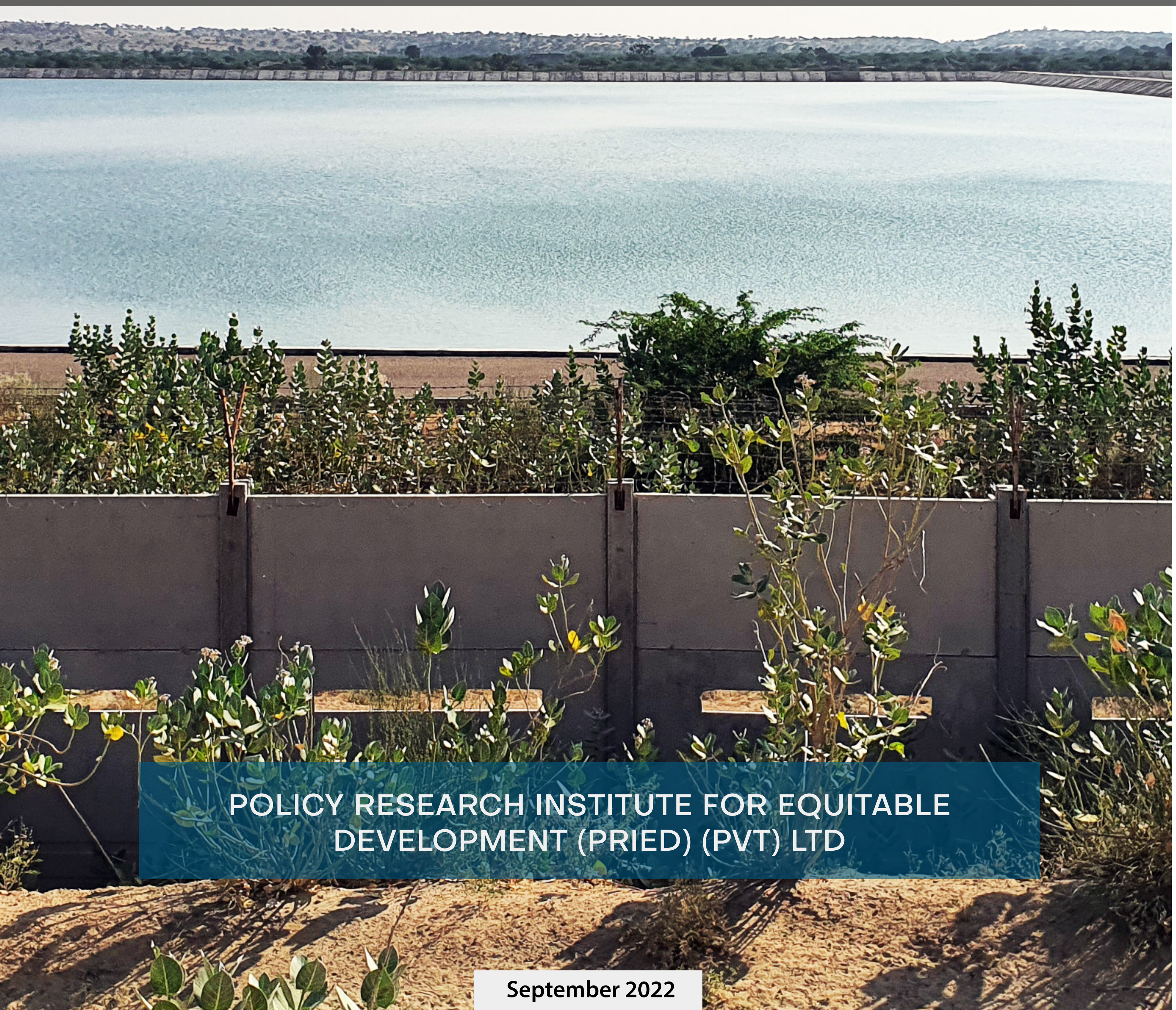
PRIED
Policy Research Institute
for Equitable Development
Private Limited

THAR'S CHANGING HYDROLOGY

Adverse Impacts of Coal Mining and Coal-based Power Generation on Local Water Resources



POLICY RESEARCH INSTITUTE FOR EQUITABLE DEVELOPMENT (PRIED) (PVT) LTD

September 2022

Acknowledgment

Policy Research Institute for Equitable Development (PRIED) is grateful to all those who have contributed their fieldwork and expert knowledge. PRIED is also deeply indebted to the Tharis, the people of Thar, who have made invaluable contributions to it by sharing their insights, knowledge and wisdom during interviews and focus group discussions.

Conceived by: Azhar Lashari

Authored by: Dr. Munir Ahmed Mangrio

Field work done by: Dr. Munir Ahmed Mangrio, Dr. Irfan Ahmed Shaikh, Engr. Rahim Bux Vistro, Muhammad Ali Kapri, Umaruddin Jarwar, Najeeb Akhter, Shahid Panhwar and the Centre of Excellence in Marine Biology at the Karachi University

Reviewed by: Dr. Hassan Abbas, independent water expert based in Islamabad

Edited by: Alefia T Hussain, senior journalist based in Lahore

Laid out and designed by: Mudasir Khoso

Copyrights

Table of Contents

List of Tables

List of Figures

List of Figures

ABBREVIATIONS

ASR	Asian Sustainability Rating
AWS	Automatic Weather Station
BHU	Basic Health Unit
BISP	Benazir Income Support Program
CDP	Community Development Program
CO	Carbon monoxide
CO2	Carbon Dioxide
CPEC	China Pakistan Economic Corridor
CSR	Corporate Social Responsibility
DMM	Department of Mines and Mineral (Govt of Sindh)
EC	Electrical Conductivity
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EPL	Engro PowerGen Limited
ESIA	Environmental and Social Impact Assessment
FY	Fiscal Year
GoP	Government of Pakistan
GoS	Government of Sindh
GSP	Geological Survey of Pakistan
GWh	Gigawatt-hour
Ha	Hectare
IBIS	Indus Basin Irrigation System
ICMM	International Council on Mining and Metals
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IMR	Infant Mortality Rate
LBOD	Left Bank Outfall Drain
M&E	Monitoring and Evaluation
MSF	Mine Service Facility
NEQS	National Environmental Quality Standards
NGO	Non-Governmental Organization
PEPA 1997	Pakistan Environmental Protection Act 1997
PEPC	Pakistan Environmental Protection Council
PM2.5	Particulate Matter of less than 2.5 micron in size
RFO	Residual Fuel Oil
RO	Reverse Osmosis
RLNG	Regassified Liquefied Natural Gas
SECMC	Sindh Engro Coal Mining Company
SSRL	Sino Sindh Resources Limited
WHO	World Health Organization

Executive Summary

Groundwater is the most precious resource in Pakistan's Thar Desert, a water-scarce region spread over 19,638 square kilometers in Sindh province's District Tharparkar. Thar has one of the largest coal deposits in the world -- estimated to be 176 billion tonnes.

The Thar coalfield is one of the biggest coal extraction operations in the whole world. Two out of a total of 13 Thar Coalfield Blocks — TCB I and TCB II — have seen considerable activity in terms of coal mining operations, development of coal-fired thermal power plants and coal-based power generation in the last few years.

Hundreds of residents faced forceful displacement from their ancestral homes and villages to make room for coalmines and thermal power plants since the start of the coal power development in the two Thar coal blocks. Apart from that, coal power projects boil water to produce steam that in turn runs their turbines. Their water requirements, therefore, have been posing serious quantitative and qualitative threat to the area's water resources.

On the other hand, groundwater is the only source of water available in Thar. An overwhelming majority of the local population depends on dug wells for drinking water and to meet their domestic needs. This groundwater is not sufficient to meet the water requirements of coalmines and thermal power plants in the area. Therefore, an auxiliary project of providing water from the Indus Basin Irrigation System (IBIS) to Thar coalfield has been undertaken.

Companies doing coal mining and power generation are also discharging their wastewater in the lands adjacent to them, thus contaminating nearby water bodies and aquifers. They have also constructed boundary walls around croplands and pastures that were once traversed freely by the desert's inhabitants. Instead of offering them alternative sources of income, these companies have prohibited them and their cattle from entering the area within those boundaries.

Such problems, coupled with a decreased access that the Tharis have to groundwater, are posing a serious threats to public health and the survival of local flora and fauna. For instance, coal-burning in power plants leaves behind a brown or black powder-like substance, known as coal ash, which contains concentrated amounts of toxic elements such as mercury, cadmium, arsenic, boron and lead -- each of which has been associated with cancer. Exposure to coal ash also increases the risk of cardiovascular diseases, neurological disorders, reproductive problems and other critical medical problems.

But coal-mining is impacting the groundwater quality and water table not just in TCB-I and TCB-II but also in their nearby areas. Exploring the gravity of the situation, this study offers important insight into the detrimental effects of coal mining and thermal power generation on water resources in Thar.

The study finds that:

- The groundwater hydrology is being speedily altered without considering its long-term consequences for communities, their livelihood, health, and overall environment in this peculiar ecological region.

- The water level in dug wells near the mining sites is decreasing rapidly. Due to this, the communities are required to put in far more efforts, time and resources to fetch the same amount of water as they used to before for their daily household and cattle-rearing requirements. This is increasing workload of women and children, and denying them equal opportunity for education and other productive activities.

- Several wells and submersible pumps have become dry because the drawdown effect of dewatering is causing groundwater level to decrease. Not only has the previous investment of local communities on wells and submersible pumps been wasted, but they also need to dig much deeper for new wells for which they require extra financial resources. They have no clue how deep they can dig to access water and be sure that their new wells will not be dry again in a year or two since no transparent information is available on the effects of coal mining on the local groundwater.

- Local communities have serious apprehensions that due to the changes in groundwater hydrology caused by mining, brackish water will soon intrude its sweet water layer.

- Although the disposal of saline water from TCB-II into the Gorano reservoir has increased water level in the nearby wells (Annex-II), it has also increased salinity in those wells. The inhabitants of Suleiman Hajjam, a village hardly 300 yards away from the reservoir, are worst affected by it. Sindh Engro Coal Mining Company (SECMC) has installed reverse osmosis (RO) plants to provide water to the nearby villages. This demonstrates that SECMC is aware of the impact of Gorano reservoir on local water resources.

- The communities near Gorano testify that soil salinity is increasing in the area and trees are dying. Emergence of salt on land surface is a new phenomenon experienced by the local communities. It has adversely impacted their access to the grazing lands. Also, several animals have died after drinking the brackish water from the reservoir.

- Like TCB-II, the development of TCB-I will require a dedicated site for the disposal of saline water and other effluents produced by coal mines. While a number of sites, including Dabri and Saringwari, are being considered for dumping wastewater from TCB-I, villagers living in the vicinity of Gorano reservoir suspect that wastewater from TCB-I will be also be disposed of in this same reservoir and once it reaches its capacity, the additional wastewater will be released into a reservoir being planned near Dukar Chaou.

- The comparison of the hydro-geo-chemical parameters examined in this study with earlier investigations (done in 2019–2021) shows that the amount of salinity, total dissolved solids, chlorides, sulfates, hardness, sodium, and potassium have increased in Thar's water over the last few years and these are now more than the acceptable levels established by the World Health Organization (WHO). This indicates that the local groundwater is no longer suitable for human and livestock consumption without treatment. The electrical conductivity (EC) of this water has increased six times in three years while the amount of chlorides, sulphates, nitrates, calcium, magnesium, hardness, and potassium in it have increased more than five times. The rising ranges of these chemical parameters in recent years, primarily caused by mining wastewater, have increased the levels of dissolved minerals, such as sodium and chloride, as well as concentrations of hazardous metals, such as copper, lead, zinc, mercury, arsenic, and chromium in Thar's groundwater.

- Plan to divert 200 cusecs of water from Nara Canal to Thar power plants will affect overall water distribution at the tail end of Nara Canal that has always suffered water shortages. The diversion of water, which is higher than the total water allocation for all three distributaries originating at Farash regulator will cause serious threat to the water rights of farmers.

- There are strong reasons to believe that when there is a water shortage in the canal system and supply to coal power plants will get priority over irrigation. This will have huge implications for the farmers' livelihood and food security.

- Even though Sindh government has improved the Nara Canal to reduce its conveyance losses so as to generate the water to be diverted to Thar coalfields, no additional provisions have been made to increase the overall discharge of water into it. Even if water discharge is increased at its head, the farmers at its tail end do not get their due water share because of the unequal distribution upstream.

- Due to the diversion of water to Thar coalfields from Nara Canal, little or no water is likely to flow to the lake, Shakoor Dhand, located downstream. This will affect the lake's ecology and will have negative implications for the livelihood of local fisherfolk who depend on it for fishing.

CHAPTER 01

INTRODUCTION

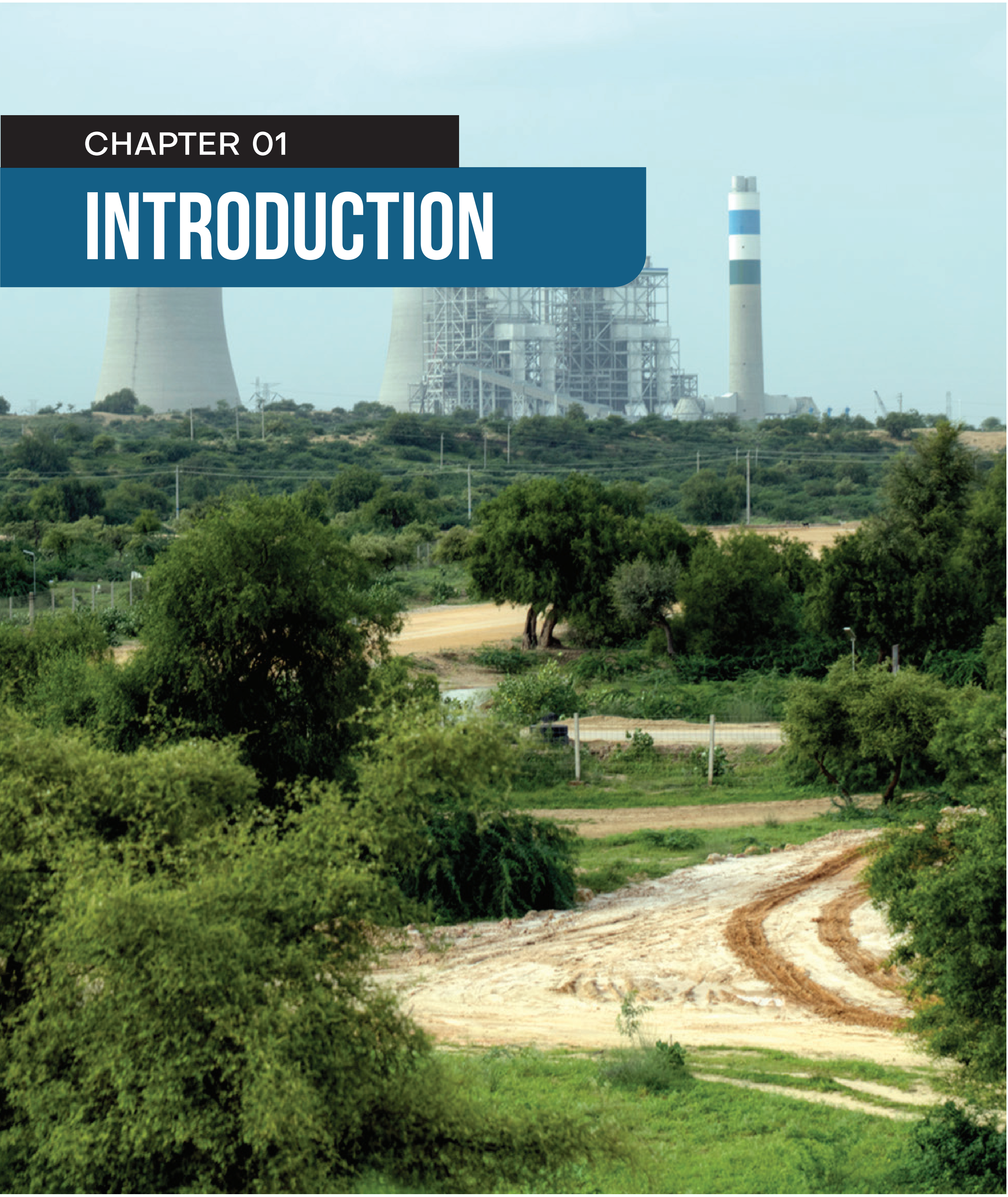


Photo credit: Kohi Marri

Introduction

Water shortages are a significant environmental barrier to economic growth in those mining areas where there are not enough supplies to meet domestic, industrial and environmental needs [1]. But these shortages notwithstanding, mining operations in some of these areas – particularly those located in emerging economies – are increasing rapidly which makes most observers wonder whether they offer any long term benefits to the local, regional and global economy and environment. Consequently, experts have suggested to put in place robust schemes for employment generation and taxation measure to make up for the harm caused by mining operations [2-3].

This is specially so in Thar region where the government started coal mining and coal-fired power generation early in the last decade. This arid desert zone has one of lowest human development indices (0.343) in Pakistan, coupled with a significantly high level of poverty [4]. Rain-fed agriculture and livestock-rearing are primary sources of livelihood in this highly drought-prone area, with an average annual rainfall of 150 millimeters which is mostly concentrated in the monsoon months of July and August [5]. Water shortage, therefore, can have significant economic effects here – as was witnessed in the dry years of between 2013 and 2015 [6].

Given such fragile water resources and considering the dire economic consequences of this fragility, it goes without saying that the detrimental effects of coal mining and coal-based power generation on Thar's natural and human ecosystems were not given due consideration. It is a well-known fact that the groundwater extraction for mining results in ecosystem loss, water table decline, water quality degradation and loss of social and economic activities [7]. This is because up to 10,000 cubic meters of groundwater need to be pumped out every hour to make coalmining possible in an open pit mine of the size that we see in Thar Coalfield Block-I and Thar Coalfield Block-II, making the groundwater table to drop suddenly [8-9].

And this is not the only hazard involved. The removal of the earth's layers for developing an open pit mine exposes groundwater resources to contaminants that are otherwise blocked by dust, sand and ricks from seeping into the aquifers. This removal, thus, causes major obstacles in the water cycle besides leading to soil erosion [10] which, in turn, can have seriously negative impacts of agriculture and grazing pastures. Local populations that depend on these activities for their livelihood are significantly impacted [11]. Other negative economic effects of mining operations include relocation of people, stress on food supplies, and deterioration of cultural and aesthetic resources [11-12]. Together all these factors put a tremendous amount of strain on the availability of water supplies – besides causing several other ecological problems – and could result in some major environmental catastrophe in mining zones [13].

This study explores all such negative impacts on water resources in Thar – particularly those being caused by mining and power generation activities in TCB-I and TCB-II.

1.1. Background

Pakistan's Faulty Energy Sector

Ever-fragile energy sector is one of the main reasons why Pakistan's economy remains vulnerable to shocks [14]. The reason for this is obvious: it does not utilize its indigenous sources of energy – particularly solar and wind energy – in an efficient, environment-friendly and consumer-centric way and instead relies heavily dependent on imported fossil fuels, such as coal, gas, liquefied natural gas (LNG), oil and residual fuel oil (RFO), for power generation. Consequently, the performance of its energy sector remains highly erratic, mainly due to a volatile global market of fossil fuels. For instance, its total electricity generation capacity stands at 41,557 megawatts but it produced only 15,500 megawatts in 2021 because it could not import sufficient oil and gas to keep all its power plants running [15].

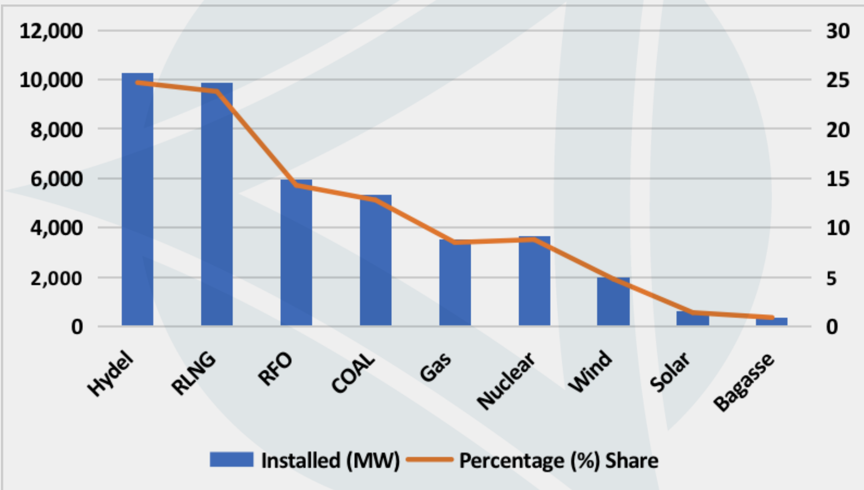


Figure 1. Share of Energy Consumption by Source (fuel-wise installed capacity) [Source: Pakistan Economic Survey 2020-21]

As is obvious from the graph above, major share of Pakistan's electricity comes from thermal sources, such as coal, gas, liquefied natural gas (LNG), oil, and RFOs. Hydro-electric installations are the second major source of power generation at 23.7% [15-16].

Given this heavy dependence on imported sources of electricity production and considering that the country's hydro-electric sources cannot utilize their maximum capacity due to seasonal changes in water flow, coal reserves found in Thar desert are being seen as a panacea for all the problems mentioned above.

