Dark and Toxic under the Lamp

Industrial Pollution and Health Damage in Singrauli

VASUDHA A

The Singrauli region produces 16% of coal and 13% of thermal power in India. Various state and non-state institutions have examined the consequent regional pollution. This paper attempts to document the health damage to the regional population. A survey of 4,383 families in southern Sonbhadra district yielded data on select health impacts, which were then mapped to correlate to the industrial gaseous emissions. The consequent economic losses were calculated using the procedure outlined in the Employee's Compensation Act, 1923 and court judgments. These economic externalities borne by the local population range from 23 to 124 times the total environmental compensation that courts have so far ordered industries to pay to the state for environmental remediation.

The author is indebted to the workers of Banwasi Seva Ashram who carried out all the fieldwork and provided observations, insights and suggestions that guided this study.

Vasudha A (*akshintalavasudha@gmail.com*) works at the Hazards Centre, New Delhi.

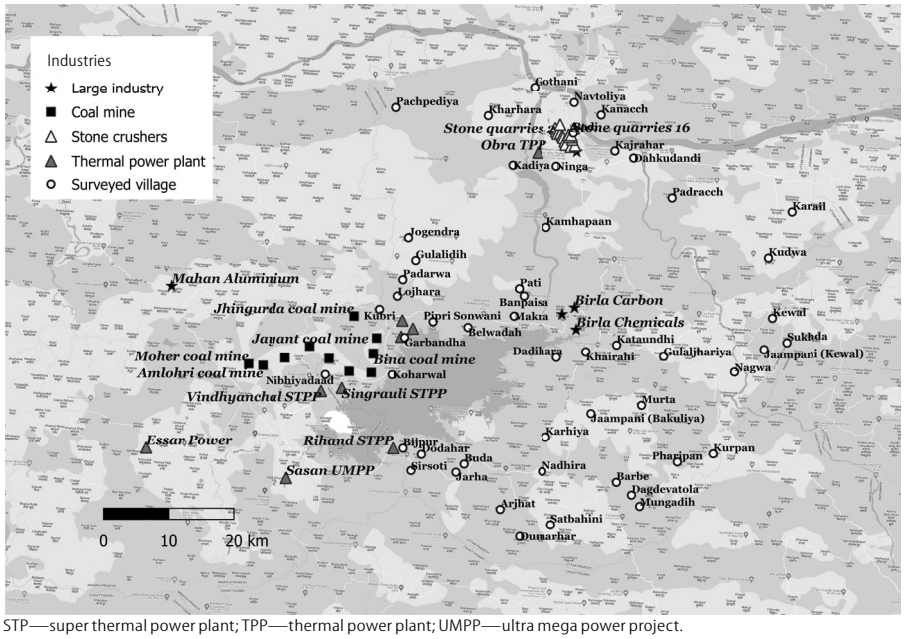
The ongoing crisis of air pollution in Delhi has resulted in a slew of measures by the federal government. This included the closure of six thermal power plants around Delhi in November 2021 (Chaudhary and Pradhan 2021), the phased introduction of 2,300 electric buses (*Livemint* 2022), and the continued expansion of the Delhi Metro network. All these measures have direct implications for the demand and supply of electricity in Delhi, which generates only about 20%–25% of its electricity requirement at upwards of 30,000 gigawatt hours (GWh) (Central Electricity Authority [CEA] 2020; Planning Department 2022).[1] Where, then, does the bulk of Delhi's electricity come from?

It comes from areas such as the Singrauli region, comprising Singrauli district of Madhya Pradesh (MP) and Sonbhadra district of Uttar Pradesh (UP), located at the borders of the respective states (Figure 1, p 48). This region has been called the energy capital of the country and has thermal power plants with a combined capacity of 21,164 megawatts (MW). In addition, there is a captive thermal capacity of 1,782 MW in the industries of the region. The Singrauli region contributed 9.75% of all electricity or 13.4% of thermal power produced in India in 2021.[2] Despite being such an important production centre for the energy requirements of the country, Singrauli itself remains energy poor. As per the 2011 census, 31% of all households in Singrauli district and 29% of households in Sonbhadra district are electrified. Thus, not even 0.4% of the electricity generated in this energy capital reaches the homes of the people inhabiting the region. Yet, they suffer from the negative externalities of this production capacity.

