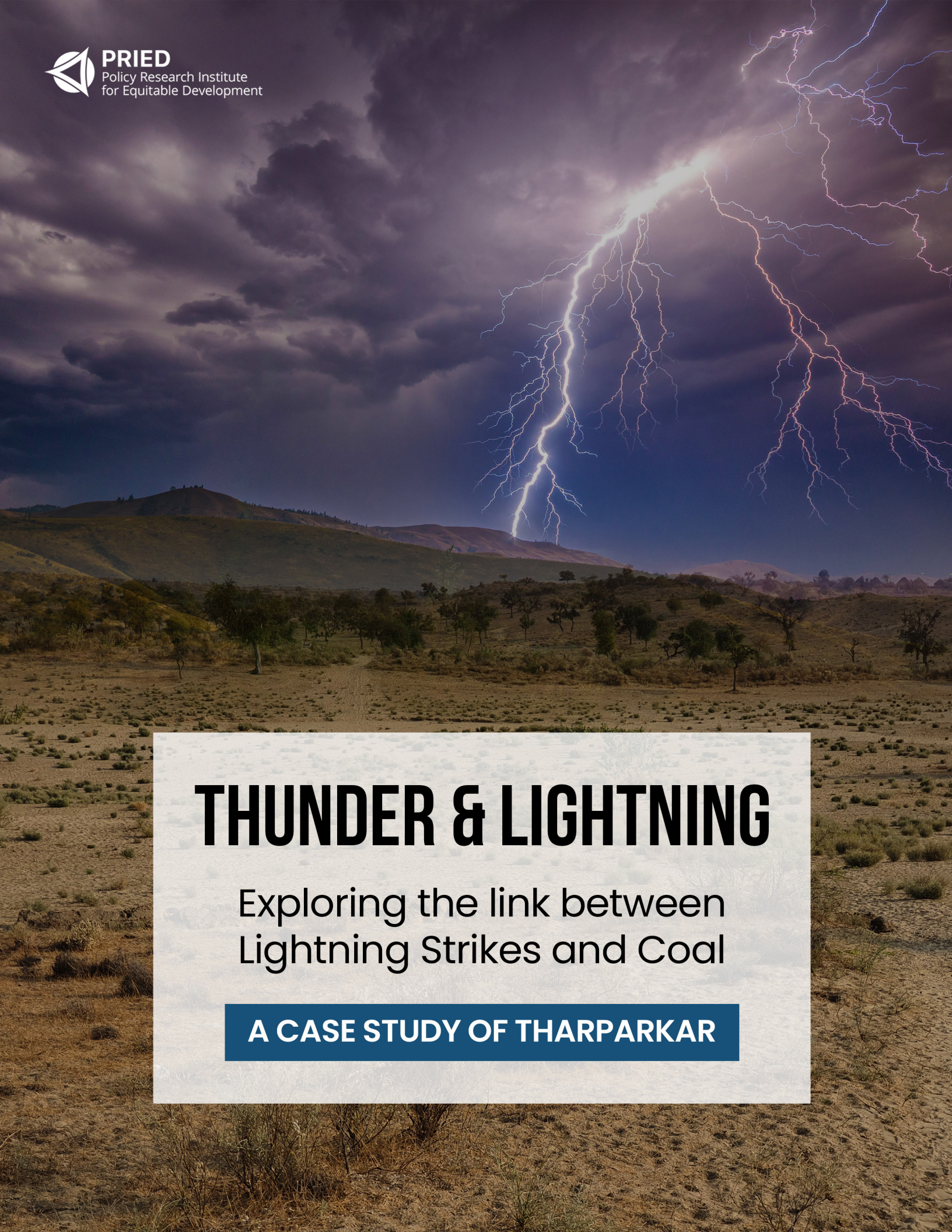

PRIED
Policy Research Institute
for Equitable Development

THUNDER & LIGHTNING

Exploring the link between Lightning Strikes and Coal

A CASE STUDY OF THARPARKAR

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Table of Content

List of Figures

Glossary

Adiabatic Process	is the transfer of energy without transfer of heat or mass to the surrounding.
Precipitation	is water that falls from the clouds towards the ground, especially as rain or snow; but even hail and sleet are types of precipitation.
Thermodynamics	is an important branch of physics that tells us that energy can neither be created nor destroyed; it can just be converted from one form to another.
Anthropogenic Emissions	are emissions of greenhouse gases (GHGs) caused by human activities such as the burning of fossil fuels, deforestation, land use changes, livestock, etc.
Hygroscopic Molecule	A hygroscopic substance of a molecule can absorb or adsorb water from its surroundings.
Ionosphere	it is the ionized part of the upper atmosphere of Earth extending from about 48 to 965 km above sea level.
Troposphere	is the lowest layer of the atmosphere that starts at ground level and extends upwards to an average of 13 kilometer.
Cloud Condensation Nuclei	also known as cloud seeds are small particles typically one-hundredth the size of a cloud droplet on which water vapor condenses and are key to making clouds, fog, haze, rain and other forms of precipitation.
Air Saturation Point	it is the temperature at which the air becomes saturated, and the relative humidity reaches 100%.
El Niño and La Nina	are the warm and cool phases of a recurring climate pattern across the tropical Pacific—the El Niño-Southern Oscillation, or "ENSO" for short.
Mesoscale Convective Systems	are organized groupings of thunderstorms in the tropics and mid-latitudes that span thousands of square kilometers (km).
Localized Air Mass Thunderstorms	are local thunderstorms that are mostly vertical in structure, relatively short-lived, and usually do not produce violent weather on Earth.
Tropical Climate	is a one where the temperature is high and humid throughout the year.
Updraft and Downdraft	the upward moving air in a thunderstorm is known as the updraft, while downward moving one is the downdraft.
Global Oceanic Circulation	is the movement of a large mass of water both at and below the surface, determined by atmospheric circulation patterns, variation in the amount of sunlight absorbed with latitude, and the water cycle.
Global Atmospheric Circulation	is the movement of air around the planet, which creates winds across the planet as air moves from areas of high pressure to areas of low pressure.