This explains why the government of Pakistan plans to expand coal's share in the energy mix from 12.8% in 2022 to 19% by 2030 [16]. But this comes at a huge environmental cost. The production of thermal energy requires a substantial amount of fresh water.

Significance of Thar Coal Region

Spread over an area of roughly 9,100 km2, the Thar coal region contains around 175 billion tons of lignite-A to lignite-B coal and is divided into 13 exploration blocks (Figure 2). The development of Thar coal exploration blocks is a crucial target in the China Pakistan Economic Corridor (CPEC) program. The socioeconomic and demographic environments of each block are mostly identical.

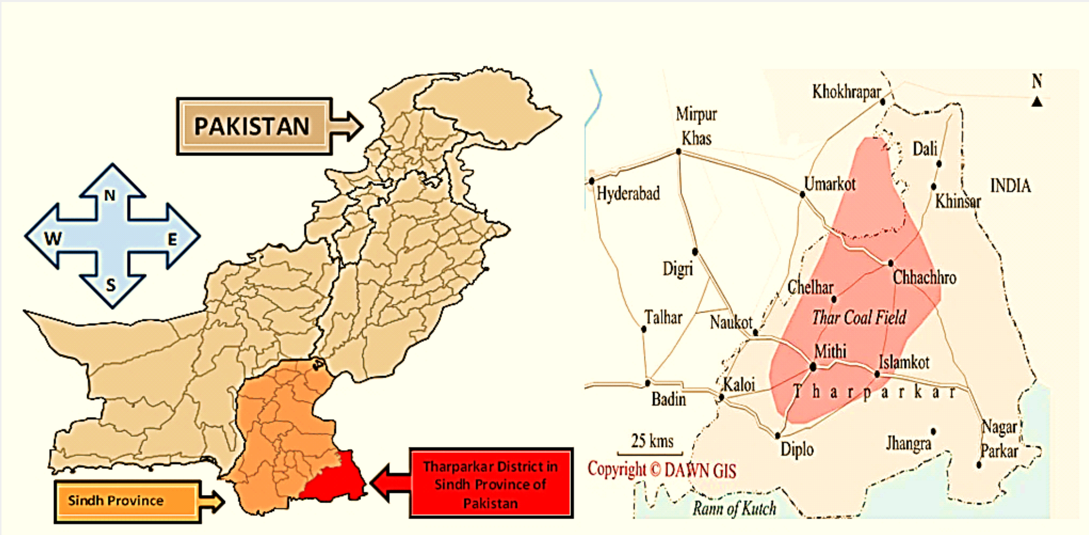


Figure 2. Location of Thar Coalfield [17-18]

Overview of Thar Coalfield Block-I

Located in the Mithi region of Tharparkar, the Block-I lies in the southern part of the Thar coalfield to the west of the Indian border and north of the Rann of Kutch. The project site is situated 12 kilometers from Islamkot and 54 kilometers from Mithi on Nagarparkar Road.

The exact size of Thar Coalfield Block-I (TCB-I) is unknown. The Environmental and Social Impact Assessment (ESIA) report on Thar Coal Mining in Sinhar Vikian Varvai Block-I says that the area covers 155 km2. However, according to the energy industry media NS Energy, it is 122 km2.

TCB- I, which has an estimate of 3.8 billion tons of coal reserves, is being developed as part of the CPEC project [19-20]. Shanghai Electric owns the majority stake and is a project partner of Sino Sindh Resources Limited (SSRL).

The civil work on the site began back in October 2019. The first unit of the power plant, with a capacity of 660 MW and a coal production capacity of 7.8 MTPA, was expected to be operational by August 2022. The entire project is scheduled to achieve commercial operation in February 2023 (Figure 3).

In January 2022, the CPEC authority claimed announced that the project is 66% complete.

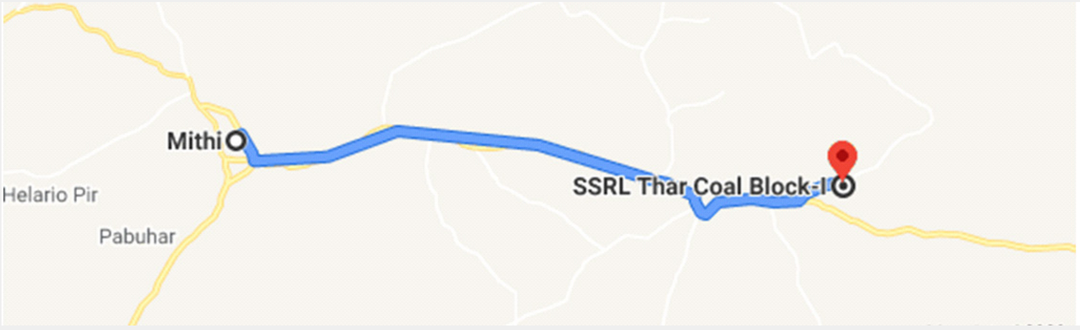


Figure 3. TCB-I project area (Source: Google Maps)

TCB-I falls largely under Union Council (UC) Khario Ghulam Shah. However, some of its area stretches to other UCs including Kehri, Sonal Beh, and Islamkot. Almost 53,000 people live in these villages, as per the 2017 census. But with a 3% annual population growth rate in 2022, the actual population should be about 61,000

.

The population figures in the ESIA are also underestimated. The Thar coal projects have been developed without taking into consideration the displacements of people that it will cause. Residents of nine villages are at the risk of being displaced due to TCB-I. These villages include Varvai, Male Jo Tar, Saren Jo Tar, Sinhar Vikio, Ajbe Jo Tar, Khario Ghulam Shah, Tilvai, Bhave Jo Tar, and Shahmir Vikio/Qurban Vikio.

Overview of Thar Coalfield Block-II

Thar Coalfield Block-II (TCB-II) is also located in Mithi, near the village of Singharo-Bitra. Sindh Engro Coal Mining Company (SECMC) started work on block II in April 2016. Engro is building TCB-II in partnership with the government of Sindh, Engro Powergen Limited, China Machinery Engineering Cooperation (CMEC), Habib Bank and Liberty Mills. Units 1 and 2 commenced commercial operation on July 9, 2019 after the successful completion of the trial operation.

The project allows an annual extraction of 3.8 million tons of lignite coal as well as the first phase operation of 2 x 330 MW power units [21]. A second mine will be included in the second phase to increase the annual production to 7.6 metric tons and the construction of 300 MW and 330 MW power plants, respectively.

According to the ESIA, TCB-II area is spread over Bhitra, Salih Jo Goth, Abban Jo Tar, Samma Jo Goth, Parbho Ji Dhani, Mansingh Bheel, Seengaro, and Nooray Ji Wandh, with a total population of 7,570 (Figure 4).

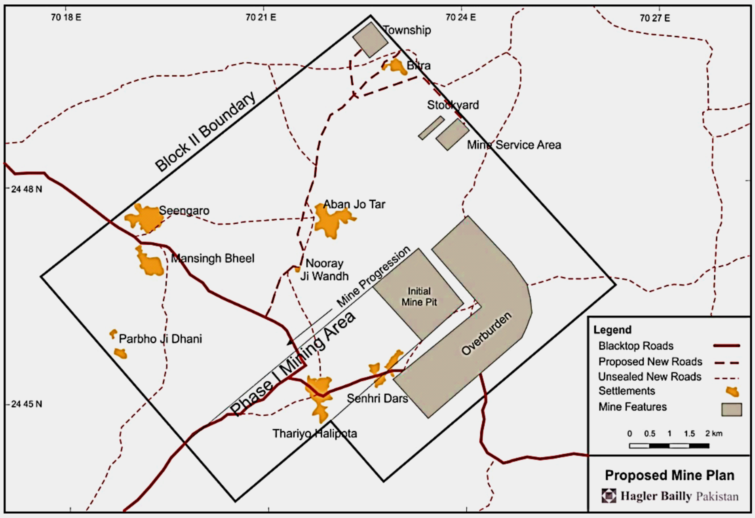


Figure 4. Thar Coalfield Block-II (Source: Hagler Bailly Pakistan)

The government sees the coal discovery in Thar as a huge opportunity for power generation. However, this comes at a big social and environmental cost. Coal mining and thermal power plants in Thar is damaging the scarce water resources and ecology of the region. Here's how:

- Coal mining in Thar is altering the groundwater flow, its layers, and geology in the area.
- Massive dewatering has lowered the groundwater table near the mining sites. It will further lower the water table and may cause saline water intrusion into already thin freshwater layers.
- The disposal of dewatering has increased salinity in nearby wells. There are also visible signs of increased soil salinity in the area.
- The cooling system of power plants requires a large quantity of water. The disposal and discharge of waste from cooling towers will further add to the environmental problems.
- The mining and land levelling for power plants will change the landscape of Thar by altering the drainage patterns and blocking routes to natural ponds for rainwater flows. These ponds are the main fresh water sources in rainy seasons in Thar.

1.2. **Scarce Water Resources of Thar**

The Thar region experiences erratic rainfall during the monsoon season, usually between June and September. The rainfall is not adequate to recharge aquifers, hence the water level remains below 35m to 45m [18]. In the entire coalfield, just 48% of 310 wells provide sweet water, whereas 50% of them in the TCB-II area are saline [19]. Due to SECMC's failure to line the Gorano reservoir, residents of 13 nearby villages have started to face the adverse impacts of saline water seepage.

The people of Thar are aware that the water-intensive coal mining and coal power generation plants will reduce the quantity of surface and groundwater. The people worry that this will produce toxic effluents that will pollute the ground and drinking water. [21]

The source of water generally in the area is at the contact of sub-recent deposits and overlying sand dunes. The drill hole geology shows three potentially present compact sand aquifer zones -- the Dune Sand at a depth of 50–60 meters, the Coal Seam Roof at a depth of 120 meters, and the Coal Seam Floor at a depth of 180–190 meters. They make Tharparkar's hydrogeology unique, as shown in Figure 5.

Out of the three aquifer zones, only the Dune Sand aquifer is suitable for human consumption. To reach the target coal depth, the groundwater aquifers must be dewatered, which involves removing the water content from coal. This dewatering is necessary for coal operations not only to reach the target coal deposits but also to ensure that the mine is dry and safe. According to modeled simulations for TCB-II, 90% of the pumped water comes from the bottom aquifer, 9% comes from the middle aquifer, and only 1% of the water pumped out comes from the top aquifer.

There are three ways that coal mining can change and impact water - dewatering, brine effluent disposal, and diverting freshwater from Nara Canal. The next sections of this report will discuss the implications in more detail.

According to the 2019 UN assessment [34], about 93% farming households in Tharparkar reported a reduction in water availability for agricultural activities due to frequent dry spells or limited rainfall. 59% of farming households in non-desert or arid areas reported severe water shortages, whereas 82% of households in desert or arid areas narrated the same issue.

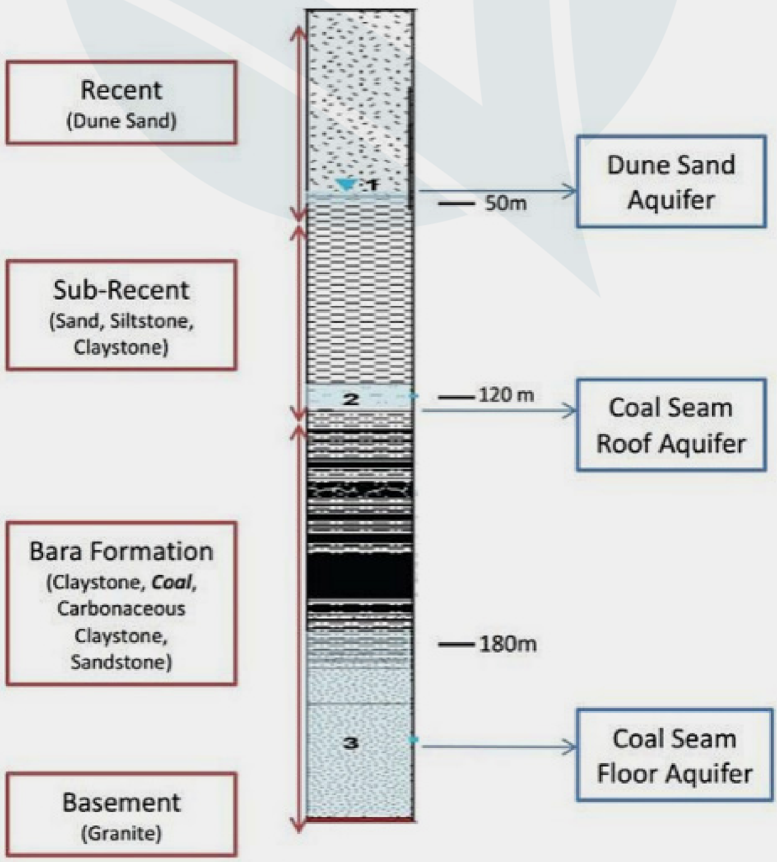


Figure 5. Aquifers of Thar coalfield (Source: The Friday Times, updated on September 21, 2021) [23]

Most of the laws and policies that are framed to secure and manage water resources for provinces pay less attention to dry lands. The Thar Desert is no exception. Yet the local communities have learned to live in harmony with nature and have developed resilient and sustainable systems. The locals have constructed drinking water ponds by collecting water run-off and managing tarai. Though they have also constructed small dams partly to improve the groundwater storage, these bodies of water are usually dry with a significant amount of sediments.

People living in these dry lands are becoming increasingly dependent on groundwater. The use of solar pumps by the ever-expanding population will overexploit the groundwater resources. Besides, the fragile aquifer systems are always at risk of being intruded by saline water. The coal mining and thermal power plants have made the situation even more complex.

1.3. **Objectives of the Study**

- Long-term effects of mining-related dewatering on groundwater and the local communities living in Thar.
- Social and environmental problems emanating from the disposal of wastewater from coal mines and coal-fired thermal power plants.
- Impact of water diversion from Nara Canal to power plants, especially on the farmers settled at the canal's tail end.
- Effects of climate change on Thar communities and the flora and fauna of the region.
- Lacunas in the current regulatory legal and policy framework on wastewater and freshwater management devised for the Thar coal power projects.
- Violations of different provincial, national, and international laws and best practices in planning and execution of mining-related dewatering, wastewater disposal and water supply from Nara Canal to coal power plants in Thar.

1.4. **Geographic Scope of the Study**

The study will cover TCB-I and TCB-II. This includes Gorano, Dukkar Chaou, and other proposed and under-construction sites for wastewater disposal, Vijihar and the command area of Nara Canal and Dhoro Puraan. It will also look at Nabisar in District Umerkot and Districts Vijihar and Tharparkar.

CHAPTER 02

METHODOLOGY

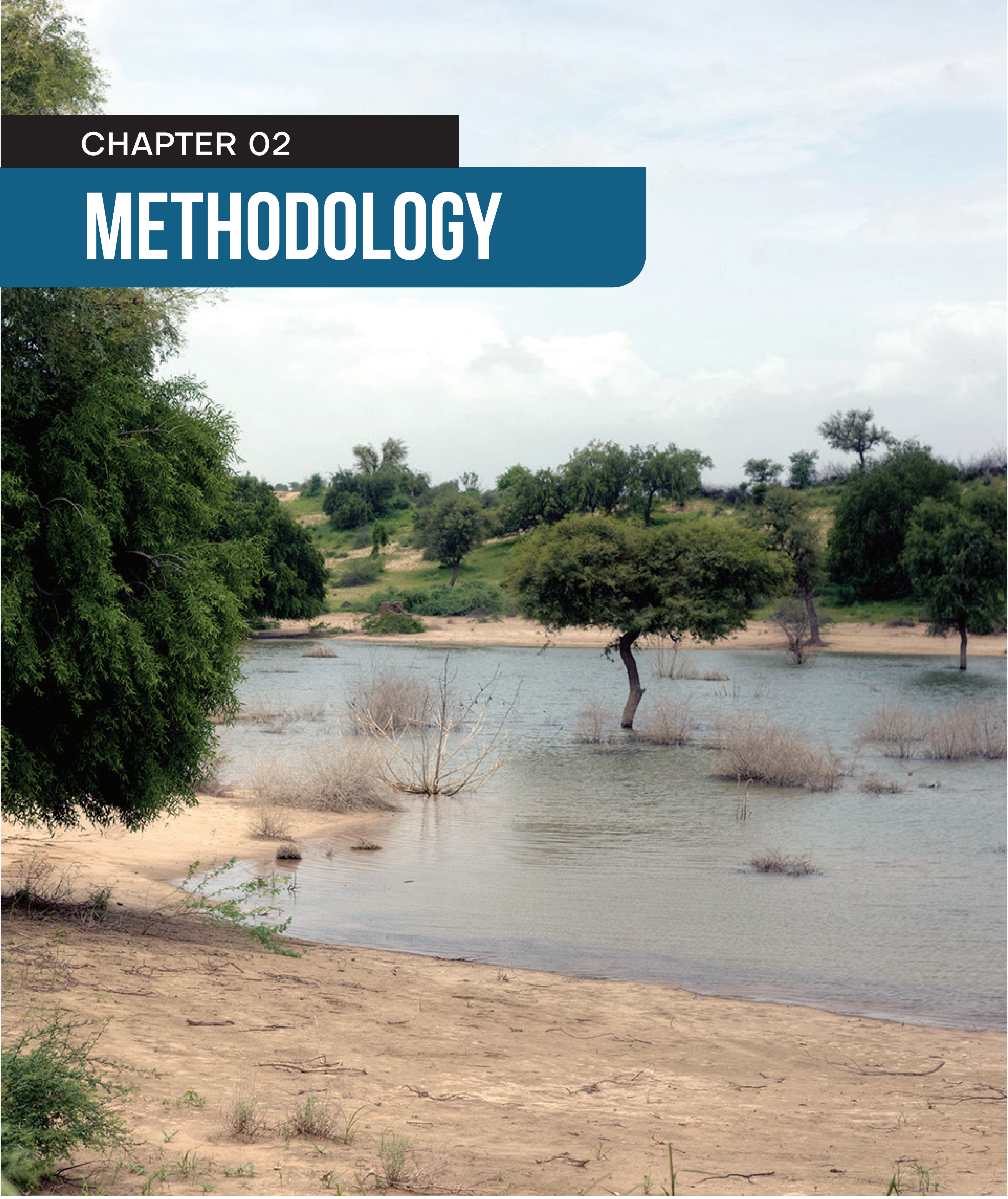


Photo credit: Kohi Marri

Methodology

2.1. Study Area

The study area of Thar coalfield is located in the Tharparkar region (Thar desert), in the south-eastern part of Sindh province, between the longitudes of 69 45 °E and the latitudes of 25 45 °N. The area stands out for its low and erratic rainfall, high levels of atmospheric aridity, and a lot of heat and sunshine. Also, winds thatproduce dust and little vegetation are peculiar features of the area. Seventy percent of its area is made up of high sand dunes and sandy plains. Among the 120 districts of Pakistan, thisarea is ranked lowest in terms of human development and foodsecurity. To meet their water requirements, the local familiesmostly rely on groundwater aquifers and stored rainwater. Location map of the study area is given in Figure 6.

Figure 6. Location map of the study area (Source: Samtio et al., 2021 [41])

2.2. Research Design

A blend of qualitative and quantitative methods was employed to collect the data. Information was gathered from the research region in both soft as well as hard formats. However, accurate data on dewatering rates, brine water disposal, and wastewater information were not easily available. Water monitoring reports submitted by coal mining corporations to the Sindh government are inaccessible. The cost and specifics of the infrastructure connecting Vijihar Pond to Thar Coal Field-II pipeline have not been disclosed.

After the review of available literature, quantitative tool was employed to collect data on structured questionnaires. The research study was completed in four and a half months, from mid-February 2022 to mid-June 2022.

2.3. **Data Collection and Sampling Process**

The sampling for primary data collection was drawn from the total number of existing villages in TCB-I and II. In the first stage, villages were selected.They were asked to get a community perspective on different issues in the second stage.

For effects of the Thar coal power projects on groundwater, a sample from existing dug wells was drawn based on the total number and representative sample accepted in social science research. Because coal mining and related power plants would alter the environment, topography, and natural resource base, we reached out to local communities to learn about their views on groundwater supplies. Some 190 randomly chosen families and 15 key informants from villages of TCB-1 and II were interviewed and asked to fill in a questionnaire. The water samples were collected from different wells surrounding the Gorano reservoir and mining sites. These samples were tested against key water quality parameters. Qualitative data was collected from a combination of desk review, key informant interviews (KII) and consultations, and focus group discussions. Key informant and stakeholder interviews were conducted to gather information on issues related to coal mining, power plants, and water supply from Nara Canal.

2.4. **Data Analysis**

The key statistics in this set of analysis are percentages, frequencies, and averages that are put into graphs and tables with the use of Microsoft Excel. The information obtained through KII and focus group discussionshas been included in relevant sections to substantiate the argument where necessary. The impact of Nara Canal water diversion is based on information collected through secondary literature review and focus group discussions.

2.5. **Limitations**

The primary limitation was the lack of data shared by coal mining and power generation companies. Therefore, the calculation of actual dewatering and the quantity and quality of brine effluent is difficult to measure. Also, measuring and monitoring of dewatering effects require long-term groundwater monitoring.

