CHAPTER ONE

INTRODUCTION

Coal is a fossil fuel formed by the accumulation of organic material in sedimentary strata in the earth's crust. It undergoes *in situ* compaction with time to form various ranks of coal. The results of accumulation of in situ residues and important debris in swamps lead to the formation of peat. After the peat has accumulated for a period, it must be buried under mineral sediment, generally clay, silt, and sand. The peat forms beds of coal that range from a few centimeters to many meters in thickness. The coal is often inter bedded with shale, sandstone, and other sedimentary rocks. A single stratigraphic sequence may include several coal beds. Coal is known to have been deposited in shallow marine and fluviatile (lake) environment. These lakes have also received lithogenic fluxes from mineralized continental shield enriching the coal with heavy metals like Pb, Zn, Cu, Cd. Co, Ni. Mn etc. (Sahu,1990).

In coal, various metals or elements, hydrogen, carbon, nitrogen, sulfur, and oxygen are determined and reported in ultimate analytical sequence. More than 55 elements are commonly present in the organic and inorganic (mineral) form or part of the coal. Some of the elements found in coal represent only in mineral forms. other elements can be present both as constituents of minerals and in complex combination with the organic material of coal.

Coal is likely to remain an important part of the Pakistan energy supply, largely because it is the most abundant domestically available fossil fuel. One of the major concerns related to the use of coal for electricity production is the release of elements during combustion and the resulting coal combustion product (CCPs)-fly ash and bottom ash-to the environment. It is therefore, necessary to acquire an accurate, reliable and quantitative information about the concentration and modes of occurrence of chemical elements, especially heavy metals in feed coal and coal combustion product.

The extraction of coal is another cause of environmental degradation of the area, which results in the serious problems related to contaminated mine drainage. Acid mine drainage from closed and abundant mines (both surface and underground) has far reaching effects on water quality, on fish and wildlife.

Naturally occurring radioactive material released by coal combustion is accumulating in the environment along with elements such as mercury, arsenic, silicon, calcium, chlorine, lead and sodium as well as metals such as aluminum, iron, lead, magnesium, titanium, boron, chromium, nickel, zinc, copper which are collectively dispersed in millions of tons of coal combustion by-products. The potential threats of these released materials will someday be of such significance that they should not be ignored (Ahearne, 1993).

In Pakistan, the environmental laws were not enacted until 1960s but in 1975 the Environmental Ministry was established as a follow up of Stockholm Declaration of

1972. During 1977 to 1988 very few environmental laws were promulgated. In this period Environmental Protection Ordinance of 1983 and Environmental Protection Act of 1997 were established. But no specific laws have been constituted for the mining sector, especially coal mining; except few labor laws exist for the coal miners. However, the federal and provincial governments had promulgated following environmental laws for petroleum activities: (1) Petroleum (exploration and production) Rules 2001, and (2) Pakistan Petroleum (exploration and production) rules 1986 and (3) DGCPs guidelines for operational safety, health, and environmental management in Pakistan's Petroleum exploration and production sector. In this regard Sindh provincial government had also established sectoral guidelines for environmental protection in 1999 for off-shore oil and gas seismic surveys. However, no specific laws have been formulated for the mining sector so far.

Mining particularly coal mining has hazardous impact on environment. It can cause various types of lung diseases in the coal miners due to air pollution when fine coal dust particles spread in air as suspended particulate matter (SPM) during mining and transportation. This fine coal dust particles can cause bronchial or respiratory diseases. The problem of acid mine drainage water (AMD) is also well known that cause sulfurization of groundwater in coal mining areas. Coal mining accidents are also common in Baluchistan province due to methane gas accumulation in coalmines. Mine waste and blasting operation during mining activity also cause negative impact on environment. It is, therefore, considered important to draw attention of scientific and law making community for making some sectoral guidelines for environmental protection in the mining sector of Pakistan.

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Keeping in view the huge deposits of Sindh coal in Pakistan, their future threats to the environment need to be studied. This study is, therefore, proposed to evaluate the Sindh coal for its use in power generation and other industrial purposes.

COALFIELDS OF SINDH

Lower Indus Basin has number of coal basins (Fig. 1.1). These basins extend westward from Thar coalfield, through Tando Muhammad Khan, Badin to Lakhra-Sonda-Thatta area. The western part falls in the folded belt zone, where as most of the eastern part covers the Platform slope. Shelf platform and carbonate deposits ranging in age from Triassic to Recent overlie the basement slope.