List of Abbreviations

Cloud Condensation Nuclei	CCN
Greenhouse Gases	GHGs
Indicative Generation Capacity Expansion Plan	IGCEP
National Disaster Management Authority	NDMA
Pakistan Meteorological Department	PMD
Thar Coalfield Block	TCB

Introduction

Until just a few decades ago, many viewed climate change as a distant, slow-moving crisis. That perspective has shifted dramatically, especially in Pakistan, which now ranks among the most vulnerable countries to global warming. [1]

In recent years, Pakistan has experienced severe weather anomalies, including intense heat, torrential rains, and melting of glaciers, among others. The country has been struck by a series of disasters, such as glacial lake outburst floods (GLOFs),[2] forest fires,[3] riverine and flash floods,[4] hill torrents, winters with barely any snow, and heatwaves.[5]

Among the list is yet another anomaly which has, largely, escaped the attention of climate experts -- a significant rise in thunderstorms and lightning strikes in the district of Tharparkar in Sindh, especially in areas where coal mining is happening and where coal-fired power plants are generating electricity.

In fact, this year's Climate Change Performance Index (CCPI)[6] Pakistan was found to be "very low" in renewable energy use, and "high" in GHG emissions and conventional energy use. This index compares the climate performance of 63 countries (Pakistan being one of them) with the European Union (EU) in four categories: GHG emissions, renewable energy, energy use and climate policy.

Killer coal

Coal has a bad rap around the world because it emits toxic substances that cause death and disease. While we do not have data to know how many Pakistanis die every year from it, a recent study[7] in the US attributed the death of 460,000 Americans in the past two decades, to coal-fired power plants.

"Air pollution from coal is much more harmful than we thought, and we've been treating it like it's just another air pollutant," said the study's lead author, Lucas Henneman, an assistant professor in the Sid and Reva Dewberry department of civil, environmental and infrastructure engineering at George Mason University.[8]

That is why many countries are trying to transition away from coal. By 2050 nearly one million coal miners will be laid off due to closure of mines according to Global Energy Monitor's 2023 report.[9]

1 https://unhabitat.org/sites/default/files/2023/06/4._pakistan_country_report_2023_b5_final_compressed.pdf
2 https://www.sciencedirect.com/science/article/abs/pii/S2212420922006112
3 https://www.globalforestwatch.org/dashboards/country/PAK/?category=fires
4 https://www.sciencedirect.com/science/article/pii/S2666592123000641
5 https://www.reuters.com/world/asia-pacific/pakistan-temperatures-cross-52-c-heatwave-2024-05-27/
6 https://ccpi.org/country/pak/
7 https://www.science.org/doi/10.1126/science.adf4915
8 https://www.theguardian.com/environment/2023/nov/23/coal-power-plants-deaths-pollution
9 https://globalenergymonitor.org/wp-content/uploads/2023/09/GEM_Coal_Mine_Employment_2023.pdf

Why doing coal now?

A little late in the day, in Pakistan, in 2014,[10] former prime minister Nawaz Sharif inaugurated coal extraction from Block II, in Sindh's Tharparkar district, by the Sindh Engro Coal Mining Company (SECMC), a joint venture between the Sindh government and Engro Powergen, although mining began in 2016. Dr Abid Suleri, executive director of the Islamabad-based think tank Sustainable Development Policy Institute (SDPI), had, likened this approach to "investing in an old gramophone".[11]

One of the reasons for mining coal was that serious power outages were crippling the industry in the early 2010, threatening to bring down the Pakistan Muslim League -N which had won elections in 2013 with the promise to wipe out power outages by 2017.[12]

Talking to Thomson Reuters Foundation in 2017, Shamsuddin Shaikh, the former head of the SECMC, admitted coal to be "the worst fossil fuel there is" but defended Pakistan's decision to mine it.[13] "Pakistan needs electricity – its GDP is currently affected by the lack of power", he said. His company was mining one percent of the deposits in one of 13 investment blocks, stretching over 9,000 sq km of Tharparkar with 158.75 billion tonnes of lignite coal reserves.

Today, much of the local coal used in electricity production comes from two coalfields block in Tharparkar -- Thar Coalfield Block-I and II (TCB-I and TCB-II) with estimated 7.8 and 3.8 million tonnes respectively.[14]

The share of local coal in Pakistan's energy generation mix, in 2024, is 11.64 percent while imported coal accounts for 3.93 percent of the electricity generation – as reported in the latest iteration of NEPRA's State of the Industry Report 2024.[15]

More carbon equals more lightning, say villagers

Not too long ago, the indigenous community celebrated the arrival of monsoons because the rain metamorphosed the dusty, arid, drought-like land into a vibrant landscape of lush green. The parched land would become fertile enough for locals to grow crops, and the dormant pasture grass and trees would thrive once again.

