

ANALYSIS OF LONG-TERM AMBIENT PM_{2.5} AND HEALTH IMPACT ASSESSMENT OF PAKISTAN'S COAL-FIRED JAMSHORO POWER PLANT

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Alliance for
Climate Justice &
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Key findings

- Long-term satellite observations from 1998 to 2023 show that annual average PM_{2.5} concentrations remain persistently elevated around the coal-fired Jamshoro Power Generation Project, with pollution extending well beyond the immediate vicinity of the plant, indicating sustained exposure for surrounding communities.
- A health impact assessment (HIA) of the one remaining operational unit at the coal-fired Jamshoro Power Generation Project finds that replacing the current fuel mix with 100% domestic lignite could nearly double premature deaths, years of life lost, and several major disease outcomes attributable to PM_{2.5} exposure over the 2025–2049 assessment period.
- The 2013 Environmental Impact Assessment (EIA) no longer reflects present-day environmental conditions. Its reliance on short-term baseline monitoring limits its ability to represent long-term air quality trends, population exposure, and associated public health risks.
- Fugitive dust emissions from coal transport, storage, handling, and ash management may contribute to ambient particulate pollution and should be considered alongside stack emissions when assessing the plant's environmental impacts.
- Together, the long-term PM_{2.5} analysis and the HIA demonstrate the need for a comprehensive reassessment of the EIA to support evidence-based decisions on future plant operations and fuel use.

Introduction

Thermal power generation is a major source of air pollution, emitting particulate matter (PM_{2.5} and PM₁₀), sulphur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases. These pollutants contribute to poor air quality, increase the burden of respiratory and cardiovascular diseases, and accelerate climate change. Coal-fired power plants are of particular concern because, in addition to directly emitting particulate matter, they release precursor gases that form secondary PM_{2.5}, allowing pollution to persist in the atmosphere and affect communities far beyond the plant boundary (Guttikunda & Jawahar, 2014).

Jamshoro district hosts one of Pakistan's largest concentrations of thermal power generation, with coal-, furnace oil-, and gas-fired power plants located within a relatively small geographic area (Global Energy Monitor, 2026). This has raised concerns about long-term air quality and population exposure to particulate pollution in the surrounding region, including nearby rural communities.

Despite these concerns, assessments of how ambient PM_{2.5} concentrations around the coal-fired Jamshoro Power Generation Project have evolved over time, or their associated public health implications, remain limited. Previous EIAs relied primarily on short-term baseline monitoring conducted before project implementation. Therefore, they do not reflect current air quality conditions or long-term population exposure (Asian Development Bank [ADB], 2012, 2024). Moreover, actual operating conditions differed from those envisaged when the project was developed; the existing generating units continued to operate long after the new coal-fired power plant was approved.

This assessment addresses that gap by combining more than two decades of satellite-derived PM_{2.5} observations around the coal-fired Jamshoro Power Generation Project with a quantitative HIA to evaluate the long-term public health implications of different fuel-use scenarios. Together, these analyses provide updated evidence to inform future environmental decision-making and the need for reassessing the existing EIA (ADB, 2012, 2024).

Five units are located within the coal-fired Jamshoro Power Generation Project. However, four of them have been delicensed. This analysis focuses on the remaining operational unit at the coal-fired Jamshoro Power Generation Project.

The study uses the coordinates of this specific plant, where a higher proportion of lignite is considered in the fuel blend, to assess annual average PM_{2.5} concentrations within 5 km, 25 km, and 50 km, from 1998 to 2023.

The distance buffers are measured from the coordinates of the specific remaining operational unit assessed, hereafter referred to as the Jamshoro Thermal Power Plant.

Methodology

Estimating ambient PM_{2.5} concentration around Jamshoro thermal power plant

Annual average PM_{2.5} concentration data for 1998–2023 were obtained from the Atmospheric Composition Analysis Group at Washington University in St. Louis, based on the global PM_{2.5} estimation dataset developed by van Donkelaar et al. (2021), to assess long-term pollution patterns around the Jamshoro Thermal Power Plant. We selected three buffer zones of 5 km, 25 km, and 50 km to provide a multi-scale spatial assessment of pollution patterns in the plant's immediate vicinity, surrounding area, and wider region. We extracted annual mean concentrations from NetCDF files in QGIS and independently replicated the analysis in RStudio using the terra, sf, and exactextractr packages. We compared results year-wise and buffer-wise, with no discrepancies between the two methods.