Most energy plants in Singrauli are central and state thermal power plants. The National Thermal Power Corporation Limited alone has three plants with a total capacity of 9,760 MW. Three private thermal power plants—other than aluminium major Hindalco's captive plant at Renusagar—have come up in the past decade. All of this thermal power development in the region occurred after coal was discovered in the 1950s while the flood area of the Rihand Dam was being demarcated. Thermal power plants began to be set up in the region because of the availability of coal and water in close proximity (Vasudha and Prem 2015).

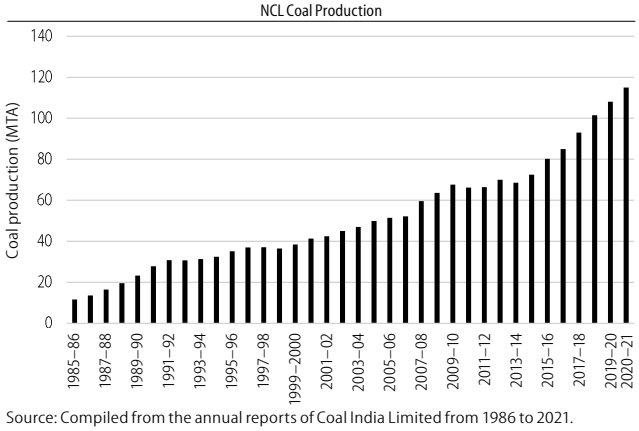
The coal for producing electricity is extracted from the Singrauli coalfields. The Northern Coalfields Limited (NCL) alone extracted about 115 million tonnes, or nearly 16% of India's coal production, in 2020–21 (Ministry of Coal 2021). Figure 2 (p 48) presents the continuous increase in coal mined from Singrauli coalfields since nationalisation, with the rate of

Figure 1: Map of Singrauli with Coal Mines and Large Industries



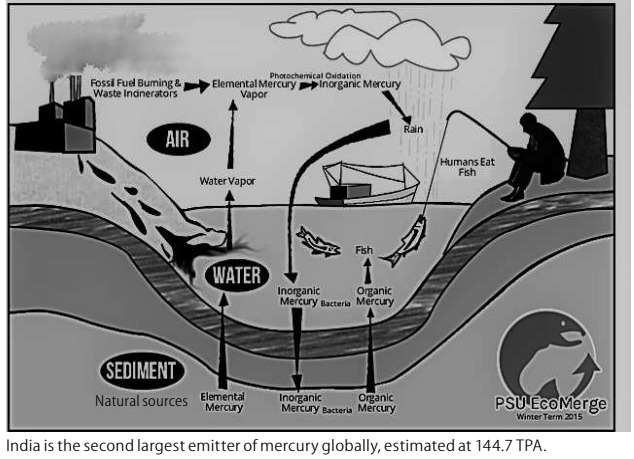
STP—super thermal power plant; TPP—thermal power plant; UMPP—ultra mega power project.
Source: Locations of villages and industries marked on Google Maps using quantum geographic information system.

Figure 2: Increase in Coal Mining in Singrauli Region by NCL, 1985–2020



Source: Compiled from the annual reports of Coal India Limited from 1986 to 2021.

Figure 3: The Mercury Cycle



India is the second largest emitter of mercury globally, estimated at 144.7 TPA. Of this, coal burning is the highest contributor at 84.7 TPA (Sharma et al 2019).
Source: PSU EcoMerge (nd).

mining increasing significantly over the past two decades. These are opencast mines, that is, large open pits with huge dumps of overburden alongside. In June 2021, three people were killed and one critically injured because of overburden slippage from the Khadia coal mine (Sharma 2021).