Since coal mining began in the Thar desert, the virgin landscape has changed. The fleeting but rare display of nature's fury – lightning – is now a frequent visitor. When it rains, the villagers fear it will bring death and destruction, so they avoid leaving their huts during storms.

The otherwise resilient residents accustomed to enduring seasons of harsh droughts and fleeting rains, found themselves grappling with a new and terrifying adversary, and almost always a harbinger of calamity, leaving a trail of devastation in its wake. The community, heavily reliant on subsistence farming and livestock, find themselves trapped in a cycle of loss with each storm exacerbating their suffering.

10 https://www.gem.wiki/Thar_Coal_Mine
11 https://www.theguardian.com/global-development/2017/feb/27/pakistan-coal-energy-needs-thar-desert
12 https://www.dawn.com/news/1167563
13 https://news.trust.org/item/20170227100020-hhhfg/
14 https://acjce.com/wp-content/uploads/2022/10/Research-Study-Thars-Changing-Hydrology-1.pdf
15 https://nepra.org.pk/publications/State%20of%20Industry%20Reports/State%20of%20Industry%20Report%202024.pdf

This prompted a study to investigate and determine whether there is a genuine link between air pollution from coal mining and power generation and the associated methane emissions to lightning strikes and human vulnerability.

To get a snapshot of how this community is reeling from these lightning strikes (when huge electricity is produced and moves from clouds to the ground and hits something), a team of Policy Research Institute for Equitable Development (PRIED) conducted field surveys in the first half of 2024 in various villages in Tharparkar to record incidents of cloud-to-ground lightning strikes. The team also conducted interviews with villagers affected by lightning strikes – directly or indirectly – and representatives of their communities and recorded data of the fatalities which the villagers confirmed were caused by lightning strikes between November 2019 and July 2024.

Take the case of Muhammad Bachal from Hingorja. Likening the roar of thunder to "multiple planes flying overhead" when lightning struck on November 26, 2023, he said, it fell on a nearby electric pole twice, which fell on his house, severely damaging the six vital solar panels that powered the village's water pump. His cow, tethered in the shed, was also injured. He had to undertake a costly trip to the city for repairs of the solar panel and veterinary care for his animal.

In Misri Shah, Bhagat Tajo, blind and now bedridden, continues to undergo unimaginable sorrow after a lightning strike killed his wife, Koinari, the family's sole caretaker, as does Liaqat Junejo in Choncha who also lost his son Qalandar to the bolt. "To be honest, this tragedy has drained all the joy and happiness from my life, and nothing seems to bring me any comfort anymore," said Junejo, echoing the sentiments of Tajo's family.

When lightning strike killed 17 goats of Rehmatullah Thebo, of Ismail Sangrasi village, the tragedy was so immense, he said, "it felt as though the ground had shifted beneath me". The entire village gathered to offer their condolences upon hearing the news. According to the herder, the loss of livestock has been tremendous and has set his family back by a decade. "People say it's just bad luck, but I don't believe that!" he said, adding: "These weather events have coincided with the increase in coal mining, and over the past five years, their frequency and severity have risen," he insisted. The wisdom of 93-year-old Nebho Kolhi echoes through the desolate landscape of how the centuries-old weather pattern has changed leaving unprecedented destruction.

Although lacking scientific evidence, there is a firmly held belief among villagers that the increasing frequency and intensity of these storms are linked to coal mining operations. These operations, which were supposed to bring progress, have instead caused environmental disruption and increased the villagers' hardships. They are witnessing changes in ancient rainfall patterns and attributing their suffering to the toxic emissions from coal-fired plants.

The field visit was supported by a desk analysis and literature review to identify potential causes of lightning. Additionally, PRIED's research team conducted interviews with experts—such as meteorologists, disaster management professionals, and researchers—to investigate the scientific basis behind these prevalent beliefs.

Data analysis

The following data on lightning strikes in Tharparkar illustrates their effects on local vegetation, livestock, human lives, and livelihoods, with a particular emphasis on the proximity of the affected areas to coal mines and power plants.

Serial #	VILLAGES	DISTANCE FROM COAL MINE (IN KILOMETERS)	DISTANCE FROM POWER PLANT (IN KILOMETERS)	TOTAL NUMBER OF STRIKES IN THE VILLAGE	DATE OF THE FATAL STRIKES	SITE OF THE FATAL STRIKE
						
01	ISMAIL SINGRASI, ISLAMKOT	28	26	27	26-11-2023	Cattle Farm
02	SOOMAR JI DHANI, ISLAMKOT	20	18	23	26-11-2023	Grazing land
03	RANPAARYO, ISLAMKOT	25	22	18	26-11-2023	House
04	VEERA WAH, NANGARPARKAR	58	62	21	26-11-2023	Grazing land
05	VAORRI DORA, CHACHRO	70	73	25	26-11-2023	Grazing land
06	HAARHO, NANGARPARKAR	150	153	13	26-11-2023	Grazing land
07	BAPRARIYO, CHACHRO	32	30	19	26-11-2023	Grazing land
08	MEHANDRO JO PAAR, CHACHRO	70	68	5	26-11-2023	House
09	BAPRARIYO, CHACHRO	32	30	19	26-11-2023	House
10	JAM JI WAND, K.G.SHAH,ISLAMKOT	1	2	32	26-11-2023	Grazing land
11	BHOOTARIYO , ISLAMKOT	53	55	8	09-07-2023	House
12	PANHIYARI, ISLAMKOT	45	48	7	20-07-2023	Field