Estimating population exposure to power plant emissions

Population exposure to PM_{2.5} from power plant emissions was estimated using the regression model developed by Zhou et al. (2006), based on atmospheric dispersion modelling and subsequently applied by Cropper et al. (2012). The model accounts for SO₂ and NO_x emissions, secondary PM_{2.5} formation, population distribution (CIESIN, 2018) and precipitation (Fick & Hijmans, 2017).

Estimating health impacts

The HIA estimates the additional health burden associated with PM_{2.5} exposure from the sources assessed in this study. We selected health outcomes based on available established concentration-response relationships, evidence from peer-reviewed epidemiological studies, and national-level baseline incidence data.

CREA's health impact assessment framework (Myllyvirta, 2020) incorporates health

outcomes identified in peer-reviewed meta-analyses across multiple populations, while seeking to minimise overlap between outcomes. The framework uses concentration-response relationships applied in peer-reviewed studies to estimate the global health burden attributable to air pollution.

For each health outcome, we estimated attributable cases using a standard epidemiological approach that accounts for population size, age distribution, baseline incidence rates, and the relative risk associated with $PM_{2.5}$ exposure. The calculation compares health risks at the baseline concentration with those at the concentration including emissions from the sources assessed in this study.

The calculation can be expressed as:

$$\Delta cases = Pop \times \sum_{age} \left[Frac_{age} \times Incidence_{age} \times \left(\frac{RR_{c,age}}{RR_{c_{base},age}} - 1 \right) \right],$$

Where:

Pop is the total population in the grid cell;

age is the specific age group for which the epidemiological studies have established a health risk;

$Frac_{age}$ is the fraction of the population belonging to the specific age group;

$Incidence_{age}$ is the baseline rate of occurrence of the health outcome for the population belonging to the specific age group;

c is the pollutant concentration from the baseline combined with pollution from the sources that had been discussed in this work, with c_{base} referring to the baseline concentration or current ambient concentration; and

$RR_{c,age}$ is the function giving the risk ratio of the health outcome at the given concentration for the given age group.

In the case of a log-linear, non-age-specific concentration-response function, the RR function becomes:

$$RR(c) = RR_0 \left(\frac{c - c_0}{\Delta c_0} \right) \text{ when } c > c_0, 1 \text{ otherwise}$$

Where:

RR_0 is the risk ratio found in epidemiological research;

Δc_0 is the concentration change that RR_0 refers to; and,

c_0 is the assumed no-harm threshold concentration.

Data sources and temporal coverage

We obtained baseline incidence rates from multiple sources, including the Global Burden of Disease results for 2023 (GBD, 2025), accessed through the Institute for Health Metrics and Evaluation (IHME, 2025). Population data were obtained from the Gridded Population of the World, version 4 (GPWv4), produced by the Centre for International Earth Science Information Network (CIESIN). The latest population grid used was for 2020, which was adjusted to the study year using population and mortality changes from the United Nations Department of Economic and Social Affairs' World Population Prospects dataset (UN DESA, 2024).

Interpretation of health impacts

The assessment estimates the health impacts associated with pollutant exposure during the study year. Some outcomes, such as asthma exacerbations and work absences, may occur over short periods, while others associated with chronic exposure may involve latency over several years. We derived the concentration-response relationships for asthma emergency room visits and work absences from studies examining daily variations in pollutant concentrations and health outcomes, but applied them to changes in annual average concentrations. Consider this distinction when interpreting the resulting estimates.

Results

Long-term $PM_{2.5}$ trends around the Jamshoro thermal power cluster

The analysis reveals a clear spatial gradient in $PM_{2.5}$ concentrations. The highest long-term concentrations occurred within the 5 km buffer surrounding the power plant, where the mean annual $PM_{2.5}$ concentration was approximately $61 \mu\text{g}/\text{m}^3$.

Concentrations gradually declined to 56 $\mu\text{g}/\text{m}^3$ within the 25 km buffer and 53 $\mu\text{g}/\text{m}^3$ within the 50 km buffer, indicating that emissions are most intense near the plant but remain elevated across the wider region.