In addition to coal mining and thermal power plants clustered around the Rihand reservoir, other large industries too add to the pollution load. Hindalco has two aluminium smelters, one of 0.41 million tonnes per annum (MTA) capacity in Sonbhadra and one of 0.36 MTA capacity in Singrauli district. There is one existing cement plant and another one seeking clearance at Dalla in the north of Sonbhadra district.

Coal, Not Just Carbon

Coal is composed of complex mixtures of organic and inorganic compounds. Coal may contain as many as 76 of the 92 naturally occurring elements of the periodic table. These are bound in coal but when coal is burnt, these are released back into the air or land (Schweinfurth 2003). Singrauli region burnt 101.5 million tonnes of coal in 2018.[3] This is about 0.28 million tonnes of coal being burnt every day.

Some of the compounds and elements present in coal are extremely toxic, a number of which are highly toxic heavy metals. When coal is burnt, these elements get released into the environment. Some of them are captured by the various environmental pollution mitigation technologies, such as the electrostatic precipitators and flue gas desulfurisation. Even though these technologies partially capture the pollutants, toxic elements nevertheless remain in the air, water and/or land. Figure 3 depicts how mercury from the thermal power plants enters various waste streams (PSU EcoMerge nd).

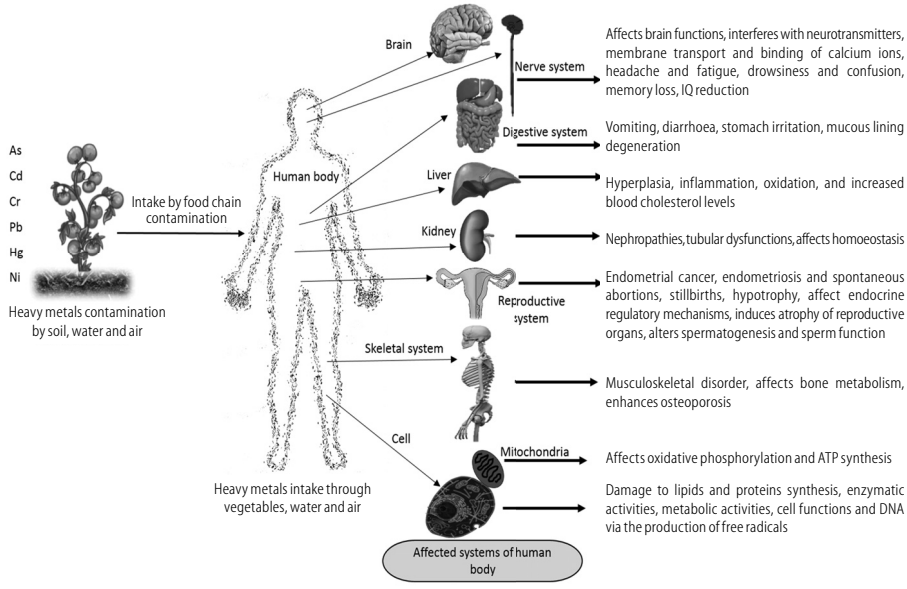
The varying amounts of elements that get released into the environment depend upon the corresponding concentration in

Table 1: $PM_{2.5}$ Values in Singrauli Region in Winter 2017–18

Cluster	Station	Distance	Range Min	Range Max	Average $PM_{2.5}$	% $PM_{2.5}$/ PM_{10}
Obra–Dalla	Obra	Close	35	298	130.1	88.1
	Bari	Close	27	(1,293)*	228.9	85.7
	Dahakudandi	Medium	25	(1,293)*	239.1	90.6
Anpara–Vindhyachal	Anpara	Close	33	273	153.3	83.5
	Basi	Close		No data		
	Chilkadaad	Close	61	375	209.9	86.3
	Faripaan	Far		No data		
Rihand	Bijpur	Close	51	311	118.1	79.8
	Jarha Chetwa	Medium	42	168	89.2	78.1
	Nadhira	Far	35	206	99.1	88.6
Hindalco	Murdhawa	Close	37	164	88.1	86.1
	Govindpur	Medium	25	203	97.0	89.3
	Jharo	Medium	27	274	98.0	85.5
	Kewal	Far	23	98	65.6	76.4