Serial #	VILLAGES	DISTANCE FROM COAL MINE (IN KILOMETERS)	DISTANCE FROM POWER PLANT (IN KILOMETERS)	TOTAL NUMBER OF STRIKES IN THE VILLAGE	DATE OF THE FATAL STRIKES	SITE OF THE FATAL STRIKE
						
13	ISLAMKOT	18	15	5	20-07-2023	Kareema Colony
14	MITHRIO BHATTI, MITHI	43	40	6	22-07-2023	House
15	VEJHIYAR, ISLAMKOT	42	40	9	09-07-2023	Grazing land
16	SAKRIYO BAJEER, ISLAMKOT	22	19	2	26-11-2023	Village
17	GORNAO, ISLAMKOT	19	16	30	26-11 -2022	House
18	GOARANO, ISLAMKOT	19	16	30	26-11-2023	House
19	VAKRIYO, ISLAMKOT	10	9	16	26-11-2023	Village
20	SIRAJ DIN JO TAR, ISLAMKOT	30	23	5	26-11-2023	Grazing land
21	HOTHI JO TAR, ISLAMKOT	27	25	7	26-11 -2023	Village
22	DONDHI JO TAR, DIPLO	80	83	15	26-11-2023	Grazing land
23	ROHAL, DIPLO	70	68	11	26-11-2023	Grazing land
24	MANJU JI DHANI	110	107	8	26-11-2023	House
25	ALL OVER THARPARKAR	-	-	25	14-11-2019	Different areas
26	ALL OVER THARPARKAR	-	-	-	26-11-2020	Different areas
27	MEER MOHAMMAD DHAKLO	25	22	20	10-07-2024	Grazing land
28	ASHOK BHEEL / KHARIO GHULAM SHAH	2	11	35	10-07-2024	Grazing land

Serial #	VILLAGES	DISTANCE FROM COAL MINE (IN KILOMETERS)	DISTANCE FROM POWER PLANT (IN KILOMETERS)	TOTAL NUMBER OF STRIKES IN THE VILLAGE	DATE OF THE FATAL STRIKES	SITE OF THE FATAL STRIKE
						
29	BILAL /GUL HERAAR	32	35	15	10-07-2024	Grazing land
30	DIN MOHAMMAD / ROHAJ	27	25	20	10-07-2024	Grazing land
31	MOOL CHAND / DOBAHAR	15	18	25	10-07-2024	Grazing land
32	LACHMAN BHEEL / HOTHI JO TAR	25	22	18	18-07-2024	Grazing land
33	LACHMAN BHEEL / HOTHI JO TAR	17	14	19	18-07-2024	Grazing land
34	CHEHNO MITHRIO BHATTI	40	37	15	18-07-2024	Grazing land
35	ALL STRIKES IN NANGARPARKAR TALUKA	70	68	350	18,19-07-2024	Grazing / House / Tree
36	ALI / MEHYARI	22	22	15	18-07-2024	Hut (Chonro)
37	PEELURO SAMEJA	70	68	25	18-07-2024	Grazing land
38	HERO THAKUR / FATEH JI DHANI NANGARPARKAR	85	87	35	18-07-2024	Waaro
39	SGER MOHAMMED / DHEENKARIO	60	59	25	18-07-2024	Grazing land
40	KOLHI VERI NANGARPARKAR	80	78	30	18-07-2024	House
41	POONI W/O PHOTO KOLHI BORLI MOSEPOTA	40	37	35	18-07-2024	House
42	WIFE AND SON OF MEGHRAJ / FULPURO	85	83	40	18-07-2024	House
43	CHANDO MAL /ASO BHEEL DHANI / CHACHRO	65	67	30	03-07-2024	Grazing land
44	RANCHANI CHACHRO	55	57	34	04-07-2024	Grazing land

Serial #	VILLAGES	DISTANCE FROM COAL MINE (IN KILOMETERS)	DISTANCE FROM POWER PLANT (IN KILOMETERS)	TOTAL NUMBER OF STRIKES IN THE VILLAGE	DATE OF THE FATAL STRIKES	SITE OF THE FATAL STRIKE
						
45	KERLO CHACHTO	70	67	40	18-07-2024	House
46	NEW WARVAI	11	9	50	18-07-2024	House

Casualties

Humans	Animals/Livestock	Buildings and Infrastructure	Vegetation/trees/crops
91 Humans	372 Goats 19 Camels 64 Sheep 01 Buffalo 01 Cow	4 Huts + Household Materials	200 kg (Baajra) 12 Tree (Jaar) 05 (Kandi)

Between 2019 and 2024, there were 91 human casualties reported from 46 lightning incidents. Of these, 19 occurred in the winter and 27 in the monsoon month of July. The data indicates that Islamkot is a potential hotspot for lightning strikes, being located 15 to 18 km from the TCB-I mining and power plant sites and 26 to 28 km from the TCB-II sites. Notably, many incidents, including some with multiple fatalities, have been recorded in this area.