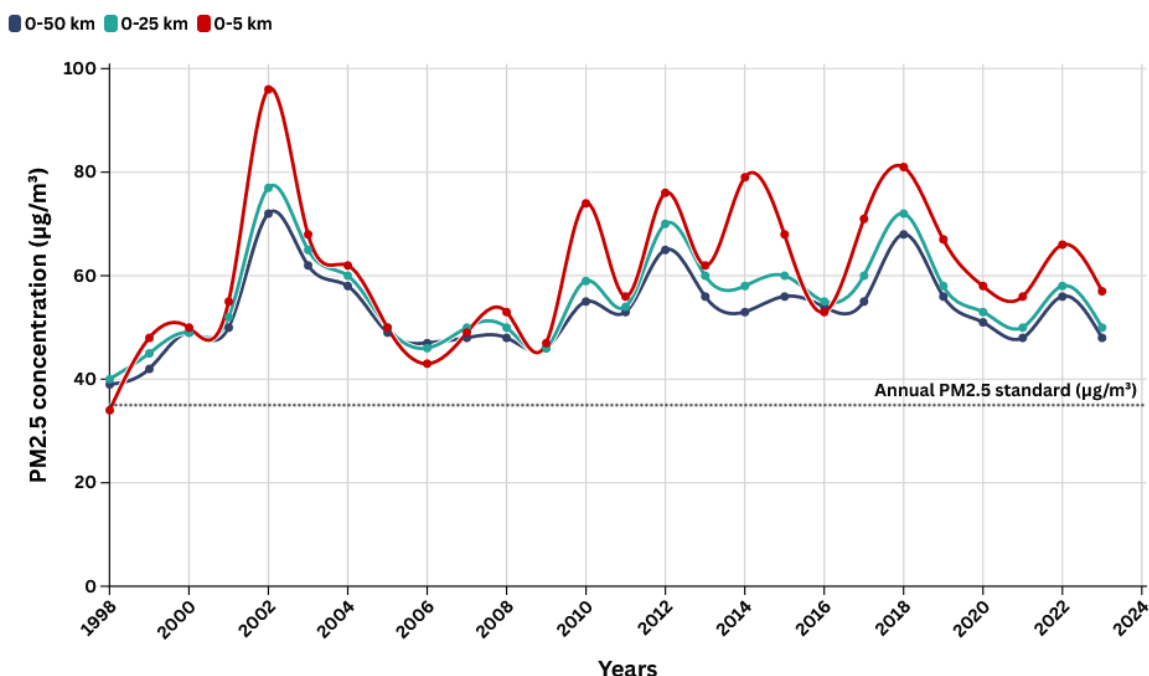


Figure 1 — Buffer-wise $\text{PM}_{2.5}$ annual mean trend at the Jamshoro Thermal Power Plant

Although pollutant concentrations decrease with distance, the reduction is relatively modest. Annual average $\text{PM}_{2.5}$ concentrations across all three buffer zones remain substantially above the World Health Organisation (WHO) annual guideline of 5 $\mu\text{g}/\text{m}^3$ (WHO, 2021). They also exceed Pakistan's national annual $\text{PM}_{2.5}$ standard of 15 $\mu\text{g}/\text{m}^3$, which was already in effect when the 2013 EIA was prepared (Government of Pakistan, Pakistan Environmental Protection Agency, 2010). The Sindh province subsequently introduced its own ambient air quality standards in 2014, including an annual $\text{PM}_{2.5}$ limit of 40 $\mu\text{g}/\text{m}^3$ (Government of Sindh, 2014). The observed concentrations therefore also exceed this Sindh benchmark, indicating that elevated particulate pollution extends beyond the immediate vicinity of the plant and across surrounding communities. These concentrations reflect the combined influence of sources within and beyond the study area, and the present analysis does not attribute across the three scenarios. Mortality among children under five due to lower respiratory infections also increases progressively from 65 deaths under the base case to 79 under the 60:40 blend and 122 under 100% domestic lignite.