Four major coalfields are named as (1) Sonda, (2) Meting-Jhimpir (both in Thatta district) (3) Lakhra (in Dadu district) and (4) Thar coalfield in Tharparkar have been explored (Fig. 1.1). These coal deposits occur in the Bara Formation (Middle Paleocene) and in the Sohnari Member of the Early Eocene Laki Formation. The Sohnari coal is restricted to the Meting-Jhimpir coalfield, consisting of about 30m thick Sohnari Member, having sandstone and lateritic clay. The coal in Lakhra and Sonda coalfield was deposited is in the Bara Formation, which is comformably overlian by the Lakhra Formation. The Bara Formation contains two main coal-bearing horizons, one is in the upper part and the other in the lower part. The lower one is known as Jheruck coalzone, found in Sonda coalfield. Sonda coal occurs relatively more persistently at three main horizons, named as Dadhuri, Sonda and Jherruck coal zone, and was deposited in the Bara Formation.

Meting-Jhimpir coal is found in the Sohnari Member of the Laki Formation of Eocene age, near the contact with Upper Paleocene of Lakhra Formation. There is only one workable coal bed, which is generally thin and lenticular and ranges in thickness from 0.3m to 1.0 meter. Thar coalfield is the largest coalfield of Pakistan and is located on the Indus Platform in Thar Desert in south-eastern corner of Pakistan. It covers an area of about 9,000 sq. kms.

The coal deposits of Sindh are developed at two different stratigraphic horizons; the lower one is associated with Bara formation (lower Ranikot) of middle Paleocene age and the upper zone is associated with the Sonhari member of the Laki formation of early Eocene age. Due to changes in facies and the depositional environment, the coal horizons at some places are represented by carbonaceous shale instead of lignitic to sub-bituminous coals.

The coal at Lakhra and Sonda-Thatta area is in the Bara formation, The upper formation consists of limestone, sandstone, siltstone and claystone. It is fossiliferous and has a thickness of 150 to 250 metres. At places, it thins out to less than 50 meters. The lower formation consists of sandstone with subordinate claystone, siltstone and coal. The main coal seams in Lakhra and Sonda area are named as Lailian bed and Sonda coal seam which normally lie about 80 to 100 metres below the top of the lower part of the lakhra formation. The coal in this formation appears to have been deposited in lacustrine conditions close to an oscillatory marine environment. Geological data are indicative of a fairly wide distribution of coal in Bara formation covering wide tracts of subsurface areas in the lower parts of Sind south and west of Hyderabad High. Regional geology of this extensive coal basin indicates that in the northern region in Lakhra, coal is formed in 'back barrier' environment, whereas in the southern region in Sonda and Sujawal the coal beds are deposited in lower deltaic plain (Waheeduddin et al., 1988). Much of this coal, outside the Lakhra and Sonda areas may lie at the depth of over 250 metres in the area lying to the east of the Indus river and in the Ranikot area where the part of the Bara formation is exposed.

Coal in Meting-Jhimpir area is present in the Sonhari beds at the base of the Laki formation of early Eocene age. The Sonhari beds are about 30 meters thick and mainly consist of sandstone and lateritic clay. The lateritic material was laid down on an old erosional surface marking an unconformity between Lakhra and Laki formations (Outerbridge et al., 1989). The Sonhari beds were deposited in lacustrine/fluviatile conditions near the coast. This environment prevailed on the Hyderabad arch during early Eocene prior to inundation by the sea and reversion of purely marine regime (Schweinfurth et al., 1988). Swamp vegetation which grew in the shallow, brackish water was buried by the later sediments and was source of coal (Outerbridge et al., 1989). Due to its origin and subsequent geological history and physiographic events the coal in the Sonhari beds are unlikely to have developed extensively within mineable depths.

Sonda coalfield

Sonda coalfield is situated close to the national highway linking Karachi with Hyderabad and covers an area of more than 600 sq.km. This field has the distinction to host both the coal horizons Lakhra coalfield and the Meting-Jhimpir coalfields. Its potential reserves, therefore, are fairly large. The lower coal horizon is associated with Bara formation of middle Paleocene age (as in Lakhra) and the upper horizon is found with the Sonhari member of Laki formation of early to middle Eocene (as in Meting-Jhimpir area).

