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Subsurface Disposal of Coal-Mine Wastewater in Tharparkar, Sindh for Safeguarding Fresh Water Aquifers & Farmlands

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ABSTRACT

The Thar coalfield in Sindh, Pakistan, generates substantial volumes of wastewater during dewatering operations. Surface disposal of this saline and high-TDS water has caused soil salinization, destruction of farmland, and contamination of shallow freshwater aquifers. This paper proposes adopting deep disposal wells similar to those routinely used in the oil and gas industry to safely manage mines wastewater. Leveraging both newly drilled wells and abandoned oil & gas wells in the surrounding region could reduce cost, protect agricultural land, and safeguard local communities. This study assesses the hydrogeologic context, evaluates risks, and provides a phased roadmap with policy recommendations for the Sindh Government and mining companies.

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1. Introduction

Coal mining in Tharparkar, Sindh, has expanded rapidly to meet Pakistan's energy demands. Dewatering operations associated with open-pit mining generate large volumes of wastewater estimated at nearly 990 L/s in Block II alone. Currently, this wastewater is discharged into surface ponds or natural depressions, leading to salinization of farmland, loss of crop productivity, and contamination of shallow groundwater. Similar challenges have long been faced by the oil and gas industry, where wastewater with high TDS and salinity is routinely managed via deep disposal wells. This proven approach can be adapted to coal mine wastewater management in Thar.

1.1. Overview of Tharparkar District

The objectives that will guide this study include:

- Population: Tharparkar District's 2017 census population was approximately 1.64 million, with a density near 130 persons per km^2; Islamkot and Mithi are key urban centers within an otherwise predominantly rural district (Pakistan Bureau of Statistics, 2017).
- Demographics: Predominantly rural, with gender disparities in access to resources and high vulnerability among scheduled castes (The Friday Times).
- Settlements: Scattered rural villages; limited urban centers like Mithi; majority dwell in basic housing; reliance on dug wells (~82%) for water (Earthwaisepk.com).

1.2. Geography & Environment

- **Location and climate:** Predominant housing is katcha construction adapted to heat and wind; living conditions hinge on water access from communal dug wells and seasonal tobas (ponds), which are vulnerable to quality and quantity shocks (Hagler Bailly Pakistan, 2011; PCRWR, 2023). Tharparkar occupies the eastern Sindh desert fringe bordering Rajasthan, India; the climate is arid to semi-arid with hot summers and scant but intense monsoon rains concentrated in July–September (MDPI remote sensing study; PMD/CDPC portal) (Saud et al., 2020; PMD, 2025).
- Mean annual rainfall at Mithi is ~277 mm with high interannual variability; ~80–90% falls in monsoon months (Saud et al., 2020; Khan et al., 2022).
- **Natural resources:** Recently exploited lignite coal; water extremely scarce and often brackish (underground salinity ~5,000 ppm vs WHO guideline 1,000 ppm) (sadf.eu).
- **Environmental vulnerabilities:** Groundwater depletion, contamination, salinization, air pollution, diminishing biodiversity and grazing lands

1.3. Economy & Livelihoods

- Economic sectors: Emergent coal mining and power generation dominate; traditional livelihoods agriculture, livestock, grazing are under pressure (PMLDaily).
- Poverty & unemployment: HDI index extremely low (~0.21), among worst in Pakistan; health and infrastructure deficits; limited livelihood diversification (The Express Tribune).

2. Hydrogeology and Environmental Context

Tharparkar lies in an arid desert environment with scarce freshwater resources. Groundwater occurs in shallow aquifers used for domestic and agricultural needs. These aquifers are highly vulnerable to contamination from saline mine effluents if disposed of on the surface. Below the freshwater aquifers, deeper saline formations exist that can serve as injection zones for wastewater disposal. Ensuring well integrity through cementing and monitoring is critical to prevent migration of contaminants into usable water supplies.

2.1. Observed and Projected Impacts

- **Rising temperatures**: Arid zone; increasing heat waves and prolonged drought cycles.
- **Precipitation changes**: Sparse and erratic rainfall (~125 mm), inadequate recharge(sadf.eu).
- **Water scarcity**: Exacerbated by coal-induced

groundwater extraction and contaminated reservoir seepage(nja.pastic.gov.pk).