The lightning bolts also harmed animals and damaged property. A total of 457 animals, including goats, sheep, camels, and cows, were reported dead or injured. Property damage included the destruction of huts and houses, as well as the burning of crops and trees, which severely impacted the livelihoods of the affected communities.

Figures 1-A, B, C, and D: Images Showing Loss of lives and livestock in Tharparkar due to cloud-to-ground lightning

Understanding storms

To understand the reason for lightning incidents, it is essential to understand the physical mechanism behind the formation of lightning in clouds in the atmosphere. This will give a better understanding of a possible correlation between lightning strikes and nearby coal mining and power generation.

What is lightning?

According to Britannica, lightning is an electrical discharge that occurs between a cloud and the Earth's atmosphere, generated by a thunderstorm.

How does lightning develop?

Water droplets and ice particles inside a cloud carry electrical charges, both positive and negative. Lightning usually occurs when too many charges of one kind build up in a cloud. There are also both negative and positive charges on the ground. Because opposite charges attract, excess negative charges in a cloud may be drawn to the positive charges on the ground. That is when lightning will occur. The same would occur if the charges in the clouds and on the ground were reversed.

In addition to the cloud-to-ground lightning that we are familiar with, lightning can occur within and between clouds, or even between a cloud and the air. The loud sound that follows lightning is called thunder. The electricity from lightning heats the gases in the air and as the latter expand, they make a loud noise.

Lightning types

There are many different types of lightning strikes such as intracloud, intercloud, cloud-to-ground, and ground-to-cloud, among others. The most significant type is cloud-to-ground, where a negatively charged 'fork' travels downward toward the positively charged ground within a millisecond and strikes tall objects or falls on open fields. This strike is returned to the clouds through a return stroke that travels 60,000 miles per second.[16] In the case of intracloud lightning, which is the most common type, the lightning jumps between oppositely charged areas within the same storm cloud. Cloud-to-cloud or intercloud lightning travels from one cloud to another[17],[18].

Cloud Formation

Small hygroscopic (moisture absorbing) one micrometer molecules in the atmosphere made of soil, smoke particles, salt, or ice crystals, are known as cloud condensation nuclei (CCN). These nuclei provide the surface area to which water droplets in the atmosphere attach to and condense to form cloud droplets.

The air pressure also drops as it rises in the atmosphere, causing expansion and cooling through an adiabatic process, where energy is neither created nor destroyed, and the total energy of the system of gases remains constant. Temperature drops by 5.5°F for every thousand-foot increase in elevation, causing the air to eventually reach a saturation point where evaporation becomes equal to condensation. This dynamic interconversion results in constant formation and dissipation of cloud droplets. Higher condensation rates lead to cloud formation in the atmosphere.[19]

Clouds form through two different processes, either when warm air rises, or when the wind forces air to rise. The cumulus, cumulonimbus, mammatus, and stratocumulus clouds form when warmer air rises from the earth's surface, condensing the water vapor in its vicinity and accumulating enough water. The wind blowing over sloping land or mountains rises and cools forming the lenticular and stratus clouds. The altocumulus, altostratus, cirrocumulus, stratocumulus, and stratus clouds are formed as a result of air traveling upwards in low-pressure areas or due to the collision of large air masses at warm and cold fronts.[20]

16 https://www.nssl.noaa.gov/education/svrwx101/lightning/types/
17 https://www.rmets.org/metmatters/types-lightning
18 https://ghrc.nsstc.nasa.gov/home/lightning/home/primer/primer2.html
19 https://www.noaa.gov/jetstream/clouds/how-clouds-form
20 https://scied.ucar.edu/learning-zone/clouds/how-clouds-form

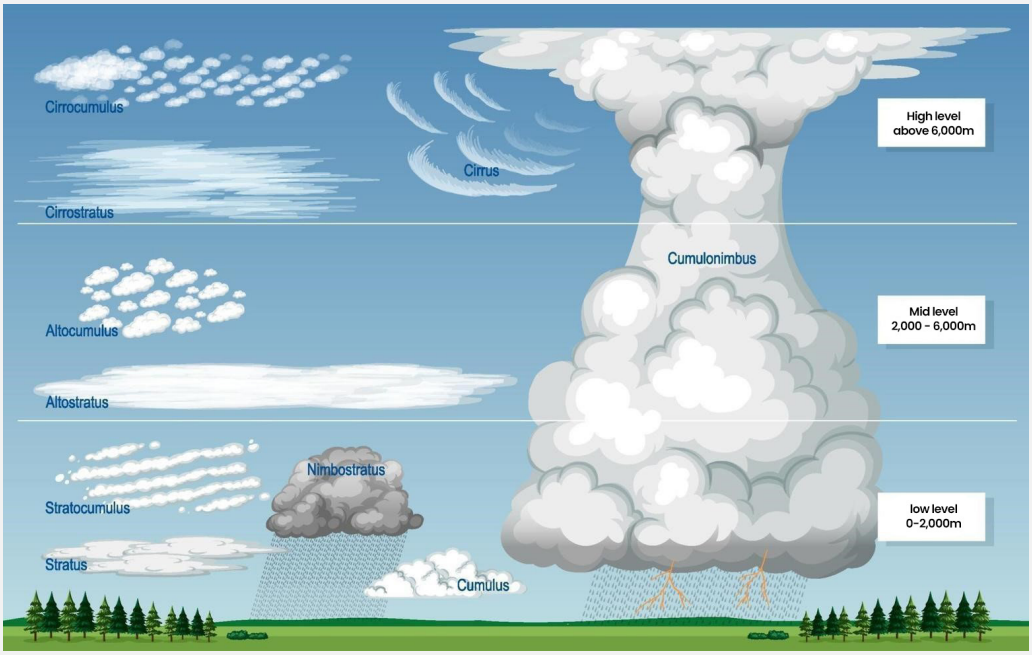

Figure 2: Types of clouds and cloud formation (Source: www.animalia-life.club/qa/pictures/types-of-clouds-diagram)

How lightning strikes?