Several coal seams are developed in the Bara formation but due to limited subsurface data, the lensoid nature of occurrence and quick facies changes, it is difficult to carry out the natural correlation. As coal outcrops are not exposed, all estimates of reserves for the coal are subsurface. The depth of the coal seams with a minimum thickness of one metre or more is generally between 80 to 250 metres.

The estimated of reserves are of 280 million tonnes in an area of 260 sq. km only (Kami et al., 1990).

Meting -Jhimpir coalfield

The Meting-jhimpir coalfield lies approximately 125 km to the east of Karachi in the vicinity of Jhimpir and Meting railway stations on the main railway line. The coalfield covers an area of about 90 sq.km. in Thatta District. The railway line between Jhimpir and Meting runs along the western limit of the coalfield.

According to Outerbridge et al. (1989) the coal in the Meting-Jhimpir area was deposited on the erosional surface of the Palcocene rocks. It is now grouped in the lower part of the Laki formation of early Eocene age. Only one workable coal seam is present which is generally thin and lenticular. Its thickness varies from 0.3 metre to 1.0 metre with an average thickness of about 0.5 metre. The coal is of lignite-A to sub-bituminous-B in rank. It is soft and friable and suffers from spontaneous combustion on exposure.

Total available resources of coal in the Meting-Jhimpir area are presently estimated as 25 million tonnes. These include 3 million tonnes proved reserves, 5 million tonnes probable reserves and 17 million tonnes possible reserves. Average annual production is of the order of 40,000 tonnes (Abbas and Atiq., 2005). This coal is used in brick kilns only located in Sindh.

Lakhra coalfield

Lakhra coal field is the second largest coal field of Pakistan, comprising an area of about 680 square kilometers. It is located 225 km north - east of Karachi in Dadu district of Sindh province. It lies between latitudes *25°30'* and *25°45' N* and longitudes *68°* 0' and *68°* 15' E and is covered in Survey of Pakistan topographic sheet Nos. 40 C/1 and 40C/2 (Fig. 1.1). Khanot is the nearest railway station, connected with Lakhra coalfield by a 19 km long metalled road up to Indus Coal mines.

The rocks exposed in the area belong to Ranikot group (Paleocene), Sonhrari member (Early Eocene), Laki limestone (Early Eocene) and Manchar formation (Pliocene). These units are composed of shallow marine and fluviatile sediments. The oldest exposed rocks, in the area belong to the Bara Formation of Early Paleocene. It is underlain by Lakhra Formation of Middle to Late Paleocene age which is unconformably overlain by the Laki Formation of Early Eocene age. The unconformity between the Lakhra and Laki formations is marked by a 38 to 63 cm thick laterite bed (Khan et al., 1988). Rocks of Middle Eocene to Miocene (intervening the Laki limestone and the Manchar Formation) are absent in the area, hence the Manchar Formation of Pliocene age directly overlies Laki Formation. A very thin cover of alluvium rests over the Manchar Formation. The thickness of the minable coal seam in the area varies between 1.5 to 3.35 meters (Khan et al., 1988).

The Lakhra coal is dull black and contains number of resin flakes. It could be extracted in large lumps, but dries to a moisture content of about 8% when brought to surface. It tends to crumble on longer exposure and is often susceptible to spontaneous combustion (Waheeduddin et al., 1986).

Thar coalfield

The Thar coalfield spread over 9100 sq km is located between latitudes 24°15'N & 25° 45' N and longitudes 69°45' E & 70° 45' E in the south eastern part of Sindh as shown in the Survey of Pakistan toposheet Nos. 40 L/2 to L/5. It is connected with a 667 km metalled road upto Islamkot from Karachi via Hyderabad-Mirpur khas-Naukot and the other route is from Thatta–Badin–Naukot. Islamkot town lies well within the western margin of this area, approximately 50 km east of Mithi, the district Headquarter of Tharparkar.

As the name implies. Thar Desert of Sindh is a vast tract of sand dunes and intervening sandy-silty plains merging imperceptibly with Indus plain in the east; in the west, it extends across the Rann of Kutch depression into Rajasthan in India. In the north, its part reaches east of Waheed ud dinpur in east Punjab and in the south, it edges the Rann of Kutch. Sand dunes are of varying height, rarely exceeding 50 m. and have a general north-south trend. The intervening sandy-silty plains are generally 40 to 50 m AMSL. In the extreme southeast corner of the Thar Desert is the tableland of Nagarparkar, an igneous and metamorphic complex (basement complex).