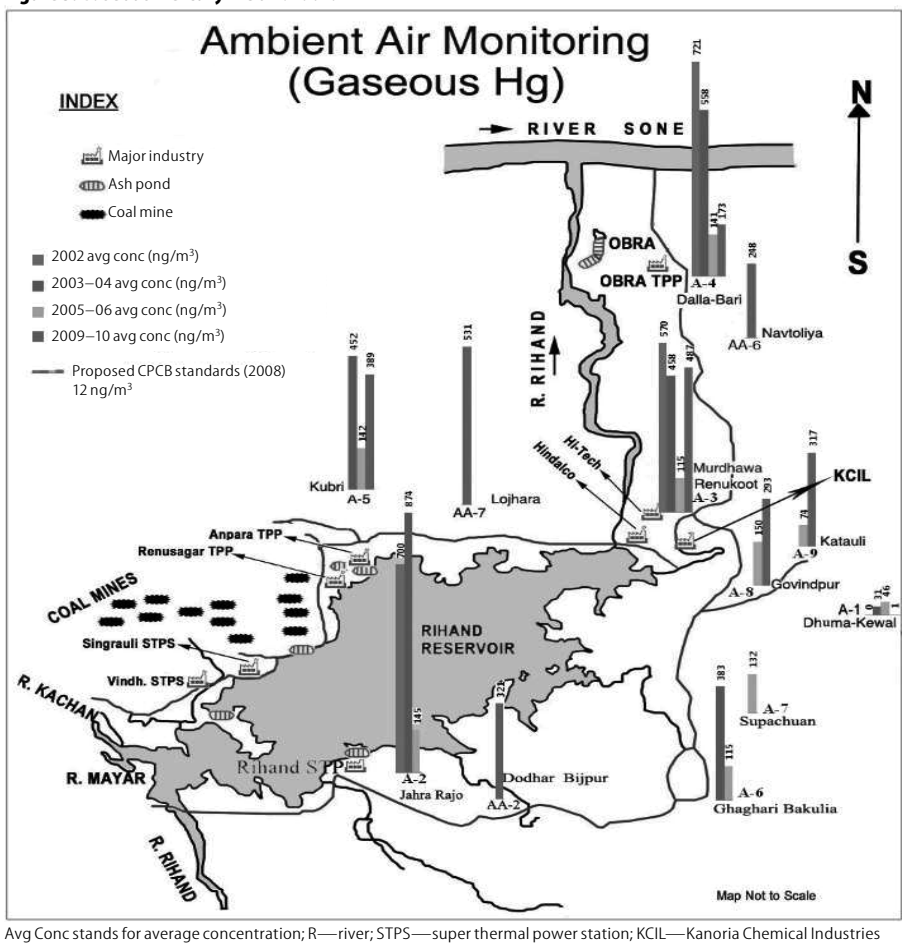
* The extremely high levels were probably due to the device getting choked and malfunctioning due to high levels of particulate matter and dust.
Source: PSI (2018).

Figure 4: Health Effects of Heavy Metals on Humans



ATP—adenosine triphosphate;IQ reduction—intellectual quotient reduction (error in the image).
Source: Kumar et al (2019).