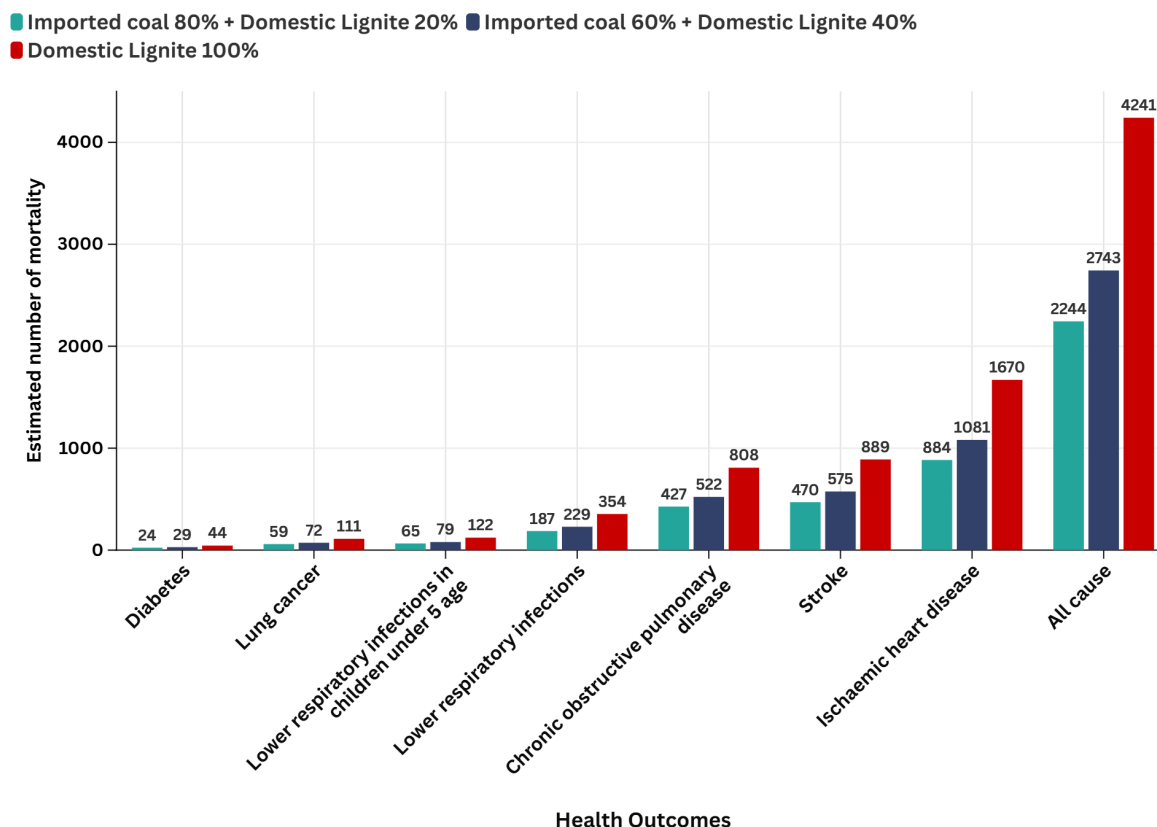


Figure 2 — Estimated mortality cases related to PM_{2.5} emissions based on coal type utilised at Jamshoro Thermal Power Plant (2025–2049)

The assessment also projects progressively higher morbidity under the two alternative fuel scenarios. Cumulative asthma-related emergency room visits among children aged 0–17 increase from 1,354 under the base case to 1,652 under the 60:40 blend and 2,547 under 100% domestic lignite, while estimates of asthma-related emergency room visits among adults increase from 1,937 to 2,366 and 3,655, respectively. Similarly, low birthweight births increase from 3,218 to 3,935 and 6,083, while preterm births increase from 2,793 to 3,411 and 5,264 across the three scenarios. The estimated number of work absence days attributable to PM_{2.5} pollution also increases substantially, from approximately 1.63 million days under the base case to 1.99 million days under the 60:40 blend and 3.08 million days under 100% domestic lignite. Thus, even the intermediate 60:40 blend is associated with an approximately 22% higher morbidity burden than the current fuel mix, while complete reliance on domestic lignite increases it by approximately 88–89%.

The disability burden (YLD) follows the same health impact pattern. COPD-related YLD increases from 1,621 under the base case to 1,983 under the 60:40 blend and 3,066 under 100% domestic lignite. Stroke-related YLD increases from 1,033 to 1,262

and 1,951, and diabetes-related YLD increases from 352 to 430 and 663, respectively. Overall, the 60:40 blend results in approximately 22% higher YLD estimates than the current 80:20 fuel mix, whereas the 100% domestic lignite scenario results in approximately 89% higher estimates. This progressive increase shows that the disability burden also rises as the share of domestic lignite in the fuel mix increases.

