lignite is to be mined out. Furnace oil required for operation of the plant is 58984 m^3 /annum. Annual water consumption for the plant is $57.23*10^6$ m^3. The fly ash released from the plant is $2.45*10^6$ tons / annum. About $17.52*10^6$ tons of CO_2 and $0.4*10^6$ of SO_3 and NO_2 are to be released out to the atmosphere per annum [7]. An integrated Neyveli Lignite Scheme was drawn by P.S.T.S. Ltd under Columbo-Plan [8] based on estimated lignite reserve of $200*10^6$ tons in Neyveli. Similar such proposal is to be implemented in the Jayamkonda-cholapuram lignite deposit to conserve other mineral resources occurring this area, so that urea, ammonia, sulphuric acid and other associated chemicals may be manufactured in addition to electric power supply. As per mineral conservation policy, minerals once exhausted cannot be recovered; therefore suitable integrated scheme should be implemented for proper utilization of by-product minerals.

9. Local Problems

Acquisition of land for mining site and thermal power plant is a crucial problem in this area. Most of the lands are covered with cashew trees and Jack-fruit tree planted over 40 years increases the land cost and annual output income per hectare exceeds over 200000. Therefore land cost is heavily increased. Further, most of farmers in this area are politically motivated against the installation of thermal plant. Since, the land has potential groundwater aquifer 100 m bgl, the prosperity for agriculture development is promising. Initially small portions of land may be acquired for plant construction and infrastructure development (5 km^2). Similarly only a few hundred hectares (5 km^2) of land may be purchased for initial mine-cut also. Mine development may be carried out in a long run by shifting processes. Mining on one side and closing on other exploited-site in a steady pace. Refilling of abandoned mined-out quarries is a major problem. Frequently, improper compaction result squeezing and collapses of ground surface threatens public safety measures. Slow shifting of mining and refilling of mined quarries create lot of environmental problems to the public especially poor village people. Atmospheric pollution of CO_2, H_2S, NO_2 NH_4, SO_3 leads to acid rainfall which is injurious to agricultural crops, cattle and human beings.

10. Conclusion

The lignite reserve over 300 million tons in Jayamkondacholapuram area is suitable for utilization of a thermal power plant of 1600 MW capacity. Mining and utilization of 9 million tons lignite the thermal plant might have 40 years longevity. The forthcoming plant will be a remedial measure for power shortage in Tamil Nadu. Disposal of fly ash and coolant water, emission of CO_2, SO_3, H_2S, NO_2, and NH_4 are the major environmental problems are to be properly controlled and treated without causing any environmental damage. Refilling ad ground treatments of abandoned quarries are to be systematically carried out without any adverse impacts. More geophysical and geological investigations are to be carried out before opening up a first mine-cut. Associated minerals like marcasite, ball clay, silica-sand and kaolinite are to be collected, processed and utilized as per mineral conservation policy. The fly ash can be utilized for cement manufacture. Table 2 shows, the ash contains high content of siliceous materials which can be compensated by sweetening processes by mixing adequate quantities of sedimentary limestone occurring in Ariyalur area.

11. Acknowledgement

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