Figure 5: Gaseous Mercury in Sonbhadra



Avg Conc stands for average concentration; R—river; STPS—super thermal power station; KCIL—Kanoria Chemical Industries Limited; A-1 to AA-7 denote the ambient air monitoring station locations.
Source: Prepared by BSA as part of monitoring undertaken in association with CPCB between 2002 and 2010.

the coal. Based on the Central Institute of Mining and Fuel Research's calculation of the average concentrations of these elements in Indian coal (Banerjee et al 2000), we can estimate that about 1.9 metric tonnes of chromium (Cr), 4.2 tonnes of lead (Pb), 1.4 tonnes of arsenic (As), 1 tonne of nickel (Ni), and 0.1 tonne of mercury (Hg) are released into the environment from the coal burnt every day in Singrauli. Figure 4 summarises the impacts of six heavy metals, including the above-mentioned and cadmium (Cd), on human health (Kumar et al 2019).

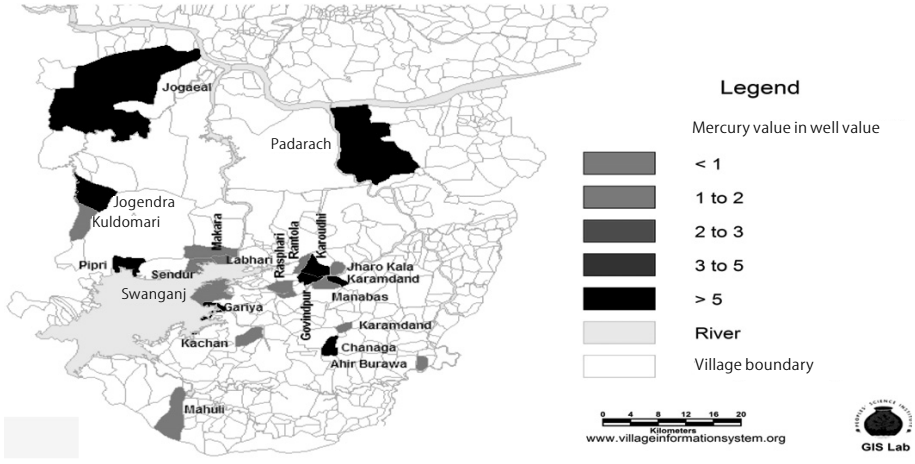
Physicochemical Monitoring

Between 2002 and 2010, the Banwasi Seva Ashram (BSA) in association with the Central Pollution Control Board (CPCB) and assisted by the People's Science Institute (PSI) at Dehradun and the Hazards Centre in New Delhi, undertook the monitoring of air, groundwater, surface water, and drains across Sonbhadra. It found high concentrations of fluoride and mercury in the air, indicating substantial impact of fugitive and stack emissions of coal combustion, aluminium smelting, and caustic soda manufacturing (BSA 2010). The CPCB has declared Singrauli region as one of the critically polluted industrial clusters to be monitored through the comprehensive environmental pollution index (UPPCB 2018).

Figure 5 shows the gaseous mercury levels in the atmosphere in Sonbhadra between 2002 and 2009 (in nanograms per cubic metre [ng/m^3]) as monitored by the BSA. The monitoring was undertaken at nine stations spread across the district, with Dhuma–Kewal in the eastern region of the district taken as a control. There is no permissible standard for mercury in India. The CPCB had proposed a standard limit of 12 ng/m^3 in 2009 but never finalised it. The levels of gaseous mercury were higher than this proposed standard throughout Sonbhadra; only Kewal (control area) had levels lower than this.