Ice particles present within clouds collide continuously and break into different-sized particles. The smaller particles acquire a positive charge, which the upward-moving air currents within the clouds carry to the top, while the larger ones are charged negatively and settle at the bottom of the cloud. Once this charge has built up to millions of volts in potential, it is released as lightning from the cloud in one of the many ways mentioned above. The speed and intensity of the vertical airflow are the main factors determining the charging and discharging process during thunderstorms[21],[22].

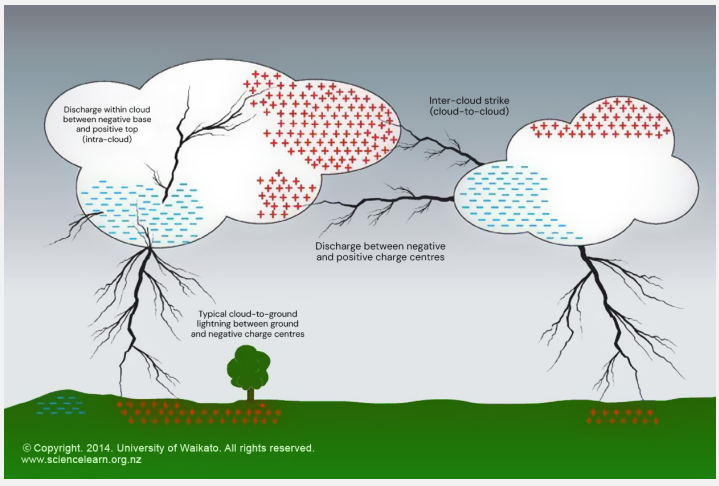

Figure 3: Charge accumulation and the phenomenon of lightning strikes (Source: www.sciencelearn.org.nz/resources/239-lightning-explained)

21 https://ghrc.nsstc.nasa.gov/home/lightning/home/primer/primer2.html
22 https://www.sciencedirect.com/science/article/abs/pii/S0169809517302399

Lightning frequency and possible causes

Several studies[23],[24],[25],[26] highlight the frequency of lightning strikes in South Asia, especially the sub-continent due to its tropical climate. Lightning has been labeled as the 'global tropical thermometer' due to its sensitivity to climate change and its indication of water vapor variability in the troposphere. Asia's monsoon region has received global recognition for its role in water circulation, leading to frequent precipitation and lightning, especially during the summer monsoon season that extends from July to October. Scientific analysis, too, has deduced a direct correlation with thermodynamic factors and shown that the high surface temperatures, wind speed and intensities, excess moisture, and humidity within the South Asian region have led to increased lightning activity[27] .

Global warming and anthropogenic GHG emissions also increase the moisture content in the atmosphere which condenses and increases precipitation due to high vapor pressure leading to extreme weather events and lightning incidents[28],[29],[30],[31]. However, a lesser discussed aspect of lightning strikes is its occurrence in and around coal exploration sites. Anecdotal evidence suggests that coal mines, often situated in regions with high atmospheric moisture, face an increased risk of lightning strikes.

Literature review

Urbanization and industrialization have proven to be key factors in the increased lightning incidents globally. High aerosol concentrations in the atmosphere which form CCN, the precursors of cloud formation, lead to increased precipitation, thunderstorms, and lightning[32],[33],[34],[35],[36].

Mesoscale convective systems (MCSs are large, organized group of thunderstorms that affects a large region all at once) forming in the tropics and mid-latitudes, are also responsible for creating hazardous and extreme weather conditions.[37]

The burning of coal in power plants leads to the accumulation of aerosols in the atmosphere, such as particulate matter less than 2.5 µm in diameter (PM2.5), water vapor, CO_2, SO_2, and NO_2[38],[39]. Substantial literature is available on cloud-to-ground lightning activity in areas near coal mines worldwide.

Tall structures like machinery and exhaust stacks within mining sites create easy discharge paths for electrical energy, akin to tall trees in open fields, while the expansive open areas characteristic of mines increase vulnerability to lightning strikes compared to densely forested regions.

23 https://www.sciencedirect.com/science/article/abs/pii/S0273117721002945
24 https://link.springer.com/article/10.1007/s00704-022-04032-5
25 https://www.tandfonline.com/doi/full/10.1080/19475705.2021.2009922
26 https://www.sciencedirect.com/science/article/abs/pii/S0169809516306950
27 https://www.sciencedirect.com/science/article/abs/pii/S2095927320305697
28 https://www.nature.com/articles/s41598-019-39306-y
29 https://www.nature.com/articles/s44221-023-00107-3
30 https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019GL086875
31 https://www.sciencedirect.com/science/article/pii/S2212094717301068
32 https://journals.ametsoc.org/view/journals/apme/34/7/1520-0450-34_7_1633.xml
33 https://www.sciencedirect.com/science/article/abs/pii/S0169809508002408
34 https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2001gl012990
35 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2003GL017496
36 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2003GL017923
37 https://www.nature.com/articles/s43017-020-0057-7
38 https://www.tandfonline.com/doi/full/10.1080/10962247.2018.1503981
39 https://link.springer.com/chapter/10.1007/978-981-97-1363-9_12

Geographical and weather-related factors further elevate lightning activity near coal deposits, potentially influenced by elevated atmospheric moisture levels and the presence of tall structures like ventilation shafts acting as lightning attractors.