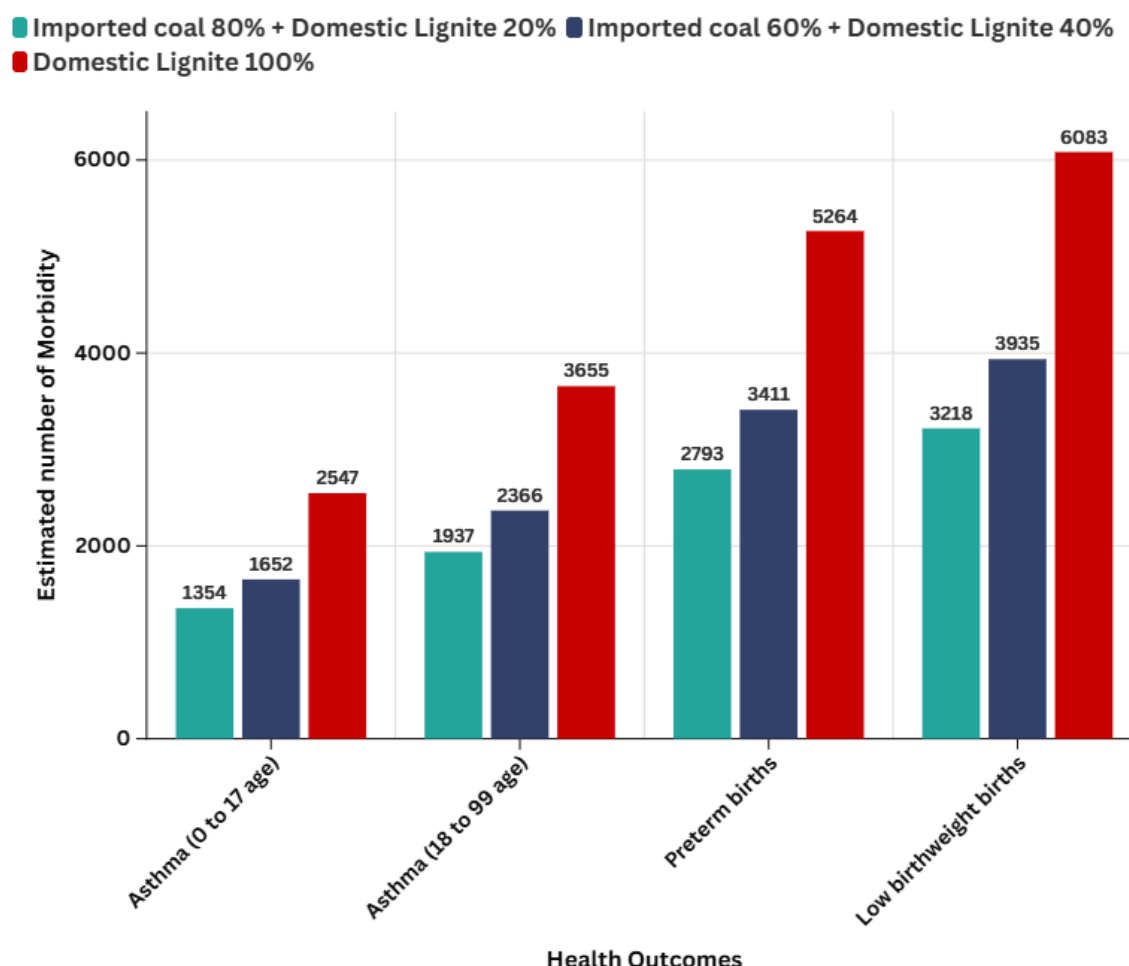


Figure 3 — Estimated morbidity cases related to $PM_{2.5}$ emissions based on coal type utilised at Jamshoro Thermal Power Plant (2025-2049)

A similar pattern is observed for YLL, representing the burden associated with premature mortality. Total YLL increases from 56,499 under the base case to 69,055 under the 60:40 blend and 106,723 under 100% domestic lignite. This corresponds to an increase of approximately 22% under the 60:40 blend and approximately 89% under the 100% domestic lignite scenario compared with the base case. Ischaemic heart disease accounts for the largest share of this burden, with YLL increasing from 25,186 to 30,778 and 47,554, followed by stroke, which increases from 12,199 to

14,916 and 23,067. COPD-related YLL increases from 8,206 to 10,037 and 15,527, while YLL associated with lower respiratory infections increases from 3,859 to 4,719 and 7,300. Among children under five, YLL due to lower respiratory infections increases from 5,802 under the base case to 7,085 under the 60:40 blend and 10,934 under 100% domestic lignite. Lung cancer-related YLL similarly increases from 1,624 to 1,984 and 3,067 across the three scenarios.