CHAPTER 03

AN OVERVIEW OF LITERATURE AND THE RELEVANT LAWS, POLICIES AND PRACTICES GOVERNING WATER MANAGEMENT IN THAR COALFIELD

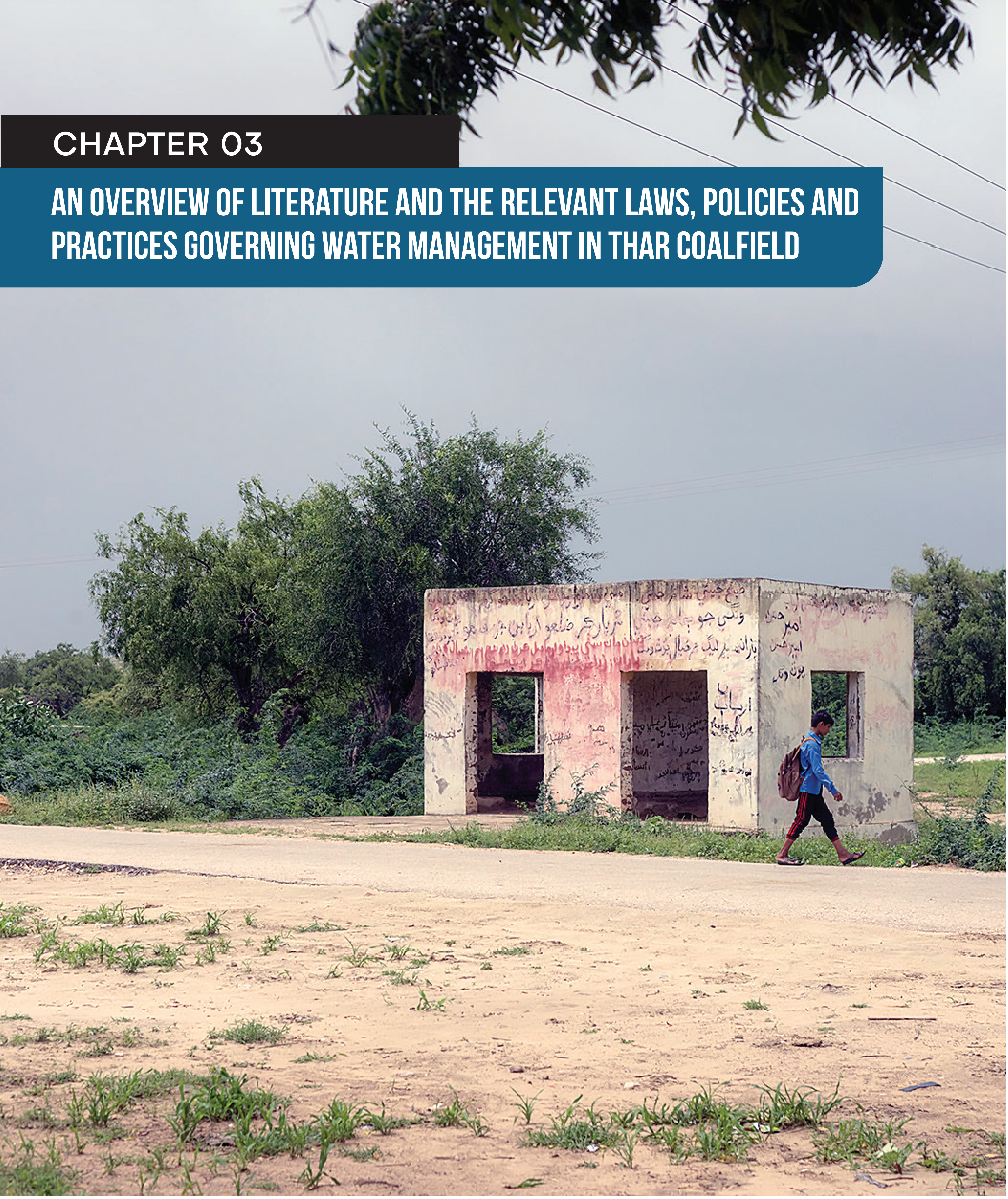


Photo credit: Kohi Marri

Regulatory and Policy Mechanisms Governing Water Management in Thar Coalfield

3.1. Literature Review

According to the diagnostic macerals and petrographic statement, the coal in Thar is humic and predominantly composed of huminite, with minor amounts of liptinite and inertinite macerals. The Thar coal is largely made up of topo genic mires that are formed under anaerobic conditions with little thermal or oxidative tissue damage [19]. Coal mining near residential areas has a substantial influence on the ecosystem, biological habitats, society, and economy of Sindh. All living creatures on earth, as well as their interactions with the lithosphere, hydrosphere, biosphere, and atmosphere are a part of the global ecosystem.

Several research studies have been conducted on rehabilitation of damage caused by open-pit coal mining. Previous literature presents coalfields as an important element of the global economy. However, greenhouse gas emissions from coal mining have exceeded the global carbon budget [22-26]. Mining, according to Cao et al. (2016) and Watts et al. (2020), is one activity that will destabilize water quality and increase water pollution [24-25]. Dueto the metal concentrations in crops and soils, the subterranean and above groundwater resources have a considerable impact on the irrigation system. Vegetable consumption has resulted in serious health problems due to the rising metal association levels, metal partitioning, soil-to-plant bio-concentration factor (BCF), and gas concentration. Coal-fired power stations have a significant influence on both the quantity and quality of accessible water. The two most serious threats to water quality are salinization processes and heavy metal contamination. Both these occurrences render hydraulic resources unfit for conventional uses, such as drinking water, agricultural cultivation, and cattle feeding [24-25].

In 2018, Qureshi stated that the primary scientific causes for salinization include,"the existence of soluble salts in soils, a high-water table, a high rate of evaporation, low annual rainfall, irrigation, de-frost, and pumping of groundwater". He concluded that Tharparkar checks off all the criteria. The salinity of the subterranean water in Tharparkar is close to 5,000 parts per million (ppm), compared to the WHO limit of 1,000 ppm. Therefore, building new power plants that use a lot of water would cause aquifer salinization to rise, which is detrimental to the existence of both people and environment [26].

The contamination of aquifers with hazardous materials is another significant problem that Tharparkar's new coal-fired power stations and coal mining will bring about. For instance, the two main processes that pollute water bodies are acid mine drainage (AMD) and acid precipitation. Jiru reported in 2017 that particulate particles (PM), carbon monoxide, mercury (Hg), nitrous oxides (NOx), and sulfur oxides (SOx) are the primary harmful pollutants discharged during acid rain. As a matter of fact, air contaminants are present in the heat emitted by the cooling towers of the plant. They build up in the atmosphere and are returned to land by rains, thus polluting soils and water supplies and causing heavy metals such as mercury to "bio-accumulate in the fish" [27].

In 2020, Lauri Myllyvirta, lead analyst of the Centre for Research on Energy and Clean Air (CREA),predicted that Thar Engro II, Thar VI, and Block II open pit mines will produce 154, 325, and 48.4 tons/year of PM2.5, respectively [28]. Samtio et al. (2021) used a geographic information system (GIS)-based technique to assess several water quality metrics of groundwater quality insub-district Dahili in the Thar desert [29].

The dewatering of saline water may infiltrate through porous sands and mix with the available water in surrounding villages. The Gorano pond area spreads over approximately 1500 acres that may get submerged with dewatering surface water and cause loss in soil and land utilization [30].According to Paul Winn [31],the gap between water required for the projects and what is available from mine dewatering is staggering. After thoroughly studying official documents, he predicted dewatering rates, evaporation, and the losses caused due to the necessity to desalinate the groundwater for thermal cooling.

During the consultation for environmental impact assessment (EIA) for TCB-II power project, the main issues and concerns that emerged pertainto relocation (not required for power plant), employment, and groundwater [32]. The same EIA also revealed that because of the high volume of water required for the projects,Thari people and their livestock might get less water.

EIA for Block-I recognizes that the pipeline providing water supply to Mithi town and a few other villages, is located at the tail end of the canal,where water is in short supply and available only on a weekly basis. The EIA also acknowledges that groundwateris the main source of water in the area and therefore, Thari women have to walk a long distance to fetch drinking water[33].

Clearly, all the reports underestimate the effects of coal mining on water quality and quantity and sustainability of local ecology and natural resources to justify the project interventions.

3.2. **The Laws, Policies, and Practices for Water Management**

In the light of the implications on both water quantity and quality, it is important that the mining companies and thermal power plant companies follow the national and provincial laws, policies, regulations, and international commitments on environmental standards.

The Table 1 below lists the legal, regulatory, and policy frameworks on the national as well as international levels.

Table1. Legal, regulatory and policy frameworks (Information retrieved from ESIA, 2012)

Dimensions	National	International
Water	National Water Policy 2018. Canal and Drainage Act 1873 and Sindh Irrigation Act 1879; Sindh Water Management Ordinance 2002; Pakistan Environmental Protection Act 1997; Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations 2000. Transboundary Agreement with India known as The Indus Waters Treaty. The treaty set out the provisions for water-sharing between the Republic of India and Pakistan, brokered by the World Bank.	Conventionon Wetlands of International Importance; Declaration on Environment and Development 1992 (or Rio Declaration)
Mining	Labor and Health and Safety Legislation: Mines Act 1923; Provincial Employees Social Security Ordinance 1965; and Workmen's Compensation Act 1923; Voluntary Principles on Security and Human Rights; National Mineral Policy 2013; Sindh Coal Act, 2012; Sindh Mining Concession Rules 2002; Mines Act 1923; Mines and Oil-fields and Mineral Development (Government Control) Act 1948; Sindh Mining Concession Rules 2002.	International Council on Mining and Metals (ICMM) Sustainable Development Framework; Good Practice: Sustainable Development in the Mining and Metals Sector.

Dimensions	National	International
Climate Change	Pakistan Environmental Protection Act 1997; Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations 2000	1992 Declaration on Environment and Development (or Rio Declaration); United Nations Framework Convention on Climate Change; Kyoto Protocol to the United Nations Framework Convention on Climate Change; Vienna Convention for the Protection of the Ozone Layer; Montreal Protocol on Substances that Deplete Ozone Layer; and associated amendments.

Sindh Water Management Ordinance, 2002

Sindh Water Management Ordinance, 2002 that superseded the SIDA Act 1997, aims to ensure the establishment of public systems for the distribution and delivery of irrigation water, the removal of drainage water and the management of flood waters, and meet transparent, accountable, efficient and operating standards acceptable to users. The ordinance has become an act after getting legal protection from the parliament.

Sindh Drinking Water Policy, 2017

The government of Sindh approved the Sindh Drinking Water Policy in May 2017 to provide safely managed drinking water and maintain its adequate and sustainable supply. This policy recognizes access to safely managed drinking water as a fundamental right of every citizen and gives priority to its allocation over other uses of water.

Groundwater

The abstraction and use of groundwater in entire province are unregulated which is causing stress to aquifer outside the canal command areas. This results in lowering of water table and intrusion of saline groundwater into freshwater zone.Monitoring the groundwater quality is critical. It must be tackled systematically with strong institutional and regulatory mechanism. Currently, groundwater is a free zone.Its abstraction is free and on the will of individual farmers.

It is important to carry out a realistic assessment of available fresh groundwater both inside and outside of the canal command areas, develop adequate institutional capacity, formulate groundwater uses laws, and regularly monitor the environmental implications of groundwater abstraction, especially on the quality of groundwater.

The Pakistan Environmental Protection Act (1997)

Pakistan Environmental Protection Act (PEPA) is the primary law that addresses environmental preservation, enhancement, protection, pollution prevention and control and promotion of sustainable development.

Sindh Environmental Protection Act 2014

This is a primary legal instrument that allows the Sindh Environmental Protection Act 2014 (SEPA) to create and oversee environmental protection legislation. The legislation covers a wide variety of concerns, including the treatment of hazardous wastes and water, industrial liquid effluent, marine, and noise pollution.

There are currently no clear regulatory requirements or guidelines for the disposal of hazardous waste. The 'Hazardous Waste and Hazardous Substance Rules' were created under PEPA. The SEPA still refers to these rules that control handling, production, storage, and import of hazardous waste and substances.

3.3.Critical Analysis of Regulatory Framework

The existing regulatory framework has two aspects. One, there are no adequate laws and regulatory mechanism to control abstraction and quality of groundwater. Most of the laws deal with surface water, which shows that low priority has been given to groundwater. Second, the few existing laws are poorly implemented, especially those pertaining to environment and water pollution. The weak governance of institutions and the legal and justice systems do not provide any incentives to the civil society to invoke these laws effectively.

The coal mining and electricity generation industries in the area are blatantly violating the existing laws. They release contaminated water into agricultural and grazing lands, as well as re-inject it into underground aquifers. This is in violation of the Sindh Environment Protection Act, the National Water Policy 2018, and generation licenses granted to them by the National Electric Power Regulatory Authority.

Thar has reserves of lignite coal (brown coal), which is the lowest grade coal with low carbon count and low heating value. As a result, larger quantities of coal are required to create energy.

Highlight

Due to a lack of surface water, Tharis are forced to use groundwater that is brackish and contains a high concentration of fluoride. High concentration of fluoride in water causes thyroid and kidney problems.

The Thar desert is known to be the most fluoride-affected region in Pakistan. In the absence of surface water, Tharis are forced to use groundwater that is brackish and contains a high concentration of fluoride. Fluoride causes thyroid and kidney problems when its concentration in drinking water exceeds 1.5 milligrams per liter (mg/l). Skeletal fluorosis that causes chronic bone and joint deformations is a common occupational disease in Thar.

The percolation of toxic water from the Gorano and Dukar Chaou reservoirs established by the mining companies, lowering of water table around the mining sites and dumping of wastewater on farmlands have threatened the environment and health of Tharis. About 20 dugwells near the reservoir have already turned salty, according to Ameer Hassan, an office bearer for Thar Samaji Tehreek. His observations on negative effects of the reservoir are part of a report compiled by the Islamabad Policy Research Institute (IPRI).

A report dated August 4, 2022 published in the Dawn newspaper on the Sindh government's brokenpromises to local people, quotes Advocate Leelaram Meghwar. He says,"Due to the discharge of highly hazardous/toxic water from the reservoir, the houses and animal grazing fields have disappeared, and the locals are now homeless".

Though China is shutting down many coal-fired power facilities, it is assisting developing nations, such as Pakistan, in mining lignite coal and constructing new power plants. The countries across the world are trying to lower the use of lignite to generate electricity.

For too long, there has not been a monitoring system to evaluate, budget, restore, and recharge groundwater to support the desert life and environment. The coal mining in Thar provides the irrigation department a chance to develop a detailed plan – to create a specialized wing, train staff, and provide equipment for the management of water resources in the region. The plan should include strong monitoring of groundwater abstraction and quality; saline water intrusion into freshwater zones; the impact of dewatering on both groundwater quality and quantity; rainfall; and recharging. The department should develop mitigation strategies based on rigorous monitoring and long-term data collection to prevent water insecurity that may threaten the ecology and lives of the desert people – and to discourage future mass migration.

CHAPTER 04

GROUNDWATER EXTRACTION FOR COAL MINING AND WATER TABLE IN THAR

Photo credit: Kohi Marri

Groundwater Extraction for Coal Mining and Water Table in Thar

The Thar desert is an enormous tableland in the south-eastern part of the Sindh province, Pakistan, where the mighty Indus River drains into the Arabian Sea. It is made up of exposed igneous rocks and dunes that are part of the north-eastern extension of the Indian shield (craton) rocks. Natural resources like kaolin, igneous rocks (granite), coal, gypsum, and lake salts are abundant in this region [30]. The amount of kaolin is relatively high, with local concentrations as high as 70 to 75 g/t.

In this area, the Bara Formation, igneous rocks, recent deposits (dune), and sub-recent (alluvial deposits) stratigraphic units are all present in accordance with several exploratory surveys[35-37].Sand is interspersed with topical deposits and shallow groundwater (dug well aquifer) is present beneath the sub-recent deposits at the foot of the lithologic unit and receives recharge from rainfall. The local population uses wells to extract fresh water from this aquifer.

Thar communities' local wisdom has grown through time as they have confronted and adapted to difficult conditions. Local wisdom is a form of environmental wisdom. It is cultural knowledgeabout models of sustainable use and management of natural resources [36].

As seen in Table 2, the demographic characteristics of the people shows that most of the respondentsare married and significantlyilliterate. A vast majority of them, therefore, does not work for the Thar coal projects.

Indicator		Response (%)
Marital Status	Married	95.8
	Unmarried	4.2
Education	No Education	53.4
	Primary/Secondary	27.2
	Matriculate	9.5%
	Intermediate	6.1%
	University	3.4%
Age	Mean	48.56
	Median	50
	Range	22 – 85
Family Members	Mean	11
	Median	10
	Range	3 – 55
Family members employed at thar coal?	Yes	28.4%
	No	71.6%

Table 2. Demographic characteristics of respondents (N = 190)

4.1. Water Resources, Availability and Quality of Groundwater

The term 'Tharparkar' is derived from the word 'tari', which means 'thirsty'. 'Tarai' -a word used for temporary surface water sources [26] -is used for drinking and other household purposes and are accessible only for a few months in a year. The size, capacity, and catchment area of each tarai varies. Tharis use the water in tarais for themselves and their animals during the wet season when they get filled with rainwater.

As it can be seen in Figure 7, of the entire population polled (n = 190), 57% of the respondents reported not utilizing tarai water, whereas 43% reported doing so.It was found that about 93% of households use tarai for less than two months in a year. They spend most of their time desperately searching for water -- peering down into wells or gazing up at the sky for rain.

For women in Thar, arranging water for their families is nothing short of a herculean task. Carrying water-filled containers from water sources located far away affects women's health, especially for pregnant women. Although women are worst affected by water shortages, but the men suffer as much. Theyhave to spend time gathering rainwater and other natural resourcesinstead of using the same time to earn livelihood to feed their families.

The principal crops farmed in the region are millet, mung beans, bulgur wheat, chilli, and oilseed. These plants can endure arid environments. But in extreme drought conditions, agricultural yieldis drastically reduced and fresh produce is hard to come by. In arid climate,tarais are barely charged and evapotranspiration and percolation are high.

Figure 7. Use of tarai water source by respondents

The Table 3 shows that the impact of coal mining or the Gorano reservoirdewatering disposal on taraisis not significant. Over 80% of households said that neither the coal mining nor the Gorano reservoir had impactedtarais. However, key informant interviews indicated that while the expanded road network has improved communication, it has also cut off the tarai catchment areas, leaving many permanently dry.

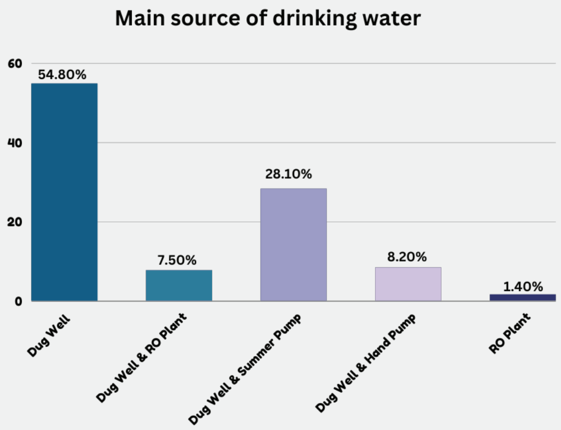
Table 3. Use of tarai water and effect of coal mining

Indicator	Response options	Response (%)
How long does tarai serve water needs	Less than 2 months	92.7%
	2 – 3 months	5.5%
	More than 3 months	1.8%
Has coal mining affected/destroyed your tarai	YES	31.9%
	NO	68.1%
Has coal mining or gorano Reservoir affected tarai water	YES	11.5%
	NO	88.5%
Has coal mining or gorano RESERVOIR DISCONNECTED tarai from its run-off	YES	17.3%
	NO	82.7%

Water is obtained from a variety of sources in Tharparkar, including pond water in 0.69% of cases, tube wells in 2.26% cases, manual pumps in 1.66% cases,and dug wells in 93.9% cases [39]. During prolonged droughts, most Tharis migrate to irrigated areas along with their cattle.

Some of the wells in the area are about 200 to 300 feet deep. More than 54.8% homes use dug wells as their primary supply of drinking water, while another 35% use dug wells, hand pumps in conjunction with RO plants, and submersible (locally known as "summer") pumps (Figure 8).

This shows that the entire population of coalfields is reliant on groundwater supplies to meet their daily water needs. Therefore, residents are able to immediately detect changes in groundwater quantity and quality.The Thar communities use different water conservation techniques. About 77% of people extract water over 120 feet.The common structures used by them for water storage are tarai, kunds, kui, khadin (or dhora), nadi, and talab.



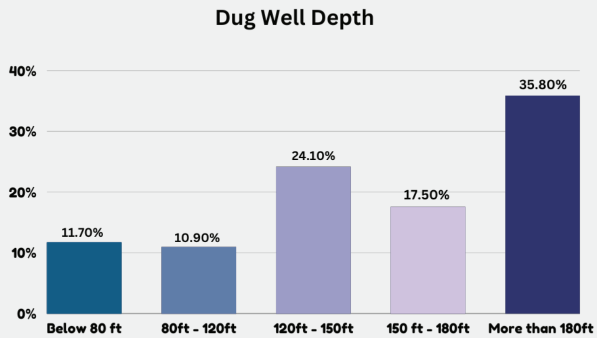


Figure 8. The primary water source and the depth of the dug well

About 70% of families requiremore than 50 liters of water a day. The water demand is based on the average family size. It equates to five litres per person, which is far below the WHO defined standards of 50 to 100 litres per person per day.