Lightning strikes in coal mines can result in severe consequences, including fires, explosions, and structural damage, necessitating the implementation of robust lightning protection systems to mitigate risks effectively. While coal mines themselves are not inherently linked to lightning phenomena, their geographical context and structural features may amplify the likelihood of lightning strikes, warranting proactive safety measures.[40]

A study[41] was conducted in Northern Georgia, in the United States, to map out the increase in incidents of cloud-to-ground lightning strikes around coal power plants and highways over a period of three years.

As part of this research, 93 counties where sea breeze influence was negligible, and coal plants were functional were shortlisted to study localized air mass thunderstorms as opposed to MCSs. The study utilized statistical modeling to quantify and determine the significance of lightning strikes and distance from the nearest coal mine. A three-fold increase of lightning strike was observed in and around coal power plants and highways in the vicinity. This relationship can be visualized through the graph below:

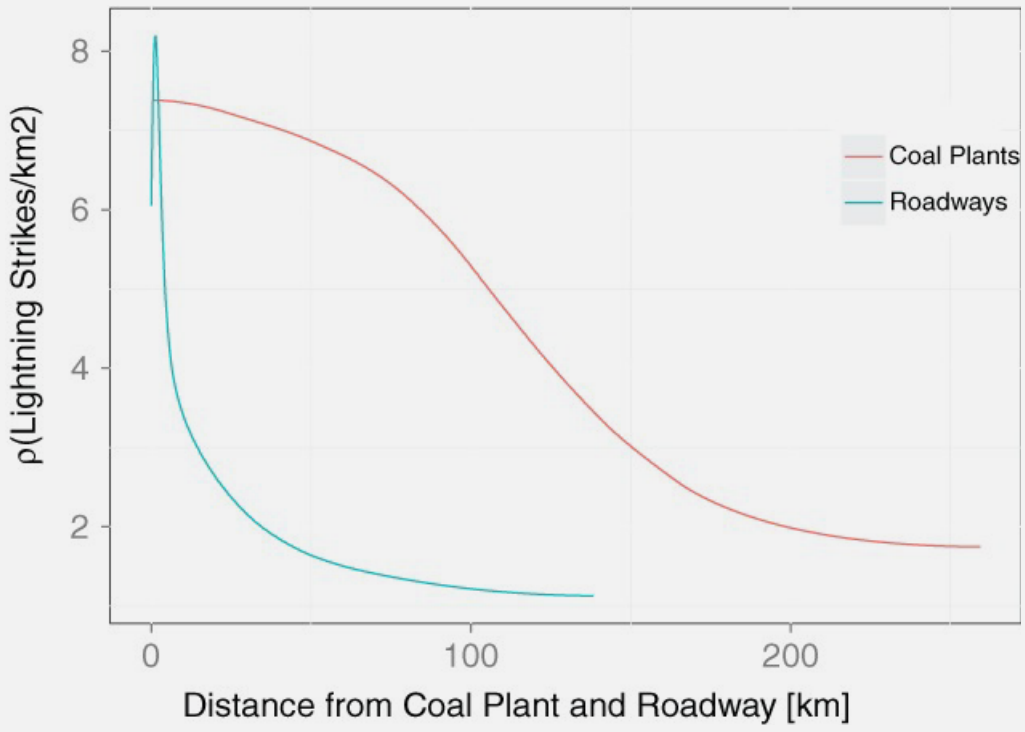

Figure 4: A comparison of lightning flash density as a function of distance from nearest highway and nearest coal plant using 2005 lightning data[42]

The literature also explores the multifaceted impacts of lightning in mining operations, encompassing risks such as electrical shocks, premature detonations, and methane ignitions. Researchers have explored the mechanisms of lightning penetration through theoretical analysis and empirical data collected from extensive measurement

40 https://ieeexplore.ieee.org/abstract/document/7791377
41 https://rmets.onlinelibrary.wiley.com/doi/10.1002/asl2.446
42 https://rmets.onlinelibrary.wiley.com/doi/10.1002/asl2.446

programmes, quantified surge characteristics, assessed methane and detonator sensitivities and proposed comprehensive risk evaluation frameworks tailored for proactive safety management.[43]

The literature, thus, highlights the intricate interactions between lightning energy and mine infrastructure, underscoring the need for effective mitigation measures to minimize the risk of lightning-induced fires in coal mines and their surrounding areas.

The experts' verdict

To get a clearer understanding of lightning strikes and whether they might be connected to coal mining in Tharparkar, we reached out to experts in atmospheric sciences, disaster management, and meteorology. These professionals shared their insights, drawing on their extensive experience and knowledge in their fields.

Chief Meteorologist Dr. Muhammad Afzaal of the Pakistan Meteorological Department explained that from July to September, Pakistan's monsoon season brought more rain and lightning due to dense clouds building up electrical charges.