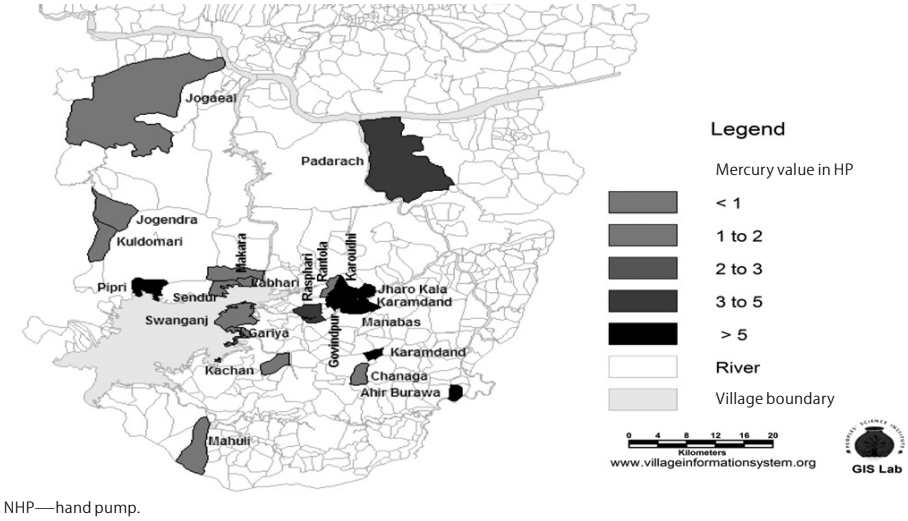
Later, between 2017 and 2018, the BSA in association with the PSI and Hazards Centre monitored particulate matter using sensors at 14 locations across Sonbhadra. The locations adjacent to as well as at some distance from the industries were monitored and particulate matter levels across the region were found consistently

Figure 6: Mercury Levels in Open Well Water in Sonbhadra Villages



Source: Prepared by PSI as a part of monitoring undertaken in association with village panchayats in 2016.

Figure 7: Mercury Levels in Hand Pump Water in Sonbhadra Villages



NHP—hand pump.
Source: Prepared by PSI as a part of monitoring undertaken in association with panchayats in 2016.

at two–three times the standard, and at times, even five–six times higher than the standard. Table 1 (p 48) gives the average values of $PM_{2.5}$ (particles that are less than 2.5 micron in diameter) found during monitoring. It also compares the fraction of $PM_{2.5}$ in PM_{10} (particles less than 10 micron in diameter), wherein it can be seen that a large fraction of particle matter is fine particle matter, which might indicate that the particulate matter is predominantly due to the combustion from thermal power plants that travels large distances. The Centre for Science and Environment (CSE) undertook a study of the data from the CPCB continuous monitoring stations in 17 towns in central India in 2021, wherein Singrauli town was found to be the worst with 95 days of very poor or critical air quality through the year (Roychowdhary and Somvanshi 2021).

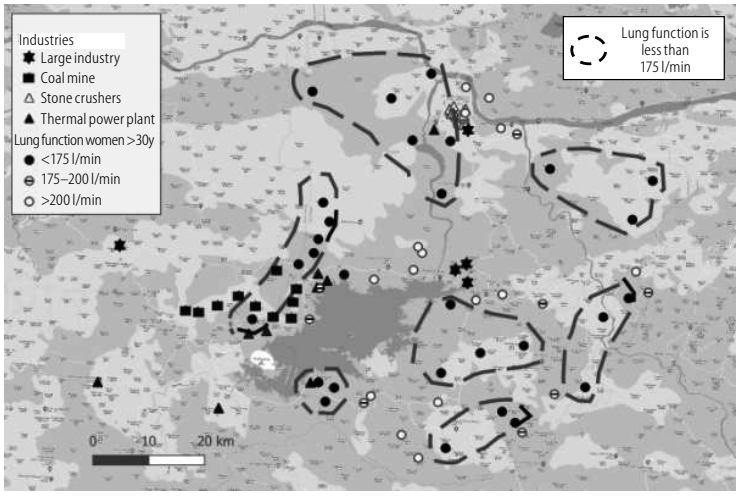
The BSA–CPCB monitoring in 2010 showed that inadequately treated waste water is being discharged into the Rihand reservoir through various small drains. As a result, the reservoir had high levels of total suspended solids, fluoride, and mercury. The Balia nullah is to the west of the reservoir, and receives effluents from ash ponds of the thermal power plants as well as the coal mines. The Dongiya nullah carries the effluents of the Grasim Industries into the reservoir. The Murdhawa nullah is downstream of the Rihand Dam and upstream of the Obra Dam and receives effluents from the Hindalco and Birla carbon factories, in addition to receiving effluents from the Hindalco township (BSA 2010). The National Green Tribunal (NGT)-appointed committee that looked at the water quality in the region in 2015 revealed, "remarkabl[y] high concentration[s] of mercury, cadmium, nickel, aluminium, chromium, and fluoride in some parts of the region is a common feature" (Core Committee for Monitoring of Potential Hazards of Industrial Development in Singrauli 2014).[4] Other studies that looked at heavy metal pollution in the region concluded that the sources of heavy metals in groundwater and surface water are the ash ponds and industries in the region (Bharadwaj et al 2020).