The study also assessed water requirements for animals. About 87% of households were of the view that their animal water requirement is more than 50 litres a day. This means each household's minimum water requirement is 100 or more litres a day. This water is usually pulled from 180-ft deep dug well.

Table 4. Daily water requirement for consumption

Indicator	Response options	Response (%)
Family Water requirement	Less than 30 Liters	17.9%
	30 – 50 Liters	11.7%
	More than 50 Liters	70.3%
Animal water requirement	25 – 30 Liters	9.2%
	31 – 50 Liters	4.1%
	More than 50 Liters	86.7%

Traditionally, the people manually fetched water. But now the people have installed submersible pumps to extract water from undergrounddue to availability of electric and solar power.

About 88% of respondents agreed that the quality of water has changed in the last few years **(Table5)** because of the increased quantity of saline water.

Table 5. Change in dug well water quality

Indicator	Response options	Response (%)
Dug well quality change over 2 – 3 years	Yes	88.4%
	No	6.8%
	Don't Know	4.7%
Reason for deteriorated water quality	More Usage	2.8%
	More Usage and Coal Mining	4.2%
	Seepage from Gorano reservoir	16%
	Coal mining and power generations	75.7%
	Other reasons	1.4%

Some 93% of respondentsliving in the reservoir's surroundingareas claim that most of the water from dug wellsis salty (Figure 9). This is clearlybecause water from the Gorano reservoiris mixing with water in the wells. They fear that drinking water may become saltier if saline water continues to mix with freshwater because of dewatering.

The water from wells tastes foul. The area around the Gorano reservoir is smelly. The soil around the reservoir is black. A majority of respondents—around three-fourth of them —blame coal mining for this kind of environmental degradation. Almost 16% of respondents think coal mining is spoiling the well water quality.

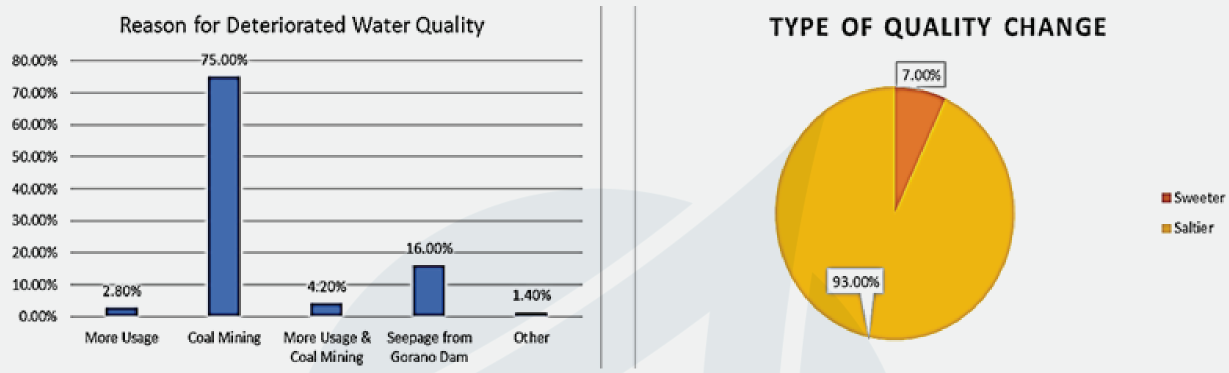


Figure 9. Reason for deteriorated water quality and type of quality change

4.2. **Groundwater Extraction from Mining**

The coalfield has been divided into 13 blocks for mining development to exploit the vast lignite deposits. Six blocks have been explored, each with measured deposits between 400 and 800 million tons (Mt), as seen in **Figure 10.**

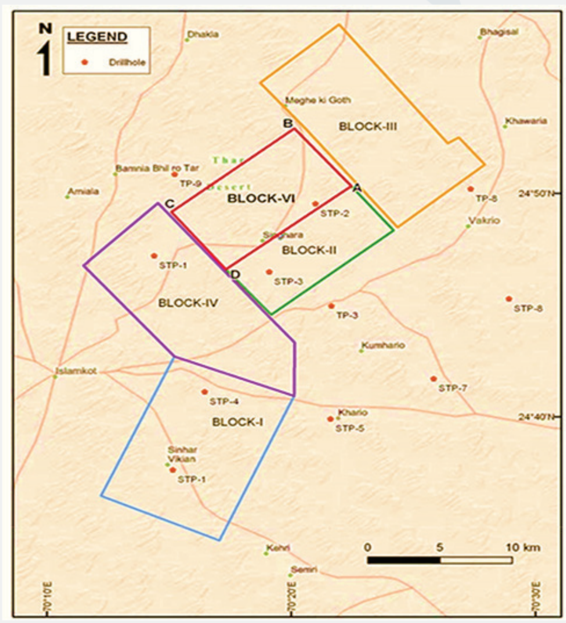


Figure 10. Location of Blocks I to VI within Thar Coal Field (Source: Matt MacDonald)

Impact on Groundwater

According to ESIA, the cone of groundwater drawdown created by mine dewatering associated with TCB-II mine is predicted to extend by 15 to 20 km from the center of the site -- and this groundwater depression may increase in future.

Groundwater resources will decrease as a result of development in other blocks. Therefore, it is important to investigate the long-term effects of this coal-related development on groundwater availability. Oracle's Block VI coal power project will need dewatering of Blocks II and VI, and maybe Block-I mines. Dewatering of one block will reduce groundwater availability of other blocks.

It is speculated that after the development of Blocks II, VI, and maybe I, the bottom aquifers' long-term capacity will not be sufficient to meet Oracle's water demands [38]. Since most of the groundwater in Oracle's Blocks comes from deep wells bored into sandstone and shales of Paleozoic age, Block I operations will lead to extinctions of several endemic plant species and disruption of tropical ecosystems.

The ESIA of the coal projects isinsufficient and inadequate in determining groundwater availability and behavior in terms of its flow direction and rate, particularly with regard to the vast artesian aquifer below the coal seams. Any sustainable development will be problematic if the region's future water supply is taken into account. Thus, any sustainable development in the region should wait until complete ESIA report is available.

Understanding groundwater behavior is crucial in determining the potential impact of coal mining activities on sustainable development in the region. The following are examples of possible effects of pit dewatering on household, ecological,and humanuses of drinking water:

1) Reduction in the availability of groundwater in the upper Dune Sand aquifer (used by communities) due to a decrease in the groundwater level.

2) Poor groundwater quality due to drawdown as well as seepage from water bodies of wastewater storage.

It was crucial to get the viewpoint of affected householdson the changes in groundwater, coal mining, dewatering, and discharge of mine water. More than 75% of households say that the groundwater has decreased, 17% say it has increased, and 7.5% see no change in it (Figure 11).

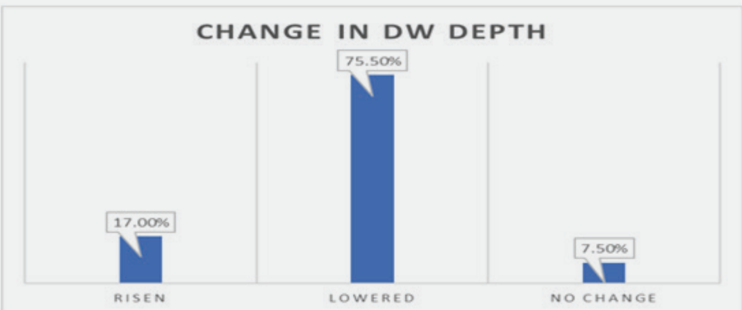


Figure 11. Change in Dug Well Depth from the Viewpoint of the Respondents

About 13% of respondents live within the radius of 500 metersand 86% within the radius of 1 km of the Gorano reservoir(Table 6). Many similar figures point to the Gorano pond's negative impactsthat have been grossly underestimated. The respondents who report an increase in the water table reside close to the reservoir and they say that it is a result of reservoir seepage. Whereas, the people who reporta reduction in groundwater live close to the pond and they thinkit is because of dewatering for mining operations.

Table 6. Distance from pond and an effect on groundwater table

Indicator	Response options	Response (%)
Distance of Gorano Reservoir from dug well	Less than 300 Meters	6.1%
	500 Meters	7.6%
	1 Kilometer	10.6%
	More than 1 Kilometer	75.8%
Ground water level lowered	Less than 5ft	84.3%
	5ft – 10ft	8.7%
	More than 10ft	7%

Views of a community member from village Ehsan Shah Jo Tar:

"In the radius of 5 to 8 km near mining sites, water table has gone down and the pumped water is brackish. In the 2 to 3 km radius of the Gorano reservoir, the water table has gone up and has become brackish due to saline water disposal. There are visible signs of salt on the soil surface near the pond which was not the case before. Trees in the vicinity are dying. My own well has become saline. My tenants have started using water from a well that is one km away."

Approximately 97% of respondents think that coal mining is impacting groundwater and 91% hold that it is the main cause of declining water table (Figure 12). This is a testimonial from more than 200 households that live close to coal mining sites about how mining affects extremely important groundwater supplies (Annex-II).

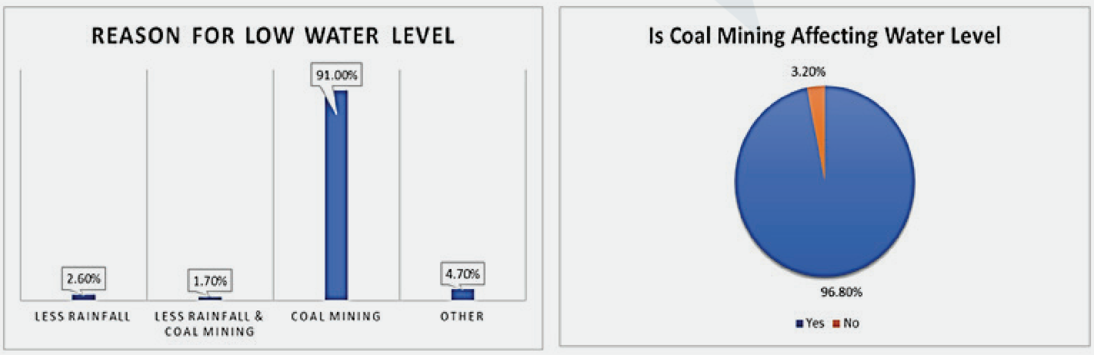


Figure 12. Reason for Lowered Water Table and Coal Mining Affecting Water Level

None of the people interviewed use water from the Goranoreservoir-- as 96% people believe it is not fit for use(Table 7).Around 99.3% are of the view that the Goranoreservoir water is not better than dug well water. Further, 98% of respondents believe that the reservoir water is saltier than dug well. This may be true because the source of the Goranoreservoir water is coal mining dewatering. It is water from deep aquifer that is more brackish than top aquifer that is recharged by rainwater.

Table 7. Quality and usage of water from Gorano Reservoir

Indicator	Response options	Response(%)
Do you use water from Gorano Reservoir?	Yes	0(%)
	No	100(%)
How fit is Gorano Reservoir water for use?	To Large Extent	0(%)
	To Some Extent	4.2(%)
	Not Fit	95.8(%)
Is Gorano Reservoir water better than dug well water?	Yes	0.07(%)
	No	99.3(%)
If no, why?	Saltier	97.9(%)
	Smellier	0.7(%)
	Saltier and Smellier	1.4(%)

According to several groundwater studies conducted outside of mining sites, there is no imminent damage to the groundwater supplies. However, dewatering is causing water levels in nearby dug wells in the Thar desert to drop by 5 feet (1.5 meters) [22, 35, 37]. Also, the model studies predict reduced availability of groundwater in the long term [35, 37].

Some 61% of respondents' family members share the responsibility of fetching water. This reflects the level of effort needed to bring water for their household consumption. Fifty percent of respondents reveal that they spend less than an hour and 35% spend 1-2 hours to get water home (Table 8). About 91% of them say that they have changed their water fetching time. 81% of the interviewed people say that the time for water fetching has increased, which is a testimony of the lowered groundwater table.

Table 8. The responsibility to fetch water and the time required

Indicator		Respondents (%)
Who is responsible for fetching water?	Male	14.3%
	Female	2%
	Male & Female	20.4%
	Children	2%
	All family members	61.2%
Time spent fetching water	Less than 1 hour	49.6%
	1 – 2 hours	34.8%
	More than 2 hours	15.6%
Change in time for fetching water	Yes	90.9%
	No	9.1%
Increase or decrease in time for water fetching	Time has reduced	9.7%
	Time has Increased	81.4%
	No change	9%

Roughly 63% of respondents say their water fetching time has increasedby less than 30 minutes, 11%say it is taking one extra hour to bring water home for use, and 27% report that their time has increased by 30 minutesto an hour. Explaining the reasons behind the increase in time, about two-thirds say that it is because the water level has fallen.Another 6% feel that theirhousehold's water needs have increased and 19% think that the water sources have been destroyed.

Views of a community member from village Tharyo Halepoto:

"Usually, in summers, water level in dug wells goes down. It is going down faster now than ever before. Because the people in the village have installed submersible pumps, our access to water from dug well has shrunk. The mining site is about 3 km away. The dug wells are as deep as 180-190 feet and submersible pumps are installed at 210-220 feet. In a village of 400 households, there are 100 submersible pumps. Out of 100, 20 are working and others have become dysfunctional due to the fall in water table and dewatering for coal mining. Water table has easily gone down by about 20-25 feet.

Though we cannot really sense the taste of water changing, our tea and daal are tasting different because of the deteriorating water quality."

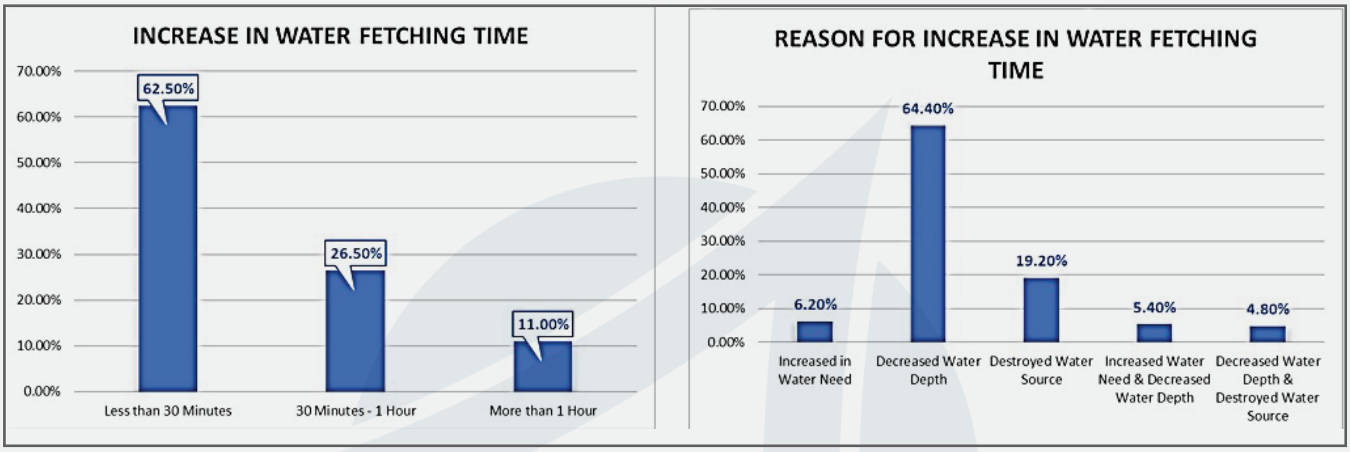


Figure 13. Reasons for increase in water fetching time

Because of pastoral economy, livestock has always been the primary source of income and life insurance in Thar. After the seasonal rains, the desert usually turns lush green and provides an abundance of food for animals to thrive on. During the research, every household had an average of 40 animals. Approximately 86% of people reported a decrease in the number of animals. According to 38% of the homes, the primary causes for decline in number of livestock is a lack of water, an increase in sickness, and a drop in fodder (Table 9). The coal project will also reduce the stretch of animal grazing land.

Table 9. The total animals and the change in number

Indicator		Response
Total animals	Mean	40
	Median	27
	Range	0 – 273
Change in number of animals	Increased	0%
	Decreased	85.7%
	No change	14.3%
Reason for decrease in number of animals	Shortage of water & poor water quality	11%
	Shortage of water, increase in diseases & decrease in livestock food	38%
	Poor water quality, increase in diseases & decrease in livestock food	14%
	Increase in diseases & decrease in livestock food	26%
	All the above reasons	11%

4.3. **Analysis of Collected Groundwater Samples**

Samples of groundwater was collected from TCB I and II areas to study major ion ranges. Names of the villages from where sample were collected are provided in Annex-III and analysis along with their averages are provided in **Table 10**.

According to National Environmental Quality Standards (NEQS) and WHO recommendations, drinking water should have a pH of 6.5 to 8.5. The pH measurement of the sample shows the groundwater is slightly acidic to alkaline in nature. The range of the value is 7 to 8.1, with a mean of 7.4. All the samples fall within the WHO standard range. Mahessar et al. (2019) state that although the key criterion used to assess the quality of water is pH, it has no direct negative effects on health [38].

Instead, the primary factor used to assess the quality of drinking water is electrical conductivity (EC). The average EC values are 6320.5 µS/cm, which is high compared to the WHO standard. Higher EC levels make it easier for groundwater to dissolve minerals, which makes it harder for plants to compete with the soil solution. Similarly, increased dissolved salt concentrations add a mineral taste to water and discolor it as well.

The breakdown of evaporating material found in surface sediments may be the cause of the total dissolved solids (TDS) excess level. The analyzed mean range of the TDS were 4045.1 milligrams per liter (mg/l), which is also the higher value than 1500 mg/l. Consequently, high TDS concentrations are typically caused by the natural minerals found in rocks. The samples with TDS levels over 3000 mg/l tasted either brackish or salty.

In 2022, Samtio et al. reported a similar tendency in EC and TDS concentration in the groundwater of District Tharparkar. The high quantity of TDS degrades the drinking water quality in the studied location [41].

Calcium and magnesium concentrations range from 80 to 650 and 29 to 1600 mg/l, respectively, with an average value of 338.73 to 189.9 mg/l, mostly due to carbonate minerals. The sodium and potassium concentrations range from 20 to 2800 and 3 to 40 mg/l, respectively, with a mean concentration of 906 and 20.4 mg/l. The sodium content is over the allowable limit. Excess sodium (Na) and potassium (K) readings result from the lithology of sodium and potassium-containing country rocks.

Chloride (Cl-) and sulfate (SO4) values range from 160 to 2400 mg/l and 150 to 1900 mg/l, respectively, with a mean concentration of 1168.9 and 984.3 mg/l. The increased Cl- and SO4 levels are caused by the dissolution of sulfate-bearing minerals and halite. Patients suffering from dyspepsia or renal problems should avoid drinking water with a higher chloride percentage. However, SO4 concentrations that are much higher than WHO recommended values can induce diarrhea and gastrointestinal issues, as well as have a laxative effect. They also add an unpleasant taste to the water.

With a mean concentration of 3.6 mg/l, the nitrate (NO_3) concentration ranges from 0.08 to 8.3 mg/l. One of the main problems that is faced during research on water quality is the nitrate pollution present in the groundwater, since nitrate nitrogen is the oxidized form of the element. High nitrate levels in groundwater are a significant issue in many parts of the world. The biosphere contributes to the nitrogen content in groundwater. Initially captured from the atmosphere, nitrogen is converted into ammonia by soil microbes. The high levels of nitrate in drinking water are harmful and lead to stomach cancer and blue baby illness, which affects youngsters and cause methemoglobinemia, a rare blood disorder that affects delivery of oxygen throughout the body by the red blood cells.

The amount of calcium and magnesium ions in water is measured as total hardness (TH), which is represented by the symbol $CaCO_3$. While iron, strontium, and manganese can also contribute to hardness, calcium and magnesium are the most prevalent cations. Calcium, which dissolves in water, is present in rocks and soils. TH concentrations in the groundwater samples varied from 320 to 3400 mg/l. Contemporary finishes with 500 mg/l or over the limit of total water hardness causes the production of scale in pipes, whereas less than 100 mg/l of total hardness can cause the pH of the water to drop and make the water corrosive. Hard water usage can result in gastrointestinal problems, renal or bladder problems, and urinary tract problems in people.

With reference to the WHO recommendation, the maximum permitted quantity of fluoride in drinking water is 1.5 mg/l. As per the findings of the analysis, fluoride levels vary from 0.58 to 1.8 mg/l with an average value of 1.2 mg/l. At concentrations below 1 mg/l, fluoride is a crucial element that strengthens skeletal tissues and teeth, whereas higher amounts above 1.5 mg/l cause renal and neurological diseases as well as dental and skeletal fluorosis.

Table 10. Results of groundwater quality parameters (Units of all parameters are mg/l, except pH, electrical conductivity (EC) µS/cm)

Parameters	Minimum	Maximum	Mean	WHO standards
EC	1195	13740	6320.5	1500
TDS	765	8794	4045.1	1000
pH	7	8.1	7.4	6.5-8.5
Cl-	160	2400	1168.9	250
SO4	150	1900	984.3	250
Ca	80	650	339	150
Mg	29	1600	190	100
Hardness	320	3400	1437.5	500
Na	20	2800	906	200
K	3	40	20.4	12
NO3	0.08	8.3	3.6	12
F	0.58	1.8	1.2	1.5

4.4. Groundwater Quality - Comparison of Current Analysis with Previous Data

Water samples were taken to access hydrogeochemical parameters (the groundwater quality and its chemical characteristics). The results were compared with earlier investigations conducted in 2019–2021.