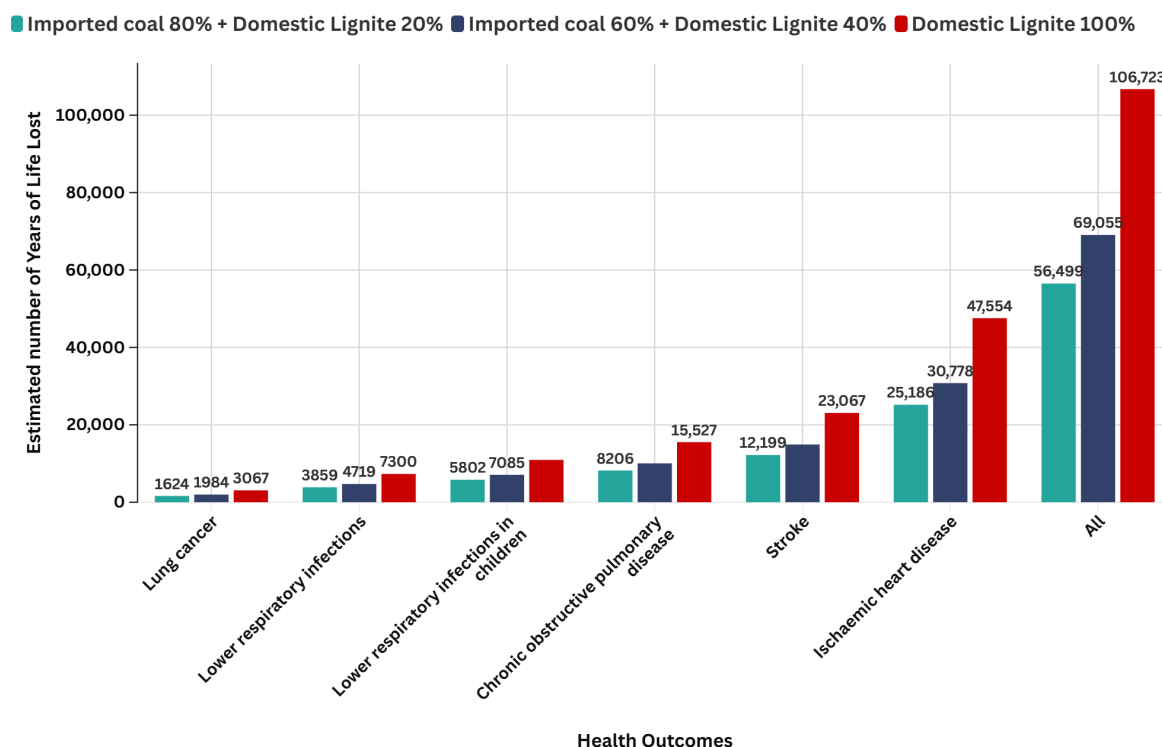


Figure 4 — Estimated cases with years of life lost related to PM_{2.5} emissions based on coal type utilised at Jamshoro Thermal Power Plant (2025-2049)

Collectively, the HIA demonstrates a consistent increase in the projected public health burden as the share of domestic lignite increases from 20% in the current base blend to 40% and 100%. Across mortality, morbidity, disability, and premature life-loss indicators, the 60% imported coal + 40% domestic lignite scenario produces approximately 22% higher cumulative health outcomes than the current 80:20 blend, while the 100% domestic lignite scenario produces approximately 88–89% higher outcomes. These findings show that fuel procurement decisions should consider not only operational and economic factors but also the long-term health costs imposed on surrounding communities. Incorporating quantitative health assessments into environmental decision-making provides a more comprehensive understanding of

the true societal costs of coal-fired power generation and highlights the importance of minimising emissions in an already polluted airshed.

The case for reassessing the Environmental Impact Assessment

The findings presented in this assessment demonstrate that the EIA prepared for the Jamshoro Thermal Power Plant in 2013 no longer provides an adequate basis for evaluating the project's environmental and public health impacts. The original assessment relied on a 48-hour baseline air quality survey conducted at three monitoring locations, providing only a short-term snapshot of environmental conditions before project implementation (ADB, 2013). This baseline does not provide information on long-term air quality trends, chronic population exposure, or changes in operating conditions over subsequent years.

The operating context also evolved differently from that envisaged when the project was developed. The project was intended to contribute to a transition away from existing HFO-based generation; however, the existing Jamshoro units continued to operate alongside the new coal-fired capacity for several years. As a result, actual operating conditions differed from the transition scenario underlying the project rationale.

This assessment combines more than two decades of satellite-derived $PM_{2.5}$ observations with a quantitative HIA to provide a longer-term assessment of ambient air quality and the potential public health implications of different fuel-use scenarios. The findings show that elevated $PM_{2.5}$ concentrations persist across the surrounding region and that increasing the share of domestic lignite could nearly double the health burden associated with $PM_{2.5}$ exposure compared with the current fuel mix.