The climate of the area is broadly classed as hot and arid. The area lies in a region where monsoon rainfall is generally low, and the distinction between the summer and monsoon seasons, is not very well marked. Although it receives some monsoon rainfall, the rain's effect on temperature for instance is minimal. The drought years are common. The mean annual maximum and minimum temperatures are 19 to 35°C respectively. Maximum summer temperature commonly exceeds 40°C in April through June.

Sand dunes cover more than 56 percent of the area. The relief in the area varies between near sea level to more than 150 metres AMSL. The sand dunes are mostly longitudinal with a NE-SW trend and are stabilised by shrub vegetation and grass. Thar coalfield is located on the Indus Platform. The presence of coal in Thar desert of Sindh was first indicated in the drilling for fresh water by British Overseas Agency in 1988 near Khario Ghulam Shah village, about 15 km east of Islamkot. In 1992, USGS/GSP confirmed huge reserves of coal in the area, with a maximum thickness of 30 meters of coal. This coalfield is divided into following block (Fig.1.2):

1. Sinhar Vikian-varvai (Block-I) is southeast of Islamkot
2. Singharo-Bhitro (Block-II),
3. Saleh Jo Tar (Block-III) and
4. Sonalba (Block-IV) in the northeast of the area.

1. Sinhar Vikian-varvai or Block – I covers an area of 122.00 sq. km and has total reserves of 3,566 million tones in clastic rocks of Bara Formation.

2. The Singharo-Bhitro Block-II covering an area of 55 sq. kms falls in northern part of the Thar coal field and has coal resources of 1584 million tones in clastic rocks of Bara Formation. The measured reserves are 640 million tones. The

cumulative coal thickness varies from 7.52 to 30.89 meters. The coal beds range in thickness from 0.30 to 20.78 meters. The minimum depth at which the coal is present is 123.80 meters. 90 % of the coal can be extracted from unto -120 meters AMSL, whereas 75 % of the coal resource lies between -75 and -120 meters AMSL.

The maceral components indicate less maturity of coal formed from herbaceous plants in warm climate with rapid rise and fall in water table and environment of raised bogs (Fassett & Durrani., 1994). The quality of coal is lignite 'B'. Claystone forms the roof as well as floor rock of coal benches (Jaleel et al., 2002).

3. The Saleh Jo Tar, Block-III, covers an area of 99.5 sq. km and falls in central part of the Southern Thar coalfield. The field area is covered by stabilized sand dunes trending longitudinally in northeast direction. It is approachable by all weather road upto 10 km. beyond Mithi and onwards by four-wheel driven vehicles through desert sand. It has coal resources of 2008 million tones in clastic sediments of Bara Formation. The measured reserves are 413 million tones. The cumulative coal thickness varies from 7.15 to 24.58 meters. The coal benches range in thickness from 0.20 to 14.65 meters. The minimum depth at which the coal is present is 114 meters. 90 % of the coal can be extracted upto -120 meters AMSL depth, whereas 85 % of the coal resources lie between -50 and -110 meters AMSL. The rank of coal is lignite 'B'. Clay stone and loose sandstone beds form the roof

as well as the floor rock of coal benches. The palynological studies show that the Thar coals are Paleocene to Eocene in age and may have been deposited in a raised bog environment (Jaleel et al., 2002).

4. The Sonalba Block-IV covering an area of 82 sq. km falls in the northern part of the Thar coal field and has coal resources of 2559 million tones in clastic rocks of Bara Formation. The measured reserves are 637 million tonnes. The cumulative coal thickness varies from 10.74 to 30.88 meters. The coal seam range in thickness from 0.30 to 20.78 meters.

The Thar coalfield area is mainly covered by sand dunes. Its subsurface geology is obtained through drilling by the Geological Survey of Pakistan during 1994 to 2000. These studies show that coal bearing strata of Palaeocene–Eocene sediments unconformably overlie the Pre-Camberian basement rocks of igneous origin which are exposed at Nagar Parkar and form the only out crop in the area.