As seen in **Figure 14**, the findings of the comparison show that the water contains salinity, total dissolved solids, chlorides, sulfates, hardness, sodium, and potassium in excess of acceptable levels established by the World Health Organization and American Public Health Association.

This indicates that the groundwater at present is not suitable for human and livestock consumption without treatment. Comparatively, the Electrical conductivity of water has increased six times in three years, while chlorides, sulphates, nitrates, calcium, magnesium, hardness, and potassium have increased more than five times.

The increasing ranges of above-mentioned chemical parameters, particularly from the waste of mining areas, are caused by the increasing levels of dissolved minerals, mainly sodium and chloride. An increase in the concentration of toxic metals, such as copper, lead, zinc, mercury, arsenic and chromium, is also the reason behind the rise in these ranges.

Furthermore, in view of the fact that these increases are consistent with increased incidences of water poisoning, it is necessary to address the issue in accordance with existing laws and regulations.

Coal-fired power plants release carbon dioxide (CO2), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM), and unburned carbon (UC). These compounds are all harmful to the environment. As greenhouse gases, CO2 and NOx are to be blamed for global warming. SOx and NOx cause acid rain, which damages plants and human health. Lung illness is a result of particulate particles. These pollutants degrade the quality of land, soil, and air.

Additionally, due to the use of coal for power generation and open cast mining, discharged waste is deposited in the low-lying areas between dunes. These activities are harmful and unsustainable for local environment and people. The dug well's aquifer has already undergone many cycles of monsoon stress and recharge. To protect the Thar region's water supplies, the aquifer beneath the dug wells needs to be closely monitored. Similarly, to prevent over-exploitation of the Thar region's water resources, the primary authorities must monitor the low-lying regions between dunes and regulate the mining requirements.

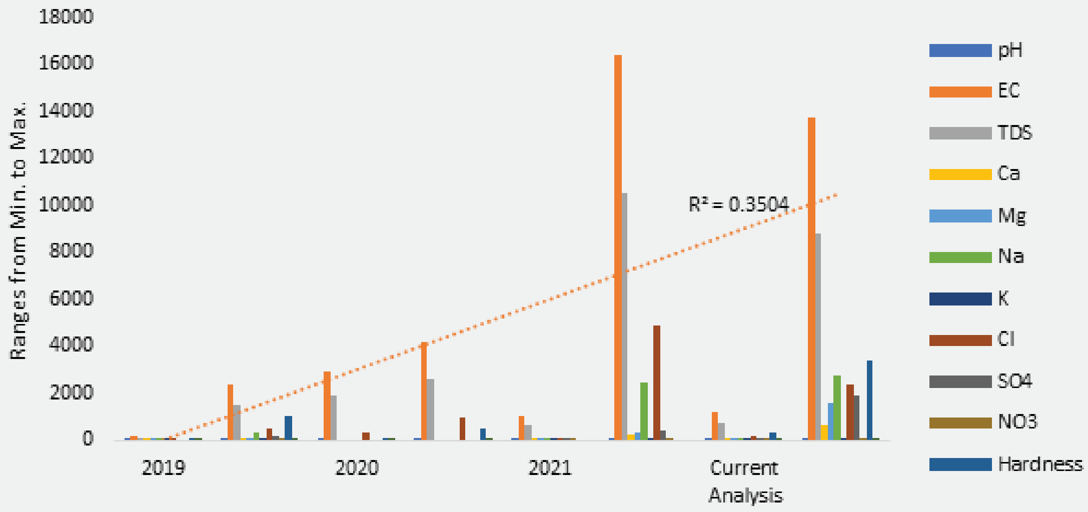


Figure 14. Comparison of the analysis of Hydrogeochemical parameters with published data - 2019 to 2021 [29, 39-40]

4.5. **Health Assessment**

The contamination of water from coal mining and power plant activities has increased many diseases among the people living in these areas. Figure 15 shows various ailments in the population n = 190.

The survey revealed that the residents in the region under research have a high rate of gastroenteritis. Other ailments prevalent in the area include kidney illness, hepatitis, high blood pressure, cardiovascular disease, cancer, bone discomfort, and skin disorders. Consumption of contaminated groundwater, collected from a community well every day, poses a grave risk to communities. They are unaware that the water is contaminated.

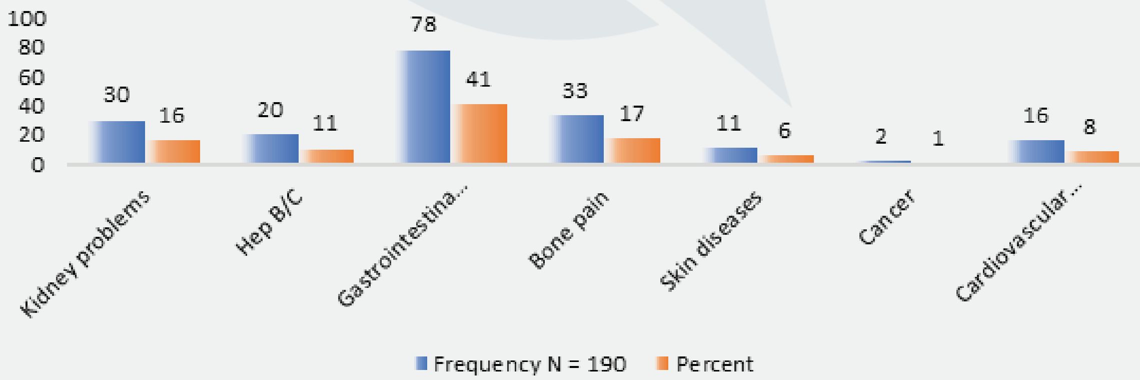


Figure 15. Health Concerns in the Study Area

4.6. **Water Balance and Impact Assessment of Groundwater Extraction**

It is estimated that the volume of water obtained from dewatering of coal mines was insufficient for the Thar power plants. The deficit in water demand for thermal plants is estimated at 83 GLpa at five years of mining operation. The deficit will be reduced to 45 GLpa after 25 years of mining operations. The detailed values are given in Figure 16.

The mine demand for water is 6.6 GLpa. When the demand of a mine is subtracted from its dewatered volume, then raw water volume stands at 76, 53 and 38 GLpa during 5, 15, and 25 years of mine operation, respectively. The dewatering from second and third aquifers has resulted in a drawdown of the water table and has impacted extraction of water from lower aquifers through tube wells for nearby villages. Nergis et al. observe that the water level in community wells surrounding Block II lowered between 2015 and 2017 [22].

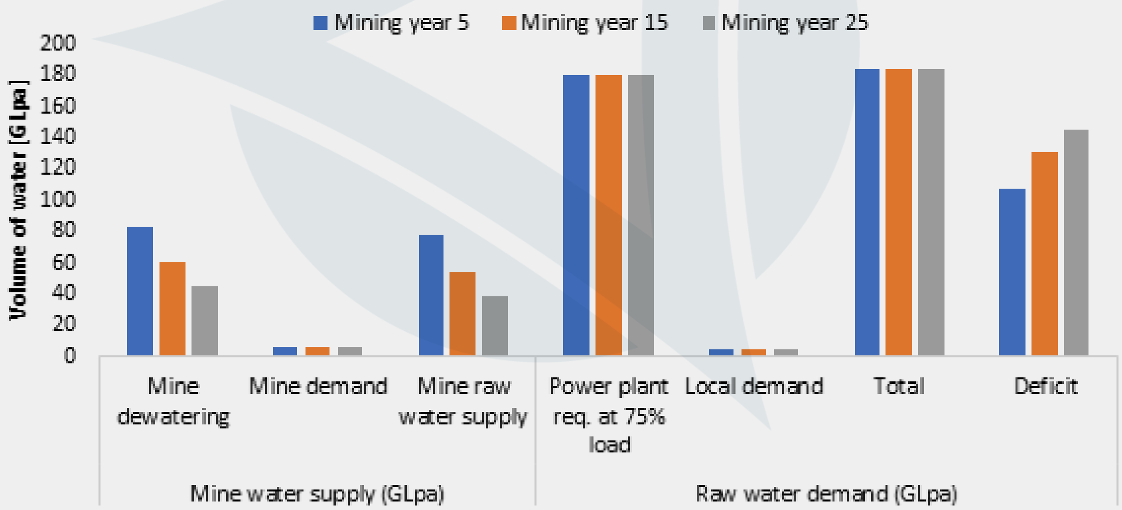


Figure 16. Water Balance for Thar coalfields

Thar power plants require plenty of water for its operation. Currently, this requirement is being met by extracting groundwater. The extraction of groundwater is impacting lives of the Thari people by changing the aquifer balance. This impact cannot be quantified through surveys or field investigations, owing to the large area and hydrogeological complexities.

As a result, this is a replication of some earlier work that used computer models to assess the consequences of groundwater extraction close to a coalfield, i.e., the Numerical Groundwater Modelling Report, Thar Coalfield Water Master Plan – carried out by Williams Sales Partnership (WSP) UK Limited in 2017; the Hydro-geological exploration study of Thar Coalfield Block I, Pakistan – by Northeast Coalfield; the Geological Survey Bureau Exploration Design Institute in 2012; Modeling Hydro-ecological Impact of Thar Coal Produced Water by Hadiqa Maqsood from Mehran University of Engineering and Technology and Shoaib Ahmed from NED University of Engineering and Technology in 2012; and the Thar Block II Coal Mining Project, Bankable Feasibility Study by RWE in 2010.

Three aquifers have been identified in Thar. The first two aquifers are unconfined and discontinuous or perched aquifers while the third aquifer is confined and has a high pressure which can be detrimental, if it is not depressurized. The information on the behavior of aquifers in the Thar coalfield area is summarized in **Tables 11 and 12**.

Table 11. Types of aquifers in Thar

Aquifers in Thar	Description
Type 1: Dune sand aquifer	The dune sand is 55 to 80 meters thick in the mining area. The dune sand aquifer is a perched, discontinuous aquifer with a saturation thickness varying from 1 to 5 meters. Aquifer transmissivity varies from 270 to 430 square meters per day. In the mining region, the thickness of sub-recent alluvium ranges from 30 to 90 meters, with the thinnest blocks in the northeast (Block V) and the thickest blocks in the south and southeast (Block II and Block VIII). It has low permeability and limited capacity for groundwater storage.
Type 2: Coal seam roof aquifer	The unit's thickness varies in the mining area, which is usually between 5 and 15 meters thick. Transmissivity values, which is the rate at which water passes through the aquifer's unit width under a unit hydraulic gradient, are in the range of 90 to 160 square meters per day. Coal/lignite-bearing strata varies from around 30 to 100 meters in thickness. It acts as an aquitard between the two main aquifer units.
Type 3: Coal seam floor aquifer	Located about 20 meters nearest to the Rann of Kutch and Thar Faults, this has a thickening to over 150 meters in the mining area around Block V and Block VII. Transmissivity values are in the range of 225 to 2,140 square meters per day.
How are these aquifers recharged?	About 300 millimeter water per year is recharged to layer 1. This is 2% of mean annual rainfall that Thar receives. Layers 2 and 4 are aquitards that store groundwater and transmit it slowly from one aquifer to another, whereas layers 3 and 5 are confined aquifer. For layer 3, the head of +3 to +20 meters above mean sea level (AMSL) is applied. For layer 5, a head of +15 to +40 m AMSL is applied.
How water discharges from these aquifers?	The total water flow through layers 1, 3 and 5 is estimated as 420 liters per second.

Table 12. Properties of the five layers of aquifers in Thar (retrieved from previous models)

Layers	Horizontal hydraulic conductivity[1]	Vertical hydraulic conductivity	Specific yield[2] (Unconfined, transient only)	Specific storage[3] (confined, transient only)
Layer 1: Dune sand aquifer	1.8 meter/day	1.8 meter/day	0.15 meter/day	-
Layer 2: Sub-recent alluvium	0.00001 meter /day	0.00001 meter /day	-	0.00001 meter/day
Layer 3: Coal Seam Roof aquifer	20 meter/day	2 meter/day	-	0.0001 meter/day
Layer 4: Coal/lignite strata	0.00001 meter/day	0.00001 meter/day	-	0.00001 meter/day
Layer 5: Coal Seam Floor aquifer	20 meter/day	2 meter/day	-	0.0001 meter/day

The volume of water that is to be dewatered from the first two aquifers is lower compared to the third aquifer. Modeling of the impact of groundwater extraction for mining and plant operation on water availability in short- and long-term can be seen in **Annex 1** and **Figures 24-26**.

[1] Hydraulic conductivity of the material can be defined as the ability of the fluid to pass through the pores and fractured rocks: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/hydraulic-conductivity

[2] Specific yield is defined as the average volume of water that can be drained, per unit surface of aquifer per unit drop of head: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018WR022938

[3] The specific storage is defined as the volume of water that is released from (or added to) storage per unit volume of saturated material: https://books.gw-project.org/hydrogeologic-properties-of-earth-materials-and-principles-of-groundwater-flow/chapter/properties-of-aquifers-and-confining-units/

CHAPTER 05

DISPOSAL OF WASTEWATER DISCHARGED FROM COAL MINES AND POWER PLANTS

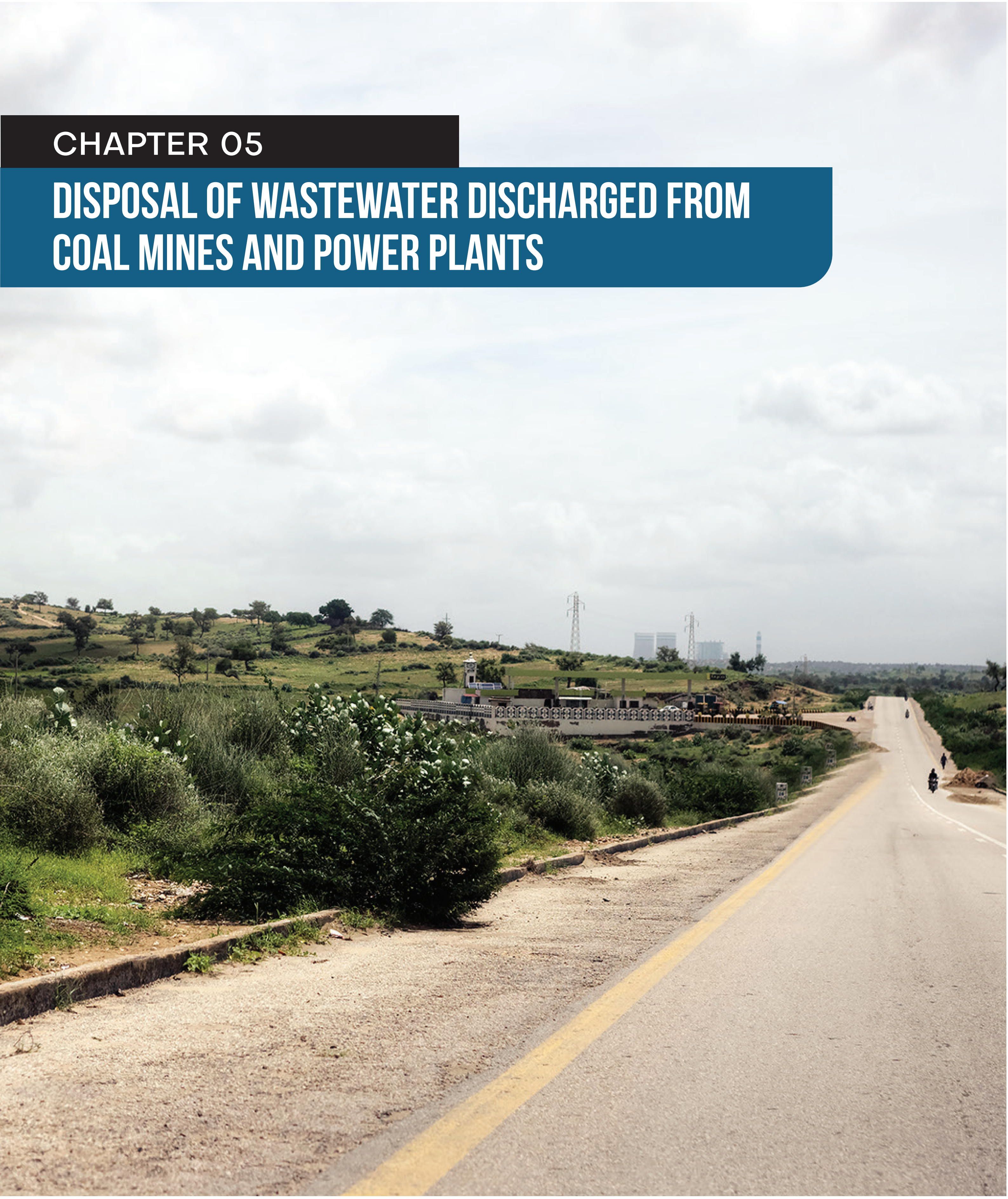


Photo credit: Kohi Marri

Disposal of Wastewater from Coal Mines and Power Plant

The coal power plant produces recurrent and incidental wastewater. The recurrent wastewater consists of ultra-filtration backwash drainage, thick water, which is acid alkali wastewater of the boiler make-up water treatment system. It also release desulfurized wastewater that is alkali wastewater of condensate polishing. The incidental wastewater includes rinse water of air pre-heater and chemical washing wastewater.

The mining waste, called Acid Mine Drainage (AMD), is highly toxic. It contains heavy toxic metals such as arsenic, cadmium, cobalt, nickel, iron, copper, and lead, which are carried into streams and groundwater, causing contamination in aquifers.

The water samples with higher values of TDS and SO4 taken from the area possessed heavier metals. So, as a result of AMD, surface water (rainwater and pond water), shallow subsurface water, and rocks, which contain sulfur-bearing minerals, combine chemically to form sulfuric acid. Due to bacteria, the process of heavy metal leaching from acid-contacting rocks significantly speeds up. The fluids from this are extremely hazardous and likely to harm people, animals, and plants when combined with soil, groundwater, and surface water [41, 42].

Highlight

Acid Mine Drainage, which is the waste from coal mines, contains toxic heavy metals including arsenic and lead that are carried into streams and groundwater, causing contamination.

Operating coal-dependent thermal plants is not the most affordable way to provide power especially because the cost of renewable energy sources is decreasing. The construction of more efficient plants will result in a smaller contribution to greenhouse gas emissions. Any legislation that Pakistan will promulgate in the coming months and years to mitigate the disastrous impacts of climate change will, in any case, limit generation of power from sources that contribute to these gases. This is true even if the long-delayed environmental standards are not implemented in the case of coal-fired power plants.

If, by ignoring the two arguments mentioned above, any additional coal-based energy generating facilities are still constructed in the area, the health of the neighboring population will suffer considerably. Centre for Research on Energy and Clean Air (CREA) disclosed the average number of deaths expected from these coal mining and power plant activities in Thar. Some 29,352 fatalities on average are expected per pollutant over a period of 30 years due to these activities in the region [35]. Moreover, about 12,458 cases of ischemic heart disease and 39,515 asthma emergency room visits (by children and adults) indicate the severity of these two main health problems [35].

As the residents of Thar continue to suffer, there is still no consensus on proper disposal of wastewater released from the coal mine and power plant in TCB-I. According to a few respondents, effluents would be disposed of in a planned reservoir in Dukkar Chaou. Others, however, believe that TCB-I will use the Gorano reservoir to discharge wastewater and that more water won't be released into the projected Dukkar Chaou reservoir until the Gorano reservoir reaches capacity.

Loss of life
29,352

is the average number of fatalities per pollutant expected over 30 years from coal mining and power plant activities in Thar.

Making matters worse for the residents, the government authorities have walled off the entire site of Block-I to prevent the locals from accessing the area. According to a study carried out by Pakistan Fisherfolk Forum in September 2020, grazing space for some 20,000 animals of the locals has been blocked with an iron fence around the TCB-I mining site [50]. Another report published in Dawn in 2022 states that SSRL started dumping wastewater on the grazing pastures of two TCB-I neighboring villages, Tilwaiyo and Warwai, in October 2021. In Tilwaiyo, a sweet water dug well has been contaminated.

In TCB-II, wastewater from the power plant is 1000 m3/day. The SECMC claims that some wastewater that is re-injected into the third aquifer will be treated and used for dust suppression. However, the exact volume of wastewater to be injected is not known.

The waste consists of sewage from the mine service area (370 m3/day), sewage from the township (500 m3/day), and oily water from the main service area (160 m3/day). A pipeline has been laid from the mining of Block-II to Meghay Jo Tar village, where a plant for water reinjection has already been built. Across the world, treated water is injected into aquifers to avoid degradation of groundwater. But, in Thar, contaminated water is injected into aquifers to pollute groundwater [51].

According to SECMC, a small volume of water is reinjected into the third layer of the aquifer, and it does not impact the aquifer used by the local people for drinking water. The SECMC authorities claim that drained water comes from the second and third aquifers, which are 120 meters and 180 meters deep, respectively, and has no impact on the top 55 meters deep aquifer, which is utilized for drinking water by the local population.

However, the dewatering at the site caused a decrease in the water table of the first aquifer in the surrounding area of TCB-II, i.e., along the vertical axis, varying from 48 to 90 m in depth [49].