Taken together, the findings indicate that the assumptions underpinning the 2013 EIA should be revisited. In particular, the EIA should be reassessed against current operating conditions and the longer-term air quality and health evidence now available. Any future decisions on fuel switching, continued operation, or plant modifications should be informed by this updated assessment, including consideration of fugitive dust emissions.

Fugitive dust emissions: An overlooked source of particulate pollution

In addition to stack emissions, coal-fired power plants generate fugitive dust from coal transportation, unloading, storage, conveyor systems, ash handling, and vehicle

movement. Unlike stack emissions, emissions from these diffused sources are released close to ground level and can contribute primarily to ambient PM_{10} , and, to a lesser extent, $PM_{2.5}$ concentrations. Under dry and windy conditions, dust can be dispersed more easily into surrounding areas, potentially exacerbating particulate pollution and population exposure in an area where $PM_{2.5}$ concentrations are already persistently elevated. Effective management of fugitive dust is therefore an important component of controlling particulate emissions from the plant.

Fugitive dust emissions may increase if the Jamshoro Thermal Power Plant relies more heavily on domestic lignite. The original EIA shows that Thar lignite has a substantially lower heating value (2,231 kcal/kg compared with 4,780 kcal/kg for imported sub-bituminous coal) and a higher ash content (15.1% compared with 9%). As the lignite share in the fuel blend increases from 10% to 20%, the blended fuel heating value decreases from 4,525 to 4,270 kcal/kg, requiring annual coal consumption to increase from 4.38 million tonnes to 4.67 million tonnes for the 1,200 MW design. Over the same range, annual ash generation increases by around 54,000 tonnes, including about 46,000 tonnes of additional fly ash, increasing the material that must be transported, stored, handled, and disposed of.

These operational changes could increase fugitive dust emissions from coal handling and ash management if not effectively controlled. Future revisions of the EIA should therefore explicitly quantify fugitive dust sources, incorporate them into air quality modelling, and evaluate the adequacy of existing mitigation measures. This would provide a more comprehensive assessment of the plant's potential contribution to local air pollution and associated health risks.

Conclusion

This assessment provides new evidence on the long-term air quality and public health implications of the Jamshoro Thermal Power Plant. Long-term satellite-derived $PM_{2.5}$ observations show that elevated particulate pollution extends across the wider study area, indicating sustained exposure among surrounding communities.

The HIA further demonstrates that fuel choice has significant implications for public health. Compared with the current fuel mix, transitioning to a higher domestic lignite blend is projected to substantially increase premature mortality, disease burden, and years of life lost attributable to $PM_{2.5}$ exposure. These findings highlight that fuel procurement decisions should consider not only energy security and operational

costs but also long-term health and environmental consequences.

Together, the long-term PM_{2.5} analysis, quantitative HIA, and evidence on fugitive emissions indicate that the environmental baseline established in the 2013 EIA does not reflect present-day conditions. Updating the EIA with contemporary air quality data, a quantitative HIA, current operating conditions, and assessment of fugitive emissions would provide a more robust basis for future operational and policy decisions.

Recommendations

Based on the findings of this assessment, the following actions are recommended for consideration by the relevant project and regulatory authorities:

1. Undertake a comprehensive revision of the 2013 EIA to incorporate long-term baseline air quality data, a quantitative HIA, and current operational conditions, ensuring that future decisions are informed by present-day environmental and public health evidence.
2. In future environmental assessments, consider emissions from other major sources in the surrounding airshed and explicitly quantify fugitive dust emissions from coal transport, storage, handling, and ash management alongside stack emissions, while assessing the adequacy of existing mitigation measures.
3. Expand long-term ambient air quality monitoring in communities surrounding the Jamshoro Thermal Power Plant, including continuous monitoring of PM_{2.5}, PM₁₀, and other priority pollutants, to improve exposure assessment and evaluate mitigation effectiveness.
4. Future decisions on fuel switching, plant modifications, or operational changes should explicitly consider public health impacts alongside technical, environmental, and economic factors to support more informed and sustainable decision-making.

Implementing these recommendations would support a more comprehensive understanding of the environmental and public health impacts of thermal power generation in Jamshoro and help ensure that future energy decisions are informed by the best available scientific evidence.