In Thar coalfield the Basement Complex is found at varying depths between 110 to 277 metres. The basement rock is generally granitic in composition which is highly altered to kaolinite. The Paleocene-Eocene coal bearing horizons, known as Bara Formation generally comprises of claystone, carbonaceous claystone, sandstone, siltstone with inter-laminated coal beds. The percentage of sand increases below the last coal beds. Claystone forms the dominant lithological unit of the formation. It is silty at places and also contains pockets of very fine sand

and scattered coal fragments. The claystone generally forms the floor as well as the roof rock. Pyrite is present as patches of fine of upto 2 mm size. Claystone also contains 3 to 30 cm thick sideretic bands and nodules.

Sandstone is very fine-to coarse-grained and consists dominantly of quartz and minor amounts of ferro-magnesian mineral grains. The lower 15-20 metres of the formation which consists the coal is saturated with brackish water.

The coal deposits of Sindh are yet to be explored fully before their large-scale exploitation and use in the power generation plants, which are going to be established in near future in the region. This study is, therefore, conducted to fully understand the geology of these coalfields and to carry out the environmental assessment of these coals deposits, which could help the planners for establishing the environmentally friendly mining activities and power generation plants in the region in future.

AIMS AND OBJECTIVES

Keeping in mind the importance of coal and its future use in power generation, environmental impact assessment of the investigated coalfield is needed in detail. For this purpose it is aimed:

- to determine the chemical (i.e., heavy, trace and light element analysis and proximate and ultimate analysis) and combustion (i.e., calorific values) properties of the Thar, Sonda and Meting-Jhimpir coalfields

- to evaluate the leaching behavior of the Sindh coal deposits which will help in predicting mine-drainage water quality.
- To compare and correlate the Sindh coal data with other known coal deposits of Pakistan and other countries of the world.
- to investigate the environmental impact in regard to heavy and trace elements concentration of the Sindh coal before its extensive utilization in power generation and also in the cement and other industries of Pakistan.

PREVIOUS WORK

The first book on Geology and Geography of Sindh was published by Lambrick (1825) in two volumes, giving details about physiographic and geological descriptions. Subsequently, in 1867, 1876, 1878 and 1879 Blanford published his research work on geology of coastal area of Sindh, Geology of Sindh, geology of eastern (Thar desert) Sindh western parts of Sindh and neighboring Punjab and Baluchistan. Gee (1940 & 1948) published his work on Geology of Indian coal, including Lakhra coal in Sindh.

Pithawala and Kaye (1946) published a book on Geology and Geography of Karachi and its neighborhood. In 1950 Khan conducted a general and geological survey to estimate the coal resources of Pakistan. Waheeduddin et al. (1954)

prepared the geological map of Sonda -Thatta coalfield. In 1980's a great work was initiated under coal reap program by Geological Survey of Pakistan and U. S. Geological Survey, and work was published by U. S. Geological Survey.

METHODOLOGY

The fresh bed coal samples were collected from thirteen coalmines at different depths operating in Metting-Jhimpir coalfield while the samples from Sonda and Thar coalfields were obtained from the Core Library of Geological Survey of Pakistan. These samples were numbered accordingly and packed in the polythene bags. The detail methodology along with instrumental standardizing conditions are given in the appendix-I, however, a brief analytical procedure adopted during this study is described bellow.

The air-dried coal samples were crushed and pulverized to 200 mesh. A known weight of the powdered coal sample was decomposed by concentrated hydrofluoric acid (HF), concentrated nitric acid (HNO_3) and 3N hydrochloric acid (HCl) in the teflon beaker and the final stock solution of 50 ml volume was prepared by using the method of Jeffery and Hutchison (1986). After preparing the stock solutions of all the coal samples, various heavy, trace and light elements (i.e., Cu, Pb, Zn, Ni, Cr, Co, Cd, Fe, Mn, Ca, Mg, Na, K) were determined in these solutions by the Perkin Elmer atomic absorption spectrophotometer.

For determining the leaching behavior of these colas. four different types of leachates were prepared by leaching the representative mixture of all the three coals of Sindh with IN ammonium acetate, 3N hydrochloric acid, concentrated hydrofluoric acid and 2N nitric acid seperately by using the method of Finkelman et al. (1900) and Palmer et al. (2000). The heavy and trace elements in these leachates were then determined by atomic absorption spectrophotometer.