The disposal of brine and wastewater has also spoilt the first aquifer's water quality, and environment and social life of Tharis. Cases of malaria have shot up in areas surrounding the wastewater reservoirs. Animals are dying because of ingesting wastewater discharged by coal mines and power plants. The water level of drilled wells near the coal mines is dropping (details in Annex-II).

5.1. Economic Costs of Wastewater Disposal

Around the world, waste disposal system is used as an approach for pollution control, which must comply with regulations regarding its design, location, and operation. The TCB-II is expected to create roughly 156,000 tons of hazardous waste, but the authorities are yet to complete their work on building a wastewater disposal system.

Back in 2017, the government of Sindh authorized a plan worth PKR 3,250.150 million to build a reverse osmosis pre-treatment system. The Thar Coal project was to receive water through the Left Bank Outfall Drain (LBOD) after being lifted from its RD-362 near Jhuddo settlement of Mirpur Khas and treated at the Nabisar reservoir. The project is ongoing since a decade with no completion in sight. SECMC, an independent power producer (IPP) and the commercial partner in this joint venture with the Sindh government, planned to lay a pipeline to supply water. However, Dawn reported on November 10, 2021, that this was delayed due to technical difficulties [52].

Unfortunately, the information collected from reports, surveys, and interviews related to wastewater is inconsistent and does not corroborate. The only confirmed information available is that the industries are dumping wastewater into natural depressions and nearby towns rather than processing and disposing it in evaporation ponds or re-injecting it into the third aquifer. A comparison of reported produced by the companies and existing disposal methods is presented in **Table 13**.

Table 13. Comparison of reported by companies and existing disposal method

	Reported by companies		Existing
Requirements / effect	**Evaporation pond**	**Re-injection into Groundwater aquifer**	**Villager's land / natural depressions**
Land requirement	✓	✓	✓
Conveyance system	✓	✓	✓
Possibility of groundwater recharge		✓	✓
Economical			✓
Less skilled labor required			✓
Skilled labor required	✓	✓	
Treatment	✓	✓	
Possibility of available groundwater's contamination		✓	✓
High operational and maintenance cost	✓	✓	

Submerging the lands of these villages with untreated wastewater is the most cost-effective solution for companies. However, in contrast to the reinjection method, this one requires extensive land. Both the methods recharge the confined aquifer.

A survey revealed that the SSRL started dumping wastewater on the grazing land of villages Tilwaiyo and Warwai of TCB-I. The SECMC has been discharging wastewater from its plant in Bitra and Jaman Samoon villages, which has rendered water in dug wells unfit for use.

No matter which method the companies select, wastewater disposal is costly. Whether they do it by installing treatment plants, laying pipelines, establishing reservoirs, coating reservoirs with geo-membrane and soil sealant or by installing reinjection plants to operate and control pollution produced by coal mines and coal power stations. Although no labour is used to dump wastewater on village lands, all other methods require skilled labour along with high maintenance and operational costs. All methods also require a conveyance system.

CHAPTER 06

WATER DIVERSION FROM NARA CANAL TO THAR COALFIELD

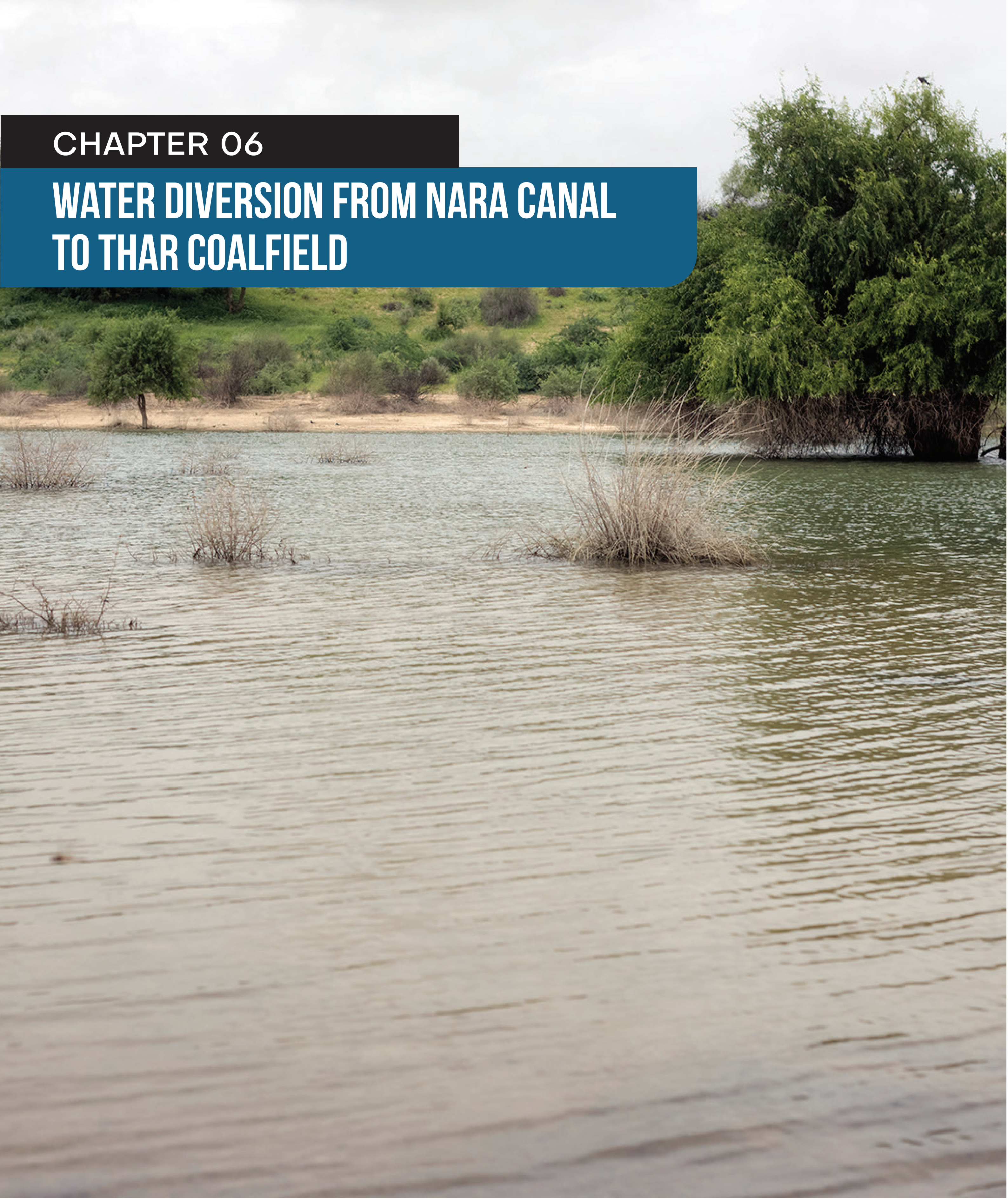


Photo credit: Kohi Marri

Diversion of Water from Nara Canal to Thar Coalfield

Being a lower riparian area of the Indus River system, Sindh frequently faces water shortage. The irrigation network and its distribution mechanism are unable to meet the irrigation demand of farmers.

The water demand for Thar coalfields is planned to be met by the existing lined water carrier canal from Makhi Farash Complex to Nabisar and a pumping-based piped supply system from Nabisar to Vijihar [46]. The diversion of surface water to Thar is expected to complicate the distribution of water from Nara Canal.

Nara Canal tail area is a chronic water shortage area, especially during the summer season when demand for water is at peak. The scarcity of water in Nara Canal has led many farmers to move out of this area. However, in the last few years, through better management of the tail end distributaries, Nara Canal is receiving more water than before.

In a situation where demand fails to meet the supply of water, the allocation of irrigation water to the Thar power plants is causing much unrest among the farming communities, especially those from the tail end of the Nara Canal system.

6.1. **Infrastructure Development**

The detailed description of the infrastructure developed for the diversion of water from Nara Canal at Farash Complex to Thar coal power plants through the water carrier (Figure 18) is as follows:

Concrete Thar Coal Water Carrier

The water carrier channel runs 61 km parallel to Hakro Dhoro, the main natural drainage carrier channel. The carrier channel lies in an area where a mild slope, parallel to Hakro Dhoro, allows water to be routed to Nabisar to feed Thar's coal storage ponds. The carrying capacity of the water carrier is 200 cusecs.

Currently, the requirement of TCB-II is 35 cusecs. But after the establishment of Block-V, the water demand will increase to 90 cusecs. Therefore, the maximum discharge of 200 cusecs will not be required to supply to Thar coal power plants in the coming years as it depends on the development of other blocks.

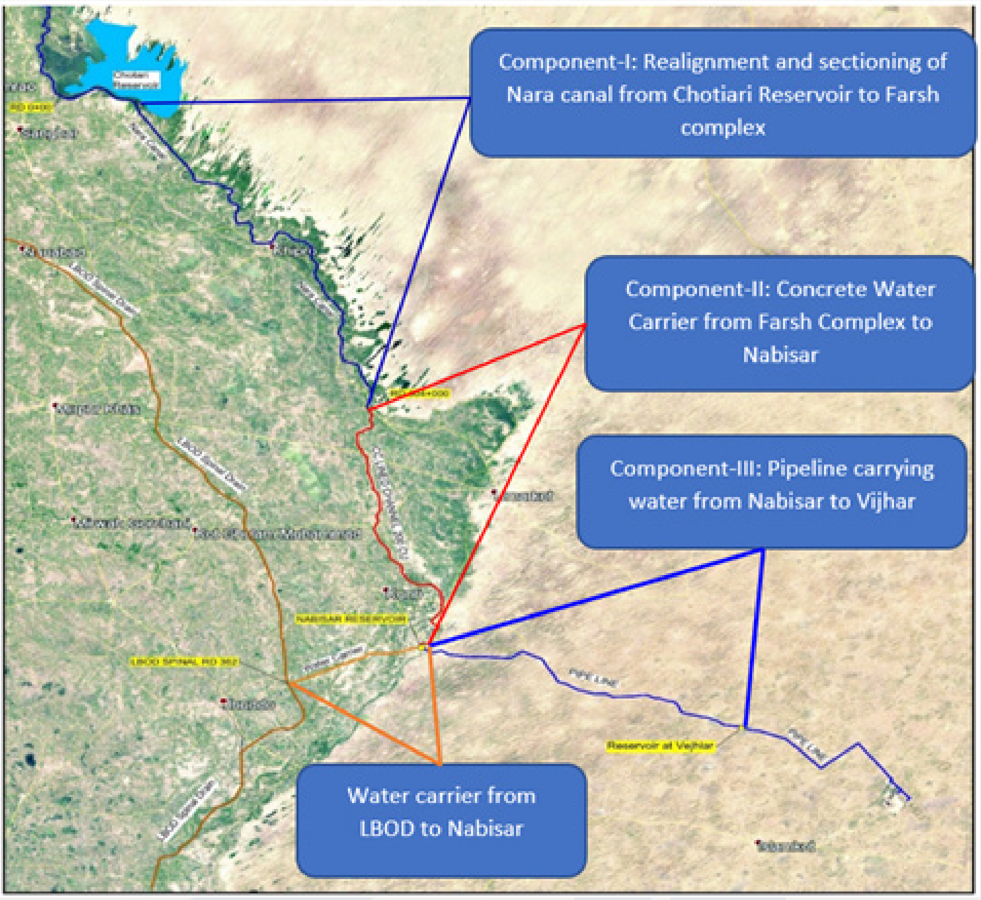


Figure 18. The map of the entire system carrying water from Nara Canal and LBOD to Nabisar water ponds and from Nabisar to Vijihar water ponds [47]

The total cost of this infrastructure development is PKR 12,111 million, which includes the cost of the water carrier channel and other associated infrastructure. Component-1 (PKR 6,213 million) of this development comprises earthwork of Makhi Farsh link canal, its CC lining, and structures like head and cross regulators of off-taking distributaries, road bridges and culverts, pipe outlets, etc. Whereas component-2 (PKR 5,897 million) includes the costs of Thar Coal Water Carrier and other associated costs of bridges, culverts, inlet and outlet structures, cross-regulators, drainage structures, siphons, pedestrian bridges, etc [48].

Water Treatment Facility for Supply to Power Plants

Another lined water carrier has been constructed by the Sindh Irrigation Department with a carrying capacity of 100 cusecs from spinal drain/LBOD at RD 362 to Nabisar, which will be supplied to Thar coal power plants through a pipeline after treatment at Nabisar. Two 26 km-long lined channels have been constructed. One channel is meant to transport water from LBOD to the water treatment facility at Nabisar, while the other to carry brine, produced after the treatment, back to LBOD. The treatment facility is associated with the 100 cusecs supply of saline water from LBOD to Nabisar.

To treat raw water from the existing LBOD, a water treatment facility has been constructed close to water ponds at Nabisar. Initially, the RO plant was designed on a single parameter i.e., 10,000 ppm TDS. Later, after the detailed analysis of LBOD water, it was revealed that without pre-treatment of LBOD water, RO would be incapable of handling other impurities (i.e., BOD and COD, etc.), and suspended solids present in LBOD water.

To address this issue, a Conventional Activated Sludge process was designed that failed to serve the purpose, thereafter the Membrane Bioreactor (MBR) technology was adopted to ensure smooth operation of the RO plant.

The capacity of this RO plant is 35 cusecs and it is meant to supply treated water to TCB-II. However, it is learned that the RO plant and other treatment facilities at Nabisar have not been utilized for the treatment of LBOD water so far. The total cost of this project is PKR 14,325 million, which covers the cost of building the lined channels, pumping stations, power stations, pre-treatment and treated water reservoirs at Nabisar, and other ancillary works, such as fencing, approach road, and water testing lab, etc. [49]

Pipeline from Nabisar to Vijihar

The length of pipelines from Nabisar to Vijihar is 62 km, with a capacity for 35 cusecs of water. The gradient from Nabisar to Vijihar is 72 meters and therefore, the water needs to be pumped. The pump house consists of four pumps of 450 horsepower. To meet the energy requirement, there is one powerhouse, comprising two generators with a capacity of 650 KW.

The cost of the infrastructure developed between Nabisar and Vijihar is around PKR 15,652 million. This includes the cost 62 km long pipeline, pumping station, power station, and other associated costs.

Pipeline from Vijihar to Thar Coalfield

There are two water reservoirs at Vijihar that keep the water stored till it is transported through another pipeline from Vijihar to the Thar coalfield.

6.2. **Water Diversion and Irrigation Rights of Farmers**

Volume of Canal Water Diverted for Coal-Fired Thermal Power Plants

The total requirement of water for all coal blocks to be developed under the Thar Coal Energy Generation Project is 300 cusecs. Out of 300 cusecs, 100 cusecs will be pumped from LBOD that will be treated through an ultra-filtration (RO) plant established at Nabisar. The other 200 cusecs water is planned to be diverted from the Nara Canal system at Farash Complex near Dhoro Naro, and will be transported to water ponds situated at Nabisar through the Thar Coal Water Carrier, as shown in Figure 19. This scheme has been designed to meet the long-term water requirement of the Thar coal power plants.

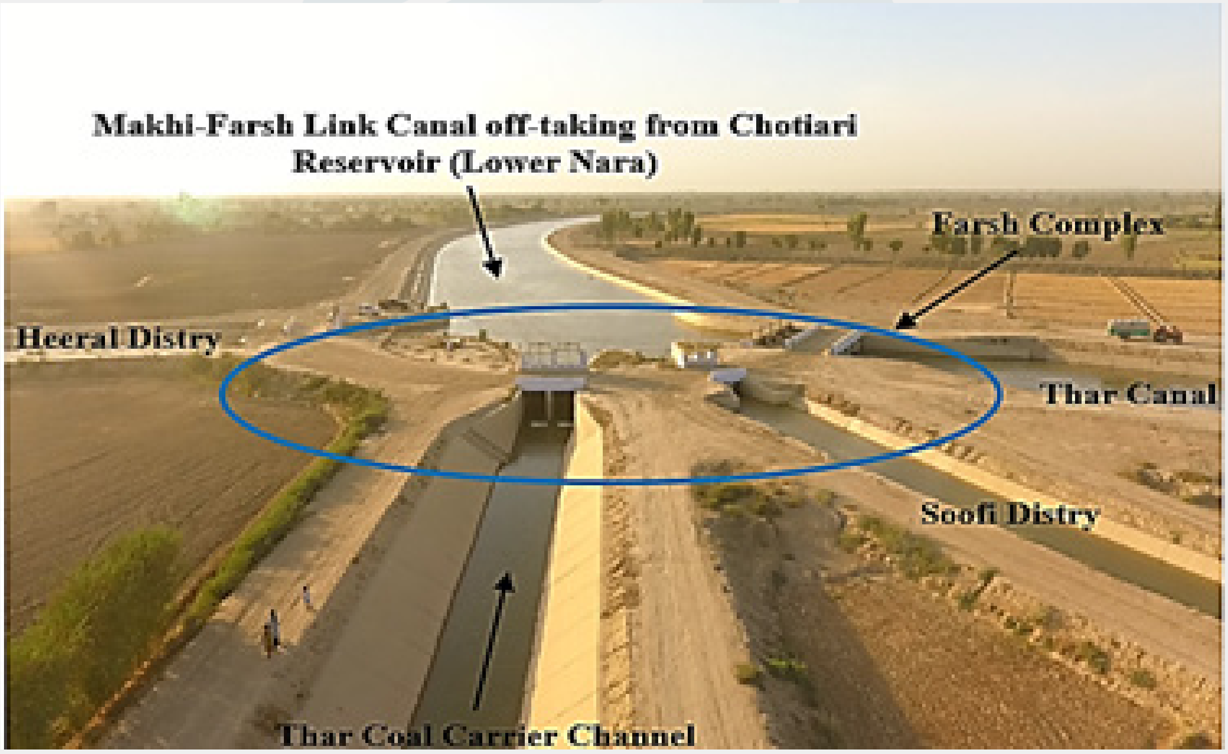


Figure 19. View of Farsh Complex [47]

Economic Implications of Water Shortage

There is a fear that the farming communities in the command area at lower Nara Canal, especially below Farash Complex, will face an irrigation water shortage once the irrigation water (200 cusecs) is diverted to the Thar coal power plants through water carrier channel. In addition to the concrete water carrier channel to supply water to Thar coal power plants, three other distributaries – Thar Canal, Sufi, and Heeral Distributary – take off from the Lower Nara at Makhi Farsh. Due to the heavy sediment load carried by the Nara-Makhi-Farsh canal, these distributaries suffer frequent silting and require regular dredging.

The command area of the three distributaries (almost 24,000 acres) is cultivated through 97 watercourses (23 WCs on Thar Canal, 34 on Sufi and 40 on Heeral distributary). It is feared that because of diversion of 200 cusecs of irrigation water to Thar coal power plants, the cultivation on 24,000 acres of land will be highly compromised, aggravating water scarcity, loss of farmers' livelihood, and worsening of food security.

According to the Sindh government, improving conveyance efficiency through the realignment and re-sectioning of lower Nara Canal between Makhi weir and Farash regulator and the lining of the water distributaries will conserve water. Therefore, it is believed that the shortage of water in irrigation systems due to the diversion of water from irrigation systems to Thar coal power plants will be compensated with improved conveyance efficiency.

Although farmers have not faced any issue related to water shortage so far, they fear that once the water is diverted to Thar coal water carrier, then conflicts and tensions will build among water users. Currently, farmers are expecting to get more water because the canal is lined, and are hoping to expand their irrigated land if water is freely available. For instance, farmers at the tail end of the Thar canal and Sufi distributary experienced a good flow of water during the Rabi season of 2021. But when the total amount of water, which is 200 cusecs, is diverted to Thar coal power plants in future, it may cause water shortage in the area.

The most vulnerable farming communities are those who own agricultural land at the tail end of Thar Wah, the tail of Thar canal and the mid and tail of Sufi distributary. Given the limited availability of water to them at present, they are extremely skeptical about the situation of water in future.

Areas Affected by Diversion of Water

Land acquisition issues have also cropped up in the area where lower Nara Canal was realigned to fix the curve in Nara Canal.

From Farash Complex, the Thar water carrier has been constructed alongside the Dhoro Puraan (a water drain) till Nabisar, without having any issue related to land acquisition. This is because it was constructed on the public land i.e., the land owned by the irrigation department but not on the privately owned land. Other canals taking off from Farash Complex are either lined or the work is in progress without harming any community living along those canals. Therefore, this development has no direct impact on the community.

Canal Water Diversion – The Legal Aspect

The legal aspect of diverting water from irrigation to non-irrigation purpose, i.e. Thar coal power plants, is unclear. It has not been defined or documented in the apportionment records of water. Logically speaking, the farmers and other water users living in the Nara Canal command area, especially in the lower Nara Canal area, have rights to water in the system.

The distributaries and watercourses have predefined water allocations, based on the demand of the command area. In contrast, the share of water to the Thar carrier has yet to be allocated from Nara Canal head.

Under the current circumstances, it seems that the Nara Canal will continue to receive the same volume of water as before. It means that the distributaries in the command area must sacrifice their due share of water for Thar coal power plants. Consequently, the irrigation rights of the farmers will be compromised.