References

- Asian Development Bank. (2012). *Power sector rehabilitation project: Rehabilitation of Jamshoro Thermal Power Station—Environmental impact assessment*. <https://www.adb.org/projects/documents/pakistan-46218-001-0>
- Asian Development Bank. (2013). *Jamshoro Power Generation Project: Environmental impact assessment*. <https://www.adb.org/projects/47094-001/main>
- Asian Development Bank. (2024). *Jamshoro Power Generation Project: Environmental impact assessment addendum*. <https://www.adb.org/projects/documents/pak-47094-001-eia-0>
- Center for International Earth Science Information Network (CIESIN), Columbia University. (2018). *Gridded Population of the World, Version 4 (GPWv4): Population density adjusted to match 2015 revision UN WPP country totals, Revision 11* [Data set]. NASA Socioeconomic Data and Applications Center. <https://doi.org/10.7927/H4F47M65>
- Cropper, M. L., Gamkhar, S., Malik, K., Limonov, A., & Partridge, I. (2012, June 26). *The health effects of coal electricity generation in India* (Resources for the Future Discussion Paper No. 12-25). Social Science Research Network. <https://doi.org/10.2139/ssrn.2093610>
- Dawn. (2026, July 30). *Thar coal to run 660MW Jamshoro project*. <https://www.dawn.com/news/2019346/thar-coal-to-run-660mw-jamshoro-project>
- Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, 37(12), 4302–4315. <https://doi.org/10.1002/joc.5086>
- GBD 2023 Causes of Death Collaborators. (2025). Global burden of 292 causes of death in 204 countries and territories and 660 subnational locations, 1990–2023: A systematic analysis for the Global Burden of Disease Study 2023. *The Lancet*, 406(10513), 1811–1872. [https://doi.org/10.1016/S0140-6736\(25\)01917-8](https://doi.org/10.1016/S0140-6736(25)01917-8)
- Global Energy Monitor. (2026, October 27). *Jamshoro power station*. https://www.gem.wiki/Jamshoro_power_station

Government of Pakistan, Pakistan Environmental Protection Agency. (2010). *National Environmental Quality Standards for ambient air* (S.R.O. 1062(I)/2010). <https://environment.gov.pk/SiteImage/Misc/files/Rules/SRO2010NEQSAirWaterNoise.pdf> -

Government of Sindh. (2014). *Sindh Environmental Quality Standards for ambient air* (Notification No. EPA/226/ADMIN/2014). <https://www.scribd.com/document/557982026/Sindh-Environmental-Quality-Ambient-Text-Form>

Ghumman, M. (2024, July 2). *Conversion of imported coal-fired power plant to Thar coal: KE initiates techno-commercial study*. Business Recorder. <https://www.brecorder.com/news/40310711>

Guttikunda, S. K., & Jawahar, P. (2014). Atmospheric emissions and pollution from the coal-fired thermal power plants in India. *Atmospheric Environment*, 92, 449–460. <https://doi.org/10.1016/j.atmosenv.2014.04.057>

Kiani, K. (2013, January 23). *CCI approves 600MW coal-based power project*. Dawn. <https://www.dawn.com/news/780979/cci-approves-600mw-coal-based-power-project>

Myllyvirta, L., & Suarez, I. (2020, December 20). *Air quality & health impacts of coal-fired power in the Philippines*. Centre for Research on Energy and Clean Air. <https://energyandcleanair.org/publication/air-quality-health-impacts-of-coal-fired-power-in-the-philippines/>

United Nations Department of Economic and Social Affairs, Population Division. (2024). *World population prospects 2024: Summary of results* (UN DESA/POP/2024/TR/NO. 9). <https://population.un.org/wpp/>

van Donkelaar, A., Hammer, M. S., Bindle, L., Brauer, M., Brook, J. R., Garay, M. J., Hsu, N. C., Kalashnikova, O. V., Kahn, R. A., Lee, C., Levy, R. C., Lyapustin, A., Sayer, A. M., & Martin, R. V. (2021). Monthly global estimates of fine particulate matter and their uncertainty. *Environmental Science & Technology*, 55(22), 15287–15300. <https://doi.org/10.1021/acs.est.1c05309>

Zhou, Y., Levy, J. I., Evans, J. S., & Hammitt, J. K. (2006). The influence of geographic location on population exposure to emissions from power plants throughout China. *Environment International*, 32(3), 365–373.
<https://doi.org/10.1016/j.envint.2005.08.028>

World Health Organization. (2021). *WHO global air quality guidelines: Particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*.
<https://doi.org/10.24>