The proximate analyses (i.e., fixed carbon and ash contents) were performed by using the method of Harker (1981) whereas the ultimate analyses (carbon, hydrogen, nitrogen and sulfur contents) were determined by EuroVector Elemental analyzer.

All the above experiments were carried out by using the facilities of the Geochemistry Laboratory of the National Centre of Excellence, University of Peshawar, Pakistan.

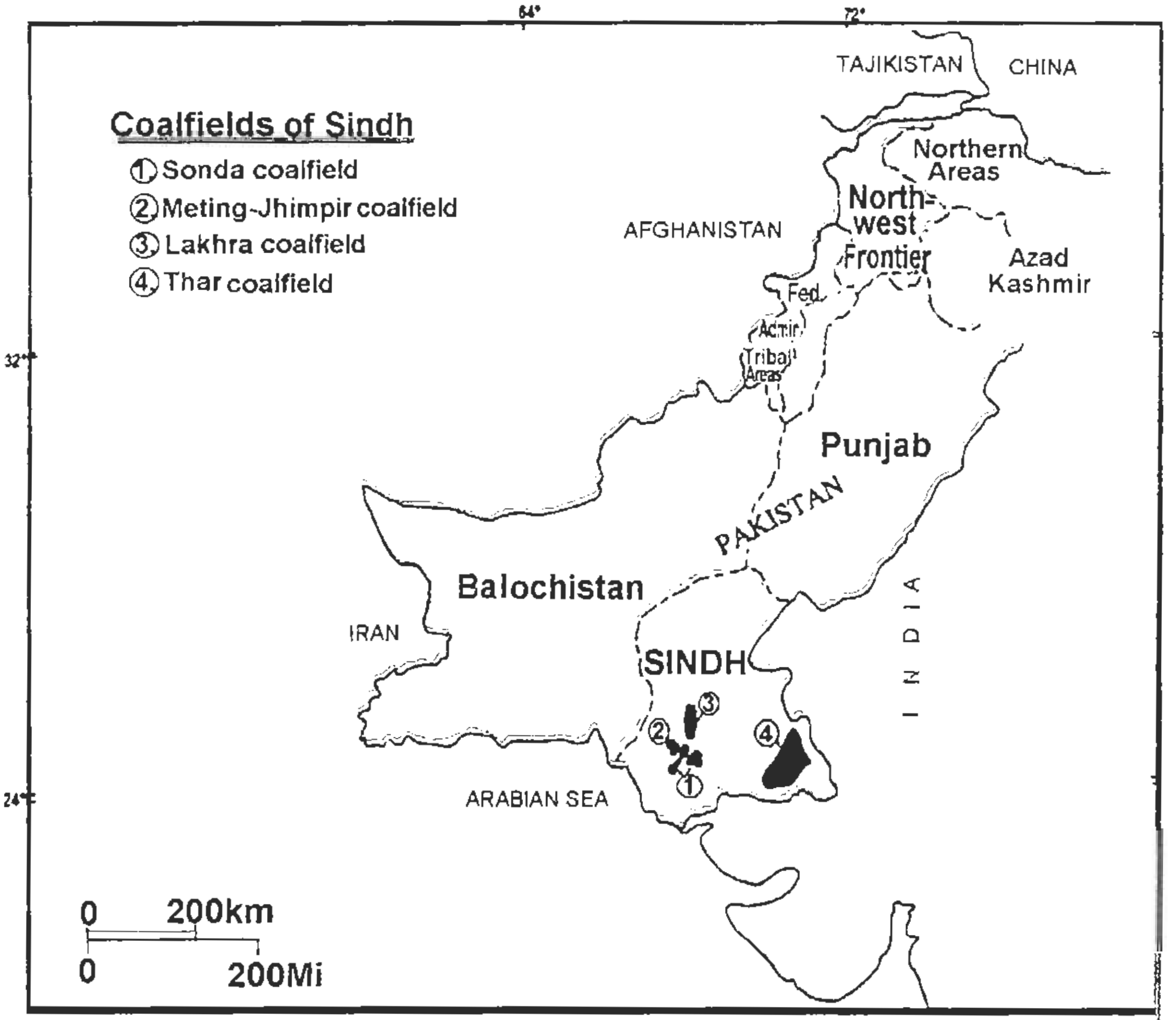

Fig. 1.1 Map showing various coalfields of Sindh province, Pakistan.