To justify the water diversion to Thar coal power plants, the mega project of the lining of canals, realigning and re-sectioning of lower Nara Canal was initiated to improve the capacity, performance, efficiency, and reliability of the systems. Therefore, the government is reasoning that the improved efficiency will cater to the demand of the existing users and the Thar coal

6.3. **Water Diversion Carrier's Technical and Social Implications**

Technically, the water carrier between Farash Complex and Nabisar has been designed and constructed keeping the farmers' rights under consideration. Farmers were taken into confidence and their concerns were addressed. Pedestrian bridges, road bridges to connect both sides, and drainage facilities have been provided to the communities.

The construction of the 60 to 62 km-long water carrier from Farash Complex to Nabisar has divided the communities living on either side of the carrier. These inconveniences were taken into consideration while constructing the water carrier. Several bridges have been constructed over the water carrier to connect communities living on both sides of the water carrier.

Potential Risks of Drainage and Flooding

Prior to the development of the Thar water carrier, the farmers settled along Farash Complex and Nabisar used to discharge water into Dhoro Puraan (drain). Farmers also used water from the drain in case water became scarce for irrigation. However, after the construction of the Thar water carrier, the natural drainage lines on left side of the drain have been blocked, barring farmers from either using or discharging water into it. The water carrier's construction has also increased the risk of flooding.

The irrigation department has addressed some of these concerns through different infrastructure development, including inlets as shown in Figure 20. However, the risk can exacerbate in late monsoon season, when the Kharif crop, especially cotton, is ready to be harvested.

Figure 20. Infrastructure developed along the water carrier channel [47]

Potential Flooding Risks at Vijihar

Water is pumped from Nabisar and transported to Vijihar through a pipeline and is stored in two ponds close to Vijihar settlements. These ponds are excavated ponds and are at a slightly lower elevation than the Vijihar settlement. Therefore, there is a low risk of flooding in the towns.

The community members living close to the pipeline report that pipeline leakages have flooded their villages in the past. But the concerned authorities were able to avert serious damages.

Based on this past experience, they fear that any malfunction in the pipeline carrying water to Vijihar ponds or from Vijihar to Thar coalfield may threaten their settlements.

Land Acquisition and Resettlement Issues

The land acquisition, resettlements, and payment of compensation have always remained an issue ever since the inception of Thar coal power projects and the developments associated with it. This is despite the authorities' claims that all the important issues have been addressed.

In terms of the water carrier's development, interestingly the process of acquiring land between Farash Complex and Nabisar by the Irrigation Department was smooth, as the carrier was constructed on public land along Dhoro Puraan. The department, however, faced issues in acquiring land in areas where Nara Canal was realigned to improve the conveyance efficiency and save water.

Figure 21. Pipeline Infrastructure from Nabisar to Vijihar. Source: authors

The communities settled between Nabisar and Vijihar report that although the authorities have installed the pipeline and constructed small structures on their land, as show in Figure 22, they have not been compensated. The underground pipeline on the Nabisar-Vijihar stretches across land of high commercial value.

6.4. **The Farmers' Perspective**

Farmers in the canal command area faced severe water crisis in 2022. Irrigation water was insufficient for the Kharif crops, especially cotton and sugarcane. They were unable to grow vegetables.

The water scarcity has exacerbated poverty and food insecurity, especially in lower Nara Canal areas. Sporadic measures taken by the authorities, such as deploying Rangers every now and then to check water theft, are unlikely to end peoples' miseries. A transparent and efficient allocation mechanism must be implemented to protect the local communities against any form of adversary. Also, diverting water from agriculture to non-agricultural use cannot be justified [50].

Impacts of Water Carrier on Neighboring Farmers

During the focus group discussion, farmers who own land on both sides of the channel, expressed that the elevated embankments of the water carrier restricts their movement. They say it is inconvenient and time consuming to cross the carrier via bridges built a kilometer away.

They are concerned about the blocking of inlets in case of rain and flood. They are apprehensive about possible structural faults and seepages from the carrier that may degrade the land quality.

Potential Water Scarcity in Future

The farmers at Sufi distributary, Thar Tail and Thar Wah distributary are well informed about the Thar coal water channel and the government's plan of water diversion (Figure 23). They point out issues pertaining to the current water crisis and worry that water diverted to Thar coal power plants may cause further shortage in future.

Poor and deprived farmers at the tail reaches, especially at Thar Wah, complain of receiving less water than others. They are able to cultivate only a few acres of their total land. Low crop yield and compromised agricultural practices have rendered them powerless and poor.

While the influential farmers can convince the irrigation department to maintain a slope in the irrigation channels to ensure better availability of water for them, the poorer ones remain disadvantaged, which often causes conflict between the influential and uninfluential farmers. The government has deployed Rangers in the area to maintain order.

Figure 22. Focus group discussion with farmers at tail end of Sufi and Thar Canal. Source: authors

Impacts of Pipeline and Reservoirs in Vijihar

Participants of the focus group discussions conducted in Thar villages, located along the Nabisar-Vinjhar pipeline, report that the pipeline has leaked twice in the past. They say that if similar incidents occur again in future, their houses, crops, and livestock will suffer immense harm. They cannot comprehend how fresh water is supplied to the Thar power projects when local villagers do not even have access to potable water.

6.5. **Environmental Implications**

During the flood season, the surplus flow of Dhoro Puraan is diverted to feed the downstream Shakoor Dhand (lake). With increasing water requirements of Thar coal power plants, the surplus water will be diverted to them instead of the lake.

Dhoro Puraan is a main source of freshwater to downstream lakes, especially Shakoor Dhand. The overall biodiversity of the lake predominantly depends on the flow and quality of water reaching the lake. It naturally creates a food web within and a life-sustaining ecosystem. If the volume of water allowed to flow into the lake is reduced, the quality of water will degrade, and adversely affect the ecosystems.

Impact on Fisherfolk

The infrastructure development in Thar is likely to impact the fisherfolk at Shakoor Dhand. Water diverted to the coalfields will needlessly destroy their livelihood.

Impact on Flora and Fauna

The Thar coal water carrier has restricted the in-land movement of wildlife across the carrier. Moreover, it is planned that the water carrier will be fenced on both sides, which will further restrict their movement. Also, during surplus flow, Dhoro Puraan used to serve as a carrier of fish to downstream lakes from Nara Canal. The built infrastructure will restrict this kind of natural movement.

CHAPTER 07

CONCLUSION AND RECOMMENDATIONS

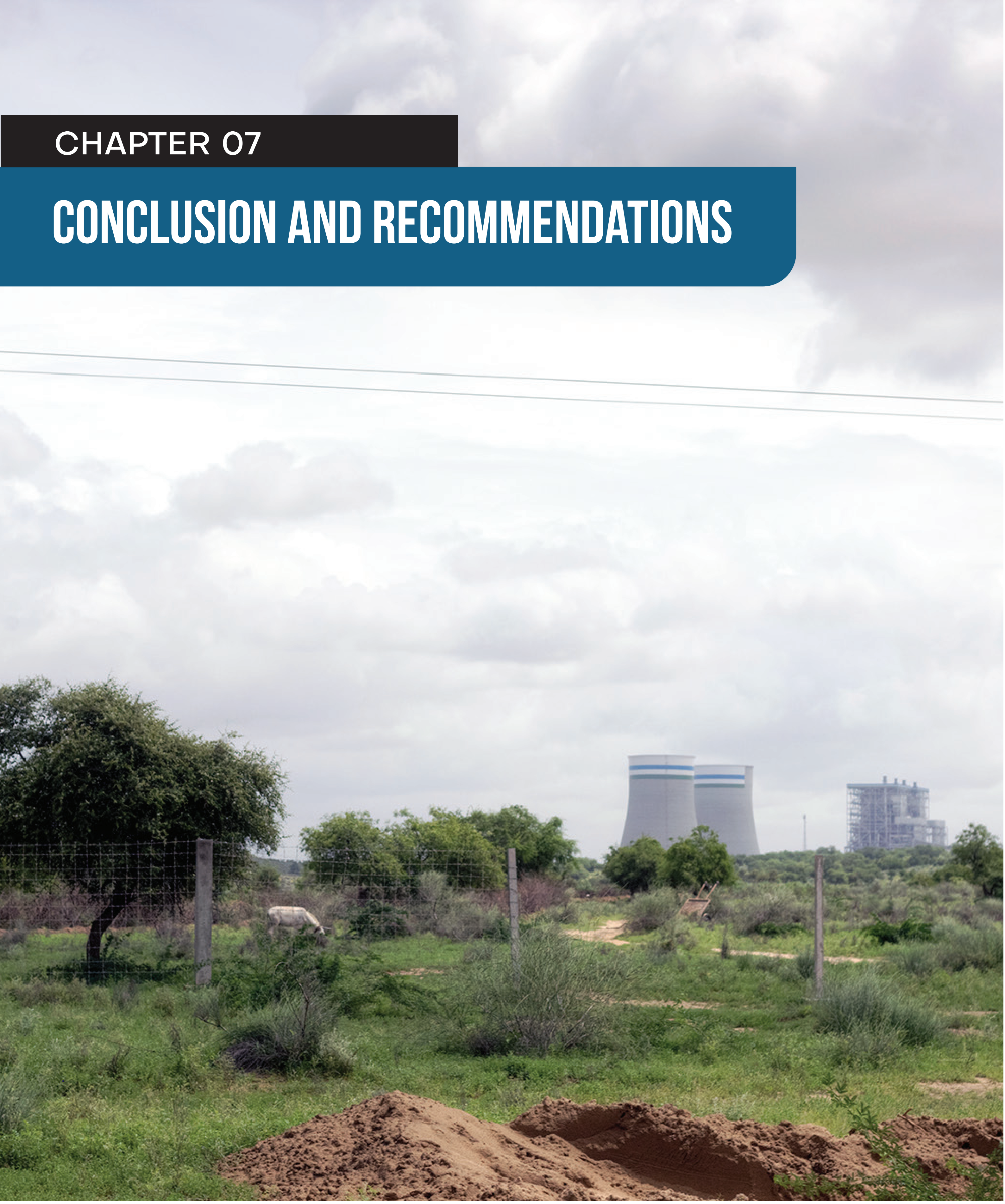


Photo credit: Kohi Marri

Conclusion and Recommendations

This study has explored the detrimental effects of coal mining and coal-based power operations on water resources in Thar. It has come to the conclusion that this region's groundwater resources run the risk of being lost due to excessive mining of coal here. As it has amply proven, mining activities interfere with groundwater recharging and aquifer re-filling. Mining and power generation also aggravate climate change by releasing toxic materials in the atmosphere. Likewise, their toxic emissions and effluents are hazardous for natural resources both aboveground and underground. They, therefore, harm water resources as much as they hurt agriculture, livestock and biodiversity. While all these effects are already apparent in TCB-II, the government is showing little caution or regard for them while developing TCB-I. Firstly, its development will need a site for the disposal of its saline effluent. This effluent may get dumped at Dabri and Saringwari villages. Villagers living around Gorano reservoir worry that it, too, might be discharged in Gorano – just like the effluent of TCB-II – before it is diverted to somewhere else.

Similarly, the unchecked utilization of Thar's groundwater sources for mining and power generation will create both qualitative and quantitative problems as far as the access to water is concerned.

The apprehensions of farmers living at the tail end of Nara Canal about losing their share of water, especially during summers, are also legitimate. It is, however, obvious that the government is more concerned about ensuring uninterrupted mining and power generation activities in Thar than addressing the concerns of these farmers regardless of the fact that the diversion of canal water to power plants will lead to a loss of livelihood and food security in villages irrigated by three tail distributaries of Nara Canal. This is especially so because no addition is being made to the water released in Nara Canal but a higher portion of its water is being allocated because of the channel built for carrying water to power plants than the combined amount of water to be supplied to all the three distributaries originating from Farash regulator.

While such complaints are always audible in and around Thar, they seldom make it to the national news media or the mainstream public and policy discourse. This is because they are either drowned by all the propaganda about development of Thar or they are stifled throughv a combination of coercion and cooption.

Lastly, the mega-level mining and power generation activities have been started in Thar without first conducting a serious and scientific research about their possible impacts. Consequently, the government lacks the institutional and legal mechanism to curtail these impacts and to mitigate them through the development of a suitable socio-economic infrastructure that helps resolve conflicts on the one hand and provides adequate and equitable access to education, healthcare, employment opportunities, housing and pollution-free environment to those displaced and displeased by these activities.

This study recommends that:

- A Lifecycle Assessment Study (LAS) of costs, benefits, and externalities of coal mining and coal-based power generation in Thar is carried out. This study should include a comparison of costs and benefits, including all conceivable externalities, of all the mining and power-generation operations over their expected 50-year lifecycle with projects of similar nature and magnitude involving renewables sources of energy such as solar and wind. Only after such a study is carried will it be possible to decide whether to continue coal mining and coal-based power generation in Thar or phase out them out as soon as possible. Such a study is all the more needed because the government studies done hastily to justify the exploitation of coal reserves have underestimated the impact of coal mining on Thar's water resources as well as on the local people and the local environment.

- Sindh government should set up an institution to develop and manage water resources in Thar. This special institution should include experts of hydrology, irrigation and water conservation along with the representatives of communities concerned. It should also be given resources and must be authorized to plan, design, and manage the use of precious water resources in these zones, keeping in mind the equity and sustainability principles. The revenue being generated from Thar's coal reserves must be utilized to finance it.

- This institution should install groundwater monitoring equipment in Thar, collect data about the changes in it and analyze those changes on a regular basis in collaboration with a university or a research institute. The findings of these analyses must be shared with local communities. These analyses should also be used for suggesting solutions to the problems identified during the monitoring process.

- The same institution should similarly monitor groundwater resources, including dewatering ponds such as the one set up at Gorano. The results of this monitoring should be recorded, reported and analyzed on regular basis.

- Sindh government should establish a high quality water-testing laboratory to periodically analyze the quality of water Thar's wells, particularly those located in around the mining areas and wastewater disposal sites. This laboratory should generate real time information on water quality and suggest mitigation measures to protect human and livestock health in the area. Its reports on water quality assessment should be made public so that the people can avoid using water from the contaminated wells.

- A compensation strategy should be devised with adequate financial allocation for those sites where dewatering might have a detrimental impact on the quality of groundwater so that people living there can utilize that compensation to plan and develop alternative livelihood sources.

- Sindh government should extend Reni canal from district Khairpur to Mithi (and as far beyond as the desert's terrain allows) in district Tharparkar via Umerkot as a means to replenish Thar's groundwater resources during the summer floods.

- Sindh government should use the riverine and in-field seasonal shallow well technology connected to a network of pipes and overhead water supply tanks to develop a reliable and safe drinking water supply system for Thar.

- Energy policy should focus on phasing out coal-based power plants – just as many governments across the globe are doing – in order to protect and preserve Thar's precious water resources. The government should instead utilize Thar's mostly dry weather and vast expanse to produce solar power.

References

[1] Aitken, D., Rivera, D., Godoy-Faúndez, A., & Holzapfel, E. (2016). Water scarcity and the impact of the mining and agricultural sectors in Chile. Sustainability, 8(2), 128.

[2] Kitula, A. G. N. (2006). The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District. Journal of cleaner production, 14(3-4), 405-414.

[3] Wall, E., & Pelon, R. (2011). Sharing mining benefits in developing countries.

[4]Hussain, A. Pakistan National Human Development Report 2003: Poverty, Growth and Governance; Oxford University Press: Oxford, UK, 2003.

[5] Qasim, H., Luqman, M., & Khan, S. (2016). A study of forest land cover changes using satellite remote sensing in Thatta District Pakistan. Sci. Int, 28, 4069-4075.

[6] Food Security Cluster, Pakistan. Sindh drought needs assessment, the state of agriculture, livelihood, food security, nutrition, water and sanitation in drought affected communities in Sindh; Food Security Cluster, Islamabad, Pakistan, 2016.

[7] Rupérez-Moreno, C., Senent-Aparicio, J., Martinez-Vicente, D., García-Aróstegui, J. L., Calvo-Rubio, F. C., & Pérez-Sánchez, J. (2017). Sustainability of irrigated agriculture with overexploited aquifers: The case of Segura basin (SE, Spain). Agricultural Water Management, 182, 67-76.

[8] Fernandez-Rubio, R., & Lorca, D. F. (1993). Mine water drainage. Mine Water Environ, 12(1), 107-130.

[9] Almeida, D. R. V. (2017). Mining, environments and people: depicting environmental, socio-economic and political understandings of mining conflicts in Cajamarca, Peru and Cordillera del Condor, Ecuador. McGill University (Canada).

[10] Zhao, Y., Long, R., & Lin, H. (2008). Study on pastoral ecosystem security and its assessment. Acta Prataculturae Sinica, 17(2), 143.

[11] McIntyre, N.; Woodley, A.; Danoucaras, A.; Coles, N. Water management capacity building to support rapidly developing mining economies. Water Policy 2015, 17, 1191–1208.

[12] Bury, J. Mining mountains: Neoliberalism, land tenure, livelihoods, and the new Peruvian mining industry in Cajamarca. Environ. Plan. A 2005, 37, 221–239.

[13] Garcia, L.C.; Ribeiro, D.B.; Oliveira Roque, F.; Ochoa-Quintero, J.M.; Laurance, W.F. Brazil's worst mining disaster: Corporations must be compelled to pay the actual environmental costs. Ecol. Appl. 2017, 27, 5–9

[14] Abbasi, Kashif Raza, et al. 2020, "Analyzing the role of industrial sector's electricity consumption, prices, and GDP: A modified empirical evidence from Pakistan." http://www.aimspress.com/article/10.3934/energy.2021003

[15] https://tribune.com.pk/story/2352847/electricity-shortfall-hits-6000mw

[16] Pakistan-Economic-Survey2020-2021, https://www.finance.gov.pk/survey/chapters_21/PES_2020_21.pdf

[17] https://commons.wikimedia.org/wiki/File:Pakistan_-_Sindh_-_Tharparkar_district.svg

[18] https://www.dawn.com/news/1145855

[19] Environmental and Social Impact Assessment of Thar Coal Mining Project Block – 1, May 2012.

[20] https://www.nsenergybusiness.com/projects/thar-block-1-integrated-coal-mine-and- power-project/

[21] http://www.tceb.gos.pk/jv-project-between-gos-engro-group-block-ii/

[22] Nergis, Y., Khan, M. J., Mughal, N. A., Sharif, M., & Butt, J. A. (June, 2018). Environmental impacts and mitigation of TLC mine dewatering operation, Sindh, Pakistan. Department of Earth and Environmental Sciences, Bahria University.

[23] https://www.thefridaytimes.com/the-water-this-desert-doesnt-want/

[24] Cao, C.; Chen, X.-P.; Ma, Z.-B.; Jia, H.-H.; Wang, J.-J. Greenhouse cultivation mitigates metal-ingestion-associated health risks from vegetables in wastewater-irrigated agroecosystems. Sci. Total. Environ. 2016, 560–561, 204–211.

[25] Watts, J. We Have 12 Years to Limit Climate Change Catastrophe, Warns UN. The Guardian. 2018, p. 8.

[26] Qureshi, Z. A., Ali, H. M., & Khushnood, S. (2018). Recent advances on thermal conductivity enhancement of phase change materials for energy storage system: a review. International Journal of Heat and Mass Transfer, 127, 838-856

[27]Jiru, M., North-Kabore, J., & Roth, T. (2017). Studying water quality using socio-environmental synthesis approach: A case study in Baltimore's Watershed. Hydrology, 4(2), 32.

[28] Myllyvirta, L. (2020). Air quality, health and toxics impacts of the proposed coal mining andpower cluster in Thar, Pakistan. Centre for Research on Energy and Clean Air (CREA).

[29] Samtio, M. S., Rajper, K. H., Mastoi, A. S., Sadaf, R., Rajper, R. H., Hakro, A. A., ... & Lanjwani, M. F. (2021). Hydrochemical assessment of groundwater from taluka Dahili, Thar Desert, Pakistan, for irrigation purpose using water quality indices. International Journal of Environmental Analytical Chemistry, 1-17.

[30] Jahangir K. (2018). Environmental impacts and mitigation of TLC mine dewatering operation, Sindh, Pakistan. Bahria University Research Journal of Earth Sciences, Vol. 3, Issue 1.

[31] Winn P. (2020). Thar Coalfield water impacts, financial and social risks.

[32] Hagler Bailly (2014). Thar Coal Block II Power Project- Environmental and Social Impact Assessment, final report volume 1 of 2.

[33] Sino-Sindh Resources, The future of energy in Pakistan [2012] Environmental and Social Impact Assessment study. Thar Coal Mining in Block-1.

[34] https://fscluster.org/sites/default/files/documents/sindh_drought_needs_assessment_february_20_2019 _uploaded.pdf

[35] Paul Winn. (2020). Thar coalfield water impacts: Financial and social risks.

[36] Unar, A. A., Kazi, T. G., & Memon, S. (2021). Evaluates the physicochemical characteristics and change in the concentration of arsenic species in groundwater, release from 2nd aquifer of coal mining area, its drain outlet and different sites of reservoir: Application of multivariate techniques.

[37] Nergis, Y., Khan, M. J., Mughal, N. A., Shareef, M., & Butt, J. A. (2018). Management of Ground-Water Hazard: A Case Study from Thar Coal Mines, Pakistan. International Journal of Economic and Environmental Geology, 9(4), 68-73.

[38] Mahessar, A. A., Laghari, A. N., Qureshi, S., Siming, I. A., Qureshi, A. L., & Shaikh, F. A. (2019). Environmental impact assessment of the tidal link failure and sea intrusion on Ramsar site No. 1069. Engineering, Technology & Applied Science Research, 9(3), 4148-4153.