While he couldn't confirm a direct link between lightning and greenhouse gases, he noted that a warmer, more humid climate, influenced by gases like methane and carbon monoxide, might have an indirect effect. He stressed the importance of understanding lightning to prevent damage and advised locals on safety measures, such as seeking shelter and using techniques like crouching low and bathing in mud to reduce the risk of lightning strikes.

Dr. Syed Muhammad Tayyab Shah, Lead Risk Assessment at the National Disaster Management Authority (NDMA), believed that extreme weather events are influenced by Earth's natural atmospheric and climatic cycles. He noted that global warming was exacerbating these events by causing more frequent weather anomalies. Key factors included global oceanic and atmospheric circulation, where warm ocean waters moved toward colder areas, these affected weather patterns. Additionally, the rise and cooling of hot air masses, along with friction between charged particles, contributed to lightning formation. Dr. Shah also highlighted that extreme weather events like flooding, tsunamis, and heatwaves were influenced by transitions between La Niña and El Niño.

Referring to the lightning strikes in Tharparkar, and describing lightning as a natural phenomenon, he stated that coal ash, being a poor conductor of charge, should theoretically reduce lightning formation.

The PRIED team also interviewed Ms. Ona Strikas, a researcher at Florida State University, whose postgraduate research investigated the rising frequency of lightning strikes near coal plants and highways in Northern Georgia, USA. She found a clear link between increased lightning strikes and the proximity to coal power plants and highways in Northern Georgia. Her research indicated that atmospheric pollution and particulate matter from these sources contribute to more frequent lightning. She also suggested that greenhouse gas emissions from coal plants and traffic cause localized warming, which increases atmospheric moisture, leading to more cloud formation and lightning events.

43 https://elibrary.ru/item.asp?id=5605513

Conclusion

Lightning is a natural climatic phenomenon that has been well-documented across the globe as part of Earth's climate patterns.

Although, the exact mechanism behind thunderstorms and cloud formation, leading to incidents of cloud-to-ground lightning strikes have yet to be determined, there are many plausible explanations presented through scientific exploration, citing the relative humidity in the troposphere, air pressure, wind speed and shear, cloud updrafts, as well as atmospheric particulate matter concentrations.[44], [45], [46]

Studies also attribute rising urbanization and associated GHG emissions (and global warming) to increased atmospheric humidity. Additionally, the rise in Earth's average surface temperature is expected to heighten the intensity and frequency of extreme events such as thunderstorms.

Limited research on lightning strikes has identified several factors contributing to their frequency. These include humidity and moisture, global warming driven by greenhouse gas emissions, particulate matter, air pollution, and disruptions in the Earth's natural cycles, which collectively lead to more extreme weather events.

Victims of lightning strikes in Tharparkar, interviewed and mapped by PRIED, consistently report a rise in lightning frequency since the onset of mining activities and the operation of coal power plants in the region. While a direct correlation between lightning strike incidents and coal mining or power generation cannot be established, it does not entirely rule out the possibility.

Experts and literature reviewed suggest that high atmospheric humidity increases the likelihood of lightning strikes by enhancing cloud formation. Furthermore, coal mining was contributing additional moisture into the atmosphere, further elevating the risk.

In addition, GHGs particularly methane, emitted during mining is a known precursor to moisture formation in the atmosphere leading to cloud formation and eventually leading to localized lightning activity.

A thorough investigation is needed to establish a connection between mining activities, coal power generation, and lightning strikes in the region through a dedicated quantitative research study.

44 https://elib.dlr.de/111089/
45 https://www.pnas.org/doi/abs/10.1073/pnas.1707603114
46 https://nhess.copernicus.org/articles/20/2463/2020/

Recommendations

Based on the current study carried out within Tharparkar, a few recommendations can be considered for implementation at the community as well as the government and policy level:

- A robust early warning system should be set up in areas prone to lightning incidents, in partnership with the NDMA, to deliver timely alerts, especially during the monsoon season.
- Lightning arrestors and rods should be installed on tall towers and buildings in the region to safely direct lightning to the ground, reducing the risk of it striking open areas and homes.
- Compensation processes for lightning strike incidents should be simplified for residents and address not only loss of life but also damages to livelihoods, livestock, and personal belongings.
- Awareness campaigns should be launched in the Tharparkar region to educate communities about the dangers of lightning strikes, their peak periods, and the proper safety measures to follow.
- The government should explore cleaner alternative energy options for production.
- The Sindh Environmental Protection Authority, in partnership with a university, should assess GHG emissions from coal mining and power plants to determine whether these emissions contribute to localized warming and increased atmospheric humidity.
- A study should assess if anthropogenic factors such as GHG emissions, particulate matter, dust, ash, and humidity correlate with increased lightning incidents.

Annex A

Interview Questions for Experts

1. Have you observed any correlations between coal mining activities and lightning strike occurrences?
2. To what extent coal mining operations potentially influence local weather patterns or lightning strike risk?
3. Are there any specific coal mining practices or conditions that could contribute to increased lightning strike risk?
4. Are there any specific circumstances or characteristics near coal mines that may make them more prone to lightning strikes?
5. Are there any regional weather phenomena that could impact lightning strike risk near coal mining sites?
6. Are there any areas where additional data or research would be beneficial to strengthen the understanding of the relationship between coal mining and lightning strikes?

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