- **Ecosystem stress**: Loss of grazing lands; increased water- and air-borne diseases; social vulnerabilities among women/children (Earthwise.pk)

2.2. Projected Intensification

- More frequent droughts; amplified salinization; increased health risks and constrained water security.

2.3. Water Quality

Regional surveys show most dug-well groundwater in Tharparkar is brackish to saline: in one extensive dataset (~2,170 wells), **57.5%** of samples had TDS > 3,000 mg/L, **14.7%** between 1,500–3,000 mg/L, and only **27.1%** below 1,500 mg/L; exceedances of chloride, sulfate, arsenic and fluoride were common even among the lower-TDS subset (Mahessar et al., 2019/2020).

PCRWR's 2023 regional assessment similarly documents patchy potable pockets amid pervasive salinity, underscoring the need to **protect** shallow fresh lenses from contamination by saline mine water (PCRWR, 2023).

2.4. Produced Water Analogy

Chemically and operationally, coal-mine dewatering brines resemble oil & gas "produced water": elevated TDS/salinity, variable hydrocarbons/metals (depending on geology), and typically unsuitable for surface discharge without advanced treatment; in oil & gas, the norm is deep formation injection (EPA UIC; Veil et al., Argonne) (U.S. EPA, 2023; Veil et al., 2004).

3. Impacts of Current Wastewater Disposal

The continued disposal of mine water onto the surface has severe environmental and socio-economic consequences. Farmers report declining yields as soils become saline and unsuitable for crops. Livestock dependent on shallow wells face reduced water availability. Freshwater hand pumps in nearby villages show increasing salinity, threatening community health. These impacts parallel those documented in oil-producing regions where produced water was historically discharged to surface environments.

3.1. Origin & Scale of Wastewater

- Dewatering Groundwater (~25 million m^3/year) yields brackish water, used partly for cooling, with significant surplus (nja.pastic.gov.pk).
- Mining pumps ~85,000 L/day; 59,500 L used, 42,500 L reinjected near villages risking contamination (earthwisepk.com).

3.2. Environmental & Social Impacts

- **Surface disposal**: Reservoirs in Gorano, Dukar Chau created to store wastewater near settlements black, smelly water with TDS 7,000–8,000 mg/L (vs WHO 300 mg/L)(WHO) (loksujag).
- **Groundwater contamination**: Seepage affecting 12 villages; health hazards; farming disrupted; displaced travel for clean water(loksujag).
- **Legal and justice concerns**: Land acquisition for disposal sites contested; EIA omitted; Supreme Court petitions highlight environmental injustice (DAWN)
- **Community impacts**: Livestock deaths, illness, protests, demands for relocation of reservoirs and improved practices (earthwaise)

4. Proposed Solution: Deep Disposal Wells

Deep disposal wells involve injecting wastewater into isolated, non-permeable formations well below freshwater aquifers. This technology has been successfully deployed in the oil and gas industry to manage large volumes of produced water. The same strategy can be applied in Thar by either drilling purpose-built wells or repurposing abandoned oil & gas wells in surrounding districts. This would significantly reduce the environmental footprint while offering a cost-effective solution.

In the United States, coalbed methane (CBM) production generates vast volumes of produced water with elevated salts and TDS. For example, in parts of Colorado and New Mexico, such water cannot be legally discharged into surface streams and must instead be injected into regulated Class II disposal wells targeting deep saline aquifers (houstonchronicle) (CSIS).

4.1 Pakistan's Own Experience

Pakistan's oil & gas operators already practice produced-water injection for disposal/pressure maintenance at multiple fields (e.g., Qadirpur, Dhakni, Bhit, Kandra), demonstrating local technical capacity, supply chains, and regulatory familiarity (IJISET OGDCL/ENI tabulations).

Historic cases such as Fimkassar field document water-flooding and inter-well tracing, illustrating competency in injection operations and monitoring (Hussain et al., 2003; Ahmad et al., 2020).