[39] Masih, A. (2018, April). Thar Coalfield: Sustainable Development and an Open Sesame to the energy security of Pakistan. In Journal of Physics: Conference Series (Vol. 989, No. 1, p. 012004). IOP Publishing.

[40] Khuhawar, M. Y., Ursani, H., Khuahwar, T. M. J., Lanjwani, M. F., & Mahessar, A. A. (2019). Assessment of water quality of groundwater of Thar Desert, Sindh. Pakistan. J Hydrogeol Hydrol Eng 7, 2, 2.

[41] Samtio, M. S., Rajper, K. H., Mastoi, A. S., Sadaf, R., Rajper, R. H., Hakro, A. A., ... & Lanjwani, M. F. (2021). Hydrochemical assessment of groundwater from taluka Dahili, Thar Desert, Pakistan, for irrigation purpose using water quality indices. International Journal of Environmental Analytical Chemistry, 1-17.

[42] Sohoo, I.; Ritzkowski, M.; Kuchta, K.; Cinar, S.Ö. Environmental Sustainability Enhancement of Waste Disposal Sites in Developing Countries through Controlling Greenhouse Gas Emissions. Sustainability 2020, 13, 151.

[43] Raghunathan, K., Marathe, D., Singh, A., & Thawale, P. (2021). Organic waste amendments for restoration of physicochemical and biological productivity of mine spoil dump for sustainable development. Environmental Monitoring and Assessment, 193(9), 1-15.

[44] Mallah, M. A., Pinjaro, M. A., Mangi, S. H., Memon, S. A., & Maitlo, A. A. (2021). Assessment of soil quality parameters for agricultural purpose in the area of Lakhra Coal Field. world, 5, 15.

[45] Kugelman, M. (2015). Woodrow Wilson International Centre for Scholars, Washington DC. Open Report, pp. 157.

[46] Government of Sindh (2021). Modified PC-1 for the Makhi Farsh Link Canal Project (Chotiari Phase -II) for Water Supply to Thar Coal. Chief Engineer Irrigation Department Region-11, Hyderabad.

[47] Irrigation Department, Government of Sindh (2022). Presentation by Project Direction/ SE, Chotiari Reservoir Circle Project, Makhi Farsh Link Canal (Chotiari Phase -II) for water Supply to Thai Coal

[48] Government of Sindh (2021). Modified PC-1 for the Makhi Farsh Link Canal Project (Chotiari Phase -II) for Water Supply to Thar Coal. Chief Engineer Irrigation Department Region-11, Hyderabad

[49] Government of Sindh (2019). Modified PC-I for Alternate Arrangement Water Supply Thar Coal Field Block-II at Vinjhar from Makhi Farsh Link Canal

[50] Pakistan FisherFolk Forum (2020). https://pff.org.pk/publications/

[51] The Friday Times (2022). Coalmining in Thar Spells Disasters for Locals. https://www.thefridaytimes.com/2022/03/23/coalmining-in-thar-spells-disaster-for-locals/

[52] Water supply to Thar Coal power plant arranged to avoid $10m/month penalty. https://www.dawn.com/news/1657105 (published November 10, 2021)

ANNEXURE-I

Modelling of impact on water availability due to groundwater extraction for mining and plant operation

In the aforementioned studies, different models were invoked, viz; MODFLOW flow model, GWDREI finite volume model, etc. Almost all models that are used to predict the behavior of aquifers require information that includes hydrogeological units, recharge, discharge, and aquifer properties.

The process depicted below in **Figure 23** is mandatory to run a model for simulating different scenarios. In the above-mentioned studies, the model was calibrated for two possible conditions which include high flow and low flow condition which is attributed to the hydraulic conductivity of the layers. The results were validated against field data obtained for layers 1, 3, and 5 during drilling operations. During the calibration process, four parameters were adjusted to improve the results of the model, viz; hydraulic conductivity, general head boundaries, the thickness of the Coal Seam Floor aquifer, and recharge. For the low flow calibration process, the residual means square error (RMSE) ranged from 2.38 to 3.73 m while for high flow conditions, the RMSE varied from 2.48 to 3.73 m for different layers. The dewatering of aquifers is needed for coal abstraction from pits.

Figure 23. Flow chart showing steps of modeling

To depressurize the third aquifer, 29 tube-wells are operational at each site of TCB-I and TCB-II. The TDS of abstracted water varies from 3000 to 8000 ppm. The simulations have been carried out by the experts to assess.

- The influence of numerous integrated mine block operations on groundwater resources
- Required abstraction rates to dewater the aquifers beneath the Dune Sand and Coal Seam Roof
- Required flow rates to depressurize the confined aquifer
- Dewatering rates for more than 25 years with I year time interval
- The availability (aquifer yield) of the groundwater resource within the main aquifer units.

The model was run for low and high flow scenarios. In the low flow scenario, the value of hydraulic conductivity was taken as 7.5 m/day while for the high flow scenario and the hydraulic conductivity was used as 16.4 m/day. These values were based on results derived from pumping test data.

The model results were obtained for active depressurization of Layer 5 (Coal Seam Floor aquifer), passive drainage of Layers 1 to 4, and potential impact on people of Thar in the vicinity of the coalfield. Following findings were put forth in previous studies after carrying out simulations through calibrated and validated MODFlow model.

- The predicted annual abstraction rates for the TCB-I and TCB-II are illustrated in **Figure 24 – 25**. Figure 24 represents abstractions for high flow conditions while Figure 25 depicts withdrawal for low flow conditions. These results are reproduced from Numerical Groundwater Modelling Report prepared by WSP UK Limited.

- When compared to the pit of TCB-II, TCB-I has the highest dewatering rates for the Dune Sand and Coal Seam Roof aquifers. The Dune Sand aquifer's saturated thickness is greatest in the region of block TCB-I (>15 m) in the mining area of the south compared to the north (10 m). Similarly, when compared to the remainder of the mining region, the thickness of the Coal Seam Roof aquifer (approx. 5 to 15 m) is greatest in the area of the block I (about 10 to 30 m).

- When all mine activities are operational in TCB-I and TCB-II, it records the highest level of abstraction in 2022. Abstraction peaks at about 313985 m3 / day in the high flow scenario. After the aquifer has been depressurized, the abstraction rates gradually decrease during the remaining years of the mine's life, keeping the heads at the required elevation at the pit's base.

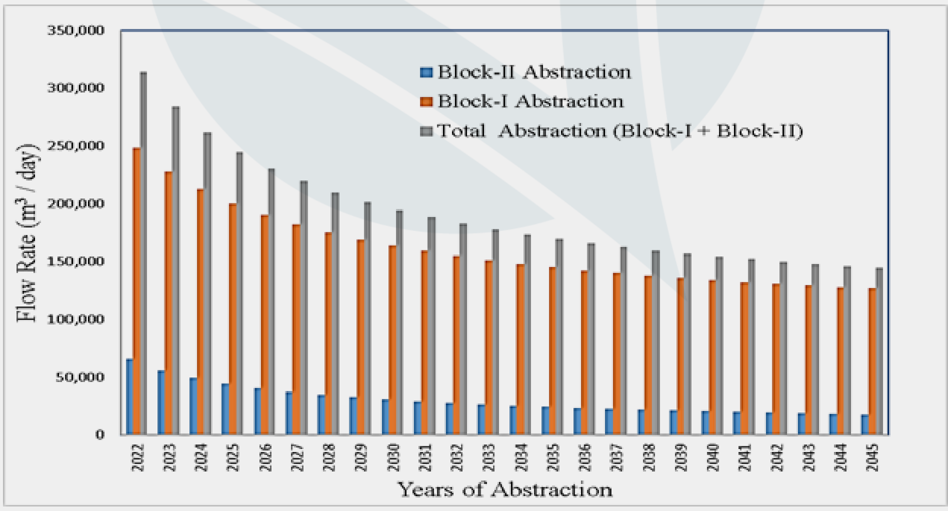


Figure 24. Predicted rate of abstractions for Block-I and Block-II under high flow condition (K = 16.4 m/ day)

- The thickness of the Coal Seam Floor aquifer influences the abstraction rate required to depressurize the aquifer in different blocks. Groundwater transmissivity and storage are highest in areas of greater thickness in TCB-I, necessitating higher rates of abstraction to lower groundwater heads in stipulated time. Because TCB-II has the smallest aquifer thickness and is additionally affected by interference from other mine block pumps, it requires lower rates of abstraction to depressurize.

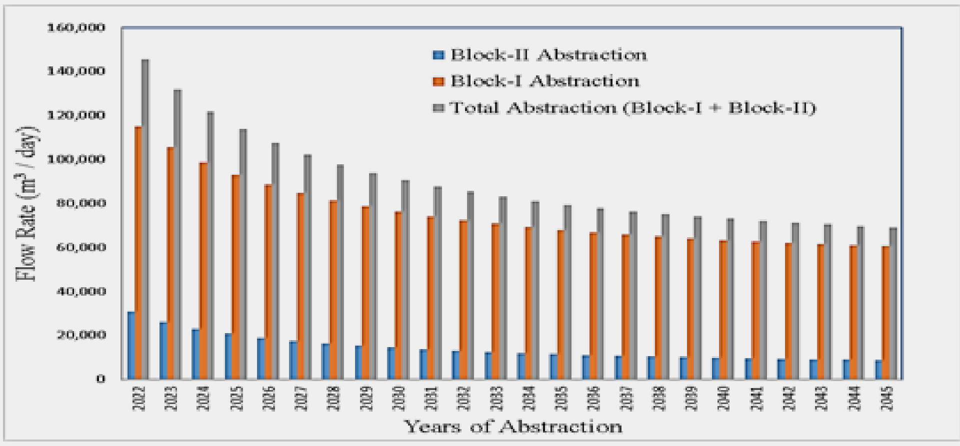


Figure 25. Predicted rate of abstractions for Block-I and Block-II under low flow condition (K = 7.5 m/ day)

- When coal mining in TCB-I and TCB-II is active, the abstraction rate for TCB-II drops dramatically, according to the model. The abstraction rate necessary to maintain the pit dry has decreased by 55 percent by annual time step 6, from 181,440 m3/day in year 1 to roughly 83,000 m3/day in year 5. By year 9, the rate has dropped to 50,000 m3/day, and after 30 years, the pumping rate has dropped to 18,000 m3/day.

- Once all mine activities are operational, the peak abstraction is recorded in 2022. Abstraction peaks at 145,596 m3/day in the low flow scenario, just under half of the peak high flow scenario abstraction rate. After the aquifer has been depressurized, the abstraction rates gradually decrease during the remaining years of the mine's life, keeping the heads at the required elevation at the pit's base. Although the magnitudes of abstraction rates are lower, the trend is consistent with the high flow scenario.

- The model predicts that the Thar Fault creates a considerable barrier to groundwater flow, causing the cone of depression to propagate to the west and north of the mining area. It has a substantial impact on nearby mining blocks' dewatering activities.

- Compared to the abstraction rates required to depressurize the Coal Seam Floor aquifer, the dewatering requirements for the dune sand and coal seam roof aquifers are minor. Mine operators are unlikely to need to actively dewater these strata, instead of relying on passive seepage into pit sumps to limit groundwater inflows.

- According to the model estimates, 31% of RO plants will be within a 50-meter drawdown zone after 10 years. Within a 100-meter drawdown zone, 13% of RO plants are located. After 30 years, 65 percent of RO plants have reached a declining zone of 50 meters. Within a 100-meter drawdown zone, 25% of RO plants are located.

- Dewatering and depressurization operations in mines have the potential to have a major influence on current water supplies (e.g., tube-wells used to supply water to village RO plants). The tube-wells that receive water from the lower (Coal Seam Floor) aquifer will be the most affected. Tube-wells that extract water from the Dune Sand and/or Coal Seam Roof aquifers, or from sand lenses within the Sub Recent, may also be impacted, only locally.

ANNEXURE-II

Name of villages where interviews were carried out

1. Aban Jo Tarr
2. Abdullah Ji Wand
3. Abun Jo Thar
4. Ajbo Bheel
5. Allanabad Hajam
6. Bheel Paro Village
7. Burho Tarai Khamesy Bheel Ji Dhaani
8. Chachhar Morhalla
9. Chachhar Village
10. Chotho Kohli
11. Dablu Vikio
12. Dano Paro
13. Darya Khan
14. Dhabri
15. Dorath Paaro Seenher
16. Dorath Paro
17. Ghopo Ji Dahani
18. Gorano
19. Gorano-Ladho Village
20. Hameer Paro
21. Ibrahim Jo Goth
22. Jaam Ji Wand
23. Jan Muhammad Khokhar Jo Tarr
24. Jeando Dars
25. Jhani Dars
26. Kaheri Village
27. Kanjyani Paaro
28. Khaario Ghulam Shah
29. Kheso Ji Dhaani
30. Khokhar Jo Tarr
31. Lanjo Nooro Ji Waand
32. Madano Ibrahim
33. Male Puto
34. Malho Bheel
35. Manglani Paaro
36. Mansing Paro
37. Mato Jo Tarr
38. Meghwar Seenhaar
39. Mero Phaani
40. Meway jo Tarr
41. Morani Ji Dhaani
42. Moraro
43. Mureed Jo Tarr
44. Mutu Jo Tarr
45. Neebraj Dam
46. Nehal Jo Parr
47. Nirbhami
48. Pabuhari
49. Rahimo Paro
50. Sanghar Vikio
51. Sarang Ji Dhaani
52. Sasan Paro
53. Seenhaar Vikio
54. Shameer Vikio
55. Shivo Bheel
56. Suleman Hajam
57. Syed Aehsan Jo Tarr
58. Talwai
59. Talwayo
60. Tarai Borch (Lakhani)
61. Tarao Borah
62. Thario Halepoto
63. Veeha Ji Dhaani
64. Verwahi Rahman Village
65. Vikio Paro
66. Village Junejo
67. Wasayo Dhaani (Morrano)
68. Wasayo Pota Village

Government of Pakistan

PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES

DRAINAGE AND RECLAMATION INSTITUTE OF PAKISTAN

Soil & Water Analysis Laboratory

S#	Sample ID	EC µS/cm	TDS mg/l	pH mg/l	CO_3 mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	Ca mg/l	Mg mg/l	Hardness mg/l	Na mg/l	K mg/l	No_3 mg/l	Fe mg/l	As ppb	F mg/l
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Gorano main pump line F-1	9210	5894	7.8	Nil	1000	1600	1300	480	131	1740	1220	30	4.50	0.06	0	1.30
2	Gorano main pump line F-2	9780	6259	7.8	Nil	1200	1650	1300	500	145	1850	1400	36	5.00	0.10	0	1.14
3	Main pump line F-3	9370	5997	7.5	Nil	1100	1620	1290	480	131	1740	1240	28	4.80	0.12	0	1.22
4	Khetto 01 (Dug well)	2220	1421	7.5	Nil	320	290	300	126	57	550	280	8	2.10	0.08	0	1.08
5	Malook Manghwar (Dug well)	1195	765	7.4	Nil	800	2400	1900	600	365	3000	1480	40	6.20	0.10	0	1.60
6	F-1 and F-2	2400	1536	7.7	Nil	340	400	300	126	57	550	280	8	2.00	0.06	0	0.80
7	Muhammad Umer Lodho 03 Dug well	1635	1046	7.1	Nil	280	2300	150	126	50	520	210.0	6	1.20	0.08	0	0.76
8	Allahwarayo Hajam 8A Seepage	11890	7610	7.9	Nil	880	2350	1880	600	365	3000	1500	38	3.60	0.88	0	1.74
9	Allahwarayo Hajam 8B Dug well	12450	7968	7.2	Nil	1100	160	1700	650	431	3400	1600	40	5.64	1.00	0	1.80
10	Warayam Hajam S-P-07	1290	826	7.1	Nil	230	1000	170	80	29	320	120	6	1.00	0.04	0	0.87
11	Ashok Kumar Dug well -10 Teacher	6380	4083	7.1	Nil	700	1800	900	350	176	1600	850	20	1.50	0.26	0	1.38
12	Jan Muhammad Dug well	10650	6816	8.1	Nil	1000	170	1680	548	299	2109	1390	30	3.80	0.40	0	1.49
13	Jan Muhammad R.O Plant 12-A	1500	960	7.6	Nil	300	340	180	88	56	450	130	3	1.00	0.10	0	0.58
14	Umed Ali Khokhar SP-17	2360	1510	7.0	Nil	350	1450	280	140	56	580	300	6	1.46	0.14	0	1.20
15	Umed Ali Khokhar Dug well	6530	4179	7.4	Nil	500	600	900	360	146	1500	800	9	3.80	0.20	0	1.36

16	Ghulam Qadir Khokhar SP	3570	2285	7.6	Nil	400	1600	550	150	74	680	450	5	1.00	0.12	0	1.26
17	Lakho Bheel Dug well	5950	3808	7.6	Nil	1000	1120	1800	500	182	2000	1400	20	1.46	0.24	100	1.62
18	Mitho Mehran Potoro Dug well	6120	3917	7.3	Nil	400	1120	940	288	141	1300	740	8	2.10	0.10	0	1.50
19	Syed Mumtaz Ali Shah Dug well	1383	885	7.8	Nil	700	950	850	350	176	1600	800	12	3.20	0.20	0	1.28
20	Molo Bheel Dug well	6880	4403	7.3	Nil	200	160	180	80	43	400	170	8	2.00	0.18	0	1.00
21	Muhmmad Penyal Wasayo Poto -Sp	7650	4896	7.7	Nil	900	1100	980	350	119	1600	850	14	4.30	0.14	0	1.39
22	Muhmmad Hashiml Wasayo Poto -Sp	9930	6355	7.3	Nil	1150	1200	1100	304	145	1250	1000	16	5.00	0.08	0	1.14
23	A) Muhab Ali Wasayo Poto Dug well	1365	874	7.3	Nil	1200	1700	1400	500	29	1850	1350	36	4.10	0.26	0	1.48
24	B) Muhab Ali Wasayo Poto Dug well -SP	7250	4640	7.3	Nil	250	160	170	80	119	320	140.0	8	2.00	0.04	0	0.86
25	Khameso Bheel -SP	11000	7040	7.3	Nil	900	1100	1000	309	299	1320	1140	8	8.30	0.28	0	0.98
26	Madan Lal Bheel Dug well	9160	5862	7.3	Nil	1250	1800	1600	548	130	2100	1400	40	7.20	0.22	0	1.46
27	Allah Dino Mehran Poto Dug well	8240	5274	7.3	Nil	1150	1500	1300	480	146	1740	1200	32	5.40	0.18	0	1.50
28	Ahmed Mehran Potor Dug well	5330	3411	7.3	Nil	1100	1300	1200	360	64	1500	1100	26	3.86	0.10	0	1.39
29	Salik Mehran Potor Dug well	53330	34131	7.5	Nil	600	700	900	274	140	950	800	18	4.00	0.14	0	1.28
30	Abdullah Dug well	6960	4454	7.3	Nil	1000	1300	1100	330	176	1400	600	26	5.16	0.12	0	1.36
31	Ali Muhammad Dug well	6330	4051	7.3	Nil	700	980	900	350	109	1600	850	30	6.00	0.08	0	1.28
32	Mano Meghwar Dug well	6840	4378	7.3	Nil	850	1000	1050	300	109	1200	980	26	5.00	0.10	0	1.3
33	Lal Muhamad Sahito Dug well	6800	4352	7.3	Nil	820	980	1040	300	243	1200	970	22	3.40	0.28	0	1.38
34	Imam Ali Dars Dug well	13740	8794	7.3	Nil	1680	2300	1800	600	176	2500	2800	40	3.96	0.10	0	1.56
35	Jan Muhammad Halapoto -SP	6480	4147	7.3	Nil	740	1000	980	350	176	1600	840	20	5.18	0.12	0	1.48
36	Muhammad Ghazi Sand Dug well	7220	4621	7.3	Nil	900	1050	1000	300	139	1320	1120	30	4.16	0.10	0	1.5
37	Ali Hakeem Noon R.O Plant	6800	4352	7.3	Nil	1200	1000	350	176	1600	850	20	3.40	0.08	0.16	0	1.36
	Permicible Limits:	**NGVS**	**1000**	**6.5 - 8.5**	**NGVS**	**NGVS**	**250**	**250**	**NGVS**	**NGVS**	**500**	**200**	**10**	**50**	**0.30**	**10**	**1.53**

APHA American Public Health Association
BDL= below detection limit
NGVS No Guideline Value Set
NSDWQ= National Standard for Drinking Water Quality
*PSQCA = Pakistan Standards Quality Control Authority, *PSQCA/NSDWQ 2010*

Note: The sample is provided by the client and this report is valid only for the sample provided.

Remarks: Found unsafe for drinking purpose for highlighted analyzed parameter only under prescribed standard.

Terms and Conditions
- *Results in this report relate only to the test items/sample submitted and tested.*
- *Analysis report is not valid for court use or business publicity.*
- *PCRWR does not accept any responsibility regarding accuracy of sample collection procedures if collected by the client.*

- *Water Quality Parameters exceeding the WHO (2004)/NEQS-1999/NSDWQ-2010 guideline values are highlighted*

PRIED
Policy Research Institute
for Equitable Development
Private Limited

THAR'S CHANGING HYDROLOGY

Adverse Impacts of Coal Mining and Coal-based Power Generation on Local Water Resources

September 2022