Implication for Thar: coal-mine brine management can leverage this existing national skill base contractors, logging services, integrity testing, and regulators lowering implementation risk and cost compared to greenfield unfamiliar methods (IJISET; U.S. EPA UIC).

4.2. Injection/Disposal Wells Overview

- **Method**: Injection of treated wastewater deep underground between impermeable layers via solid-walled pipes to prevent contamination, widely used in industrial and oil/gas sectors.
- **Benefits**: Protects surface water, limits seepage if properly designed.

4.3 Risks: Induced Seismicity & Contamination

- **Contamination hazards**: Poorly managed wells can allow toxics to migrate into shallower aquifers.
- **Mitigation**: Requires rigorous site selection, monitoring, seismic surveillance, and regulatory oversight.

4.4. Repurposing Old Oil & Gas Wells

- Analogous method in New Mexico: treated produced water reused or injected; demonstrates potential for reusing existing infrastructure (Reuters).
- Advantages: Economical reuse; quicker deployment. Caveats: Well condition, sealing integrity, regulatory approval.

Table 1: *Key Parameters of Disposal-Well Plan*

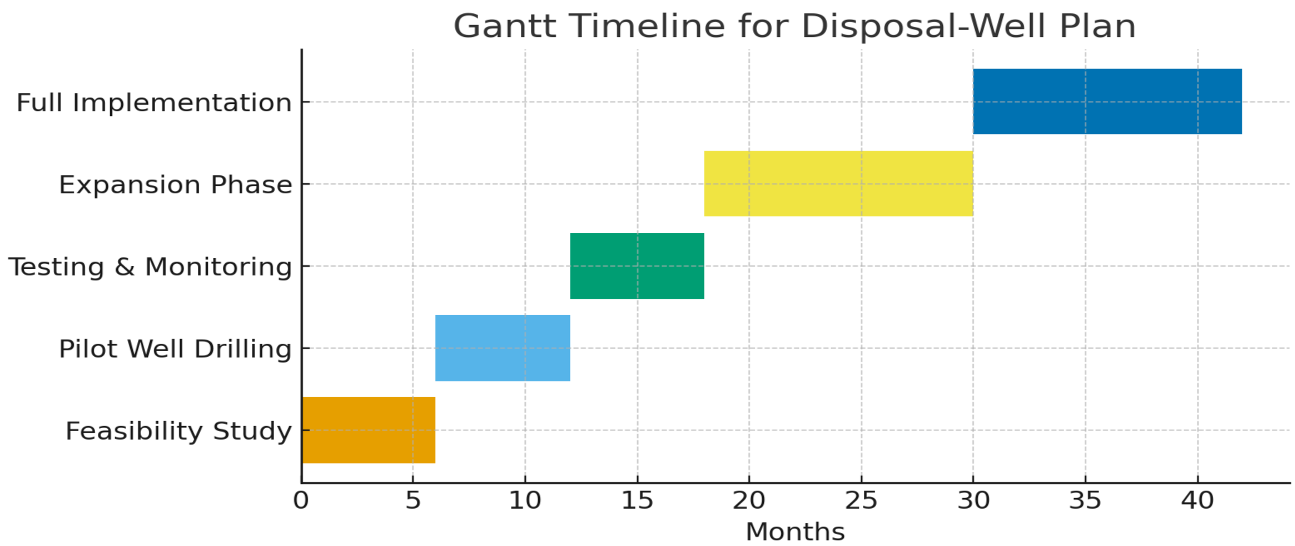
Parameter	Value / Range
Target Injection Formations	Saline sandstone, >250 m below USDWs
Baseline Mine Discharge	≈ 990 L/s (Block II, JICA 2013)
Pilot Wells (Phase 1)	1 new + 1 repurposed O&G well
Full Network (Phase 2)	4–6 wells across mining area
Integrity Testing	Initial MIT + 5-year retesting
Monitoring Rings	Groundwater + soil EC + seismicity
Pipeline Length	~10–20 km per well

Table 2: *Risk and Mitigation Matrix*

Risk	Impact	Mitigation
Well Integrity Failure	Contamination of aquifer	Cement bond logs, MIT, monitoring wells
Seismic Activity	Induced seismicity	Injection pressure limits, seismic monitoring
Pipeline Leaks	Soil/water contamination	Pipeline integrity testing, leak detection
Community Concerns	Social resistance	Transparency, community engagement

(Osama, 2024)

Figure 1: *Project Gantt Timeline*



5. Climate Change Adaptation & GHG Context (≈500 words)

- **GHG sources**: Coal-based power emits CO_2, SO_x, NO_x, $PM_{2.5}$, reported emissions include 154–325 t/year from various Thar facilities.
- Recognize that wastewater management is a climate vulnerability exacerbator; proper disposal well strategies reduce surface contamination, health impacts, and lower CO_2-intensive water transport.
- **Adaptation recommendations**: integrate wastewater injection into broader climate adaptation complement renewable energy adoption, reduce community health burden, preserve groundwater.

6. Roles and Responsibilities (Measurable, Achievable, Relevant, Time-Bound)

6.1. Political Leadership (Sindh Government):

- Mandate **zero routine surface discharge** of mine brines within **18 months**, except emergency surges in lined ponds; condition future ESIA approvals accordingly (Government of Sindh policy).
- Establish a **Disposal Well Code** adopting UIC-style integrity and monitoring rules within **12 months** (U.S. EPA UIC model).

6.2. Government Departments (Energy, Irrigation, SEPA):

- Approve AoR-based siting; create a shared **disposal hub** framework with tariffed third-party access in **24 months** (Government of Sindh policy).
- Fund **community sentinel monitoring** around Islamkot/Mithi; publish dashboards quarterly (PCRWR, 2023).

6.3 Civil Society & Academia:

- Independent audits of groundwater/soil transects and public reporting; support grievance redress for farmers (Hagler Bailly Pakistan baseline references).

6.4 Media:

- Evidence-based coverage of brine management and monitoring dashboards to sustain accountability (Government of Sindh transparency aims).

6.5 Businesses (SECMC/Other Mining & IPPs):

- Implement **Phase 1 pilots** within **12–18 months**, **Phase 2 scaling** by **36 months**; publish injectivity and integrity reports (JICA baseline; U.S. EPA UIC).

6.6 Citizens:

- Participate in well sentinel sampling, report anomalies; co-design farm soil EC monitoring (PCRWR community engagement).

7. Conclusion

Tharparkar's mine dewatering brines are not a conventional wastewater problem; they are a produced-water problem already solved at scale in the oil & gas sector through deep subsurface disposal. Pakistan's own upstream industry uses injection at Qadirpur, Dhakni, Bhit, Kandra and others, proving local feasibility. Given JICA's inflow estimates (~990 L/s for Block-II) and the fragility of Thar's shallow freshwater pockets, continuing surface storage/discharge courts avoidable harm to farmland and tobas. A phased program of new deep disposal wells and repurposed retired O&G wells designed with UIC-style integrity controls, AoR management, and community-visible monitoring offers a technically robust, cost-sensible path to protect water, land, and livelihoods while enabling energy development.

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Define **Deep Brine Disposal Wells (DBDWs)** as injection wells drilled or repurposed to dispose of saline mine water into designated non-potable formations **below** the deepest USDW, with mandatory MIT before service and at 5-year intervals (U.S. EPA UIC).

Prohibit routine surface discharge of mine water; require **emergency-only** lined surge capacity with leak detection; mandate AoR mapping and legacy well remediation prior to injection (Hagler Bailly Pakistan; U.S. EPA UIC).

Population and administrative facts rely on **PBS** (Government of Pakistan).

Hydrology/ESIA details rely on **Hagler Bailly Pakistan** reports commissioned for Thar projects and **JICA**'s official study.

Groundwater quality/freshwater scarcity rely on **PCRWR** and peer-reviewed/technical studies.

Disposal well practice and risk management draw on **U.S. EPA UIC** primary documentation and peer-reviewed syntheses (**Science/USGS**, **Energies**).

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Declaration of Conflicting Interest

The author declared no potential conflicts of interest with respect to research.

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