In 2016, panchayats in Sonbhadra collected water samples from wells, hand pumps, and ponds, and tested them through PSI for fluoride, mercury, arsenic, and general characteristics such as total dissolved solids and pH, which denotes a substance's acidity or alkalinity on a logarithmic scale ranging from 0–14. Figures 6 and 7 show the mercury levels in water from wells and hand pumps, respectively. Well water was found to be more contaminated than the water from hand pumps. This might indicate that a possible source of mercury at the locations of some distance from mines and industries is fallout from the atmosphere and not from rocks in the region as the water from deeper hand pumps has lower levels of mercury.

Health Impacts

Multiple studies on the health of the regional population have been carried out. In 1997–98, the Indian Institute of Toxicological Research, Lucknow tested blood and hair samples for mercury. It found that the mean mercury levels in the blood of Singrauli residents was 21.37±2.11 nanograms per millilitre (ng/ml) compared to the control level of 1.75±0.22 ng/ml, and the same in hair was 1.90±0.101 μg/ml in the region compared to 0.89 μg/ml in the control (Industrial Toxicology Research Centre 1998). The CSE similarly tested for mercury in 2014, and found its average concentrations in human blood, hair and nail were 34.30 part per billion (ppb), 7.39 part per million (ppm) and 0.83 ppm, respectively (Sahu et al 2014).

Figure 8: Peak Expiratory Flow Rate in Women Older Than 30 Years



Source: Based on the primary health survey carried out by the BSA.

The NGT core committee found health issues pertaining to the toxicity of minerals in the region. It found fluorosis to be highly prevalent, especially in Chopan and Myorpur bocks of Sonbhadra. It also found that many villagers complained of body aches and other symptoms suggestive of peripheral neuropathy, whereas some of them had blue lines on their gums suggestive of lead toxicity. In addition, the committee also found some patients with a history suggestive of mercury toxicity. Patients with lung manifestations were found in the area around the Dalla cement factory (earlier owned by Jaiprakash Associates Limited and now by UltraTech) as well as people near the coal transport areas (Core committee 2014).

In 2011, a pilot health survey was conducted by the BSA (assisted by the Hazards Centre) with 1,613 people in 21 villages of Sonbhadra. The survey found chronic exposure of the population to a combination of pollutants, such as respirable suspended particulate matter, heavy metals, fluoride, sulphur dioxide, and nitrogen oxides, which had led to a general deterioration in the health of the local population (Vasudha and Prem 2015).

Following this, a more detailed study of 4,383 families in 52 villages of Sonbhadra was carried out by the BSA (with assistance from the Hazards Centre) in 2012–13. The 52 villages were spread throughout the district, located at differing distances from the industries. Every third family and, in larger villages, every fourth family was surveyed, wherein *swasthya mitras* (health associates) of the BSA recorded the families' socio-economic parameters, health, and women's reproductive health. The focus was on recording the exposure to mercury and fluoride. Simple tests were carried out, such as measuring peak expiratory flow rates (PEFR) to record lung health, body mass index and muscle tone. We observed indicators such as the yellowing of teeth due to the exposure to fluoride, and the occurrence of tremors in the hand that can occur due to mercury exposure. Tests of individuals aged 16 and above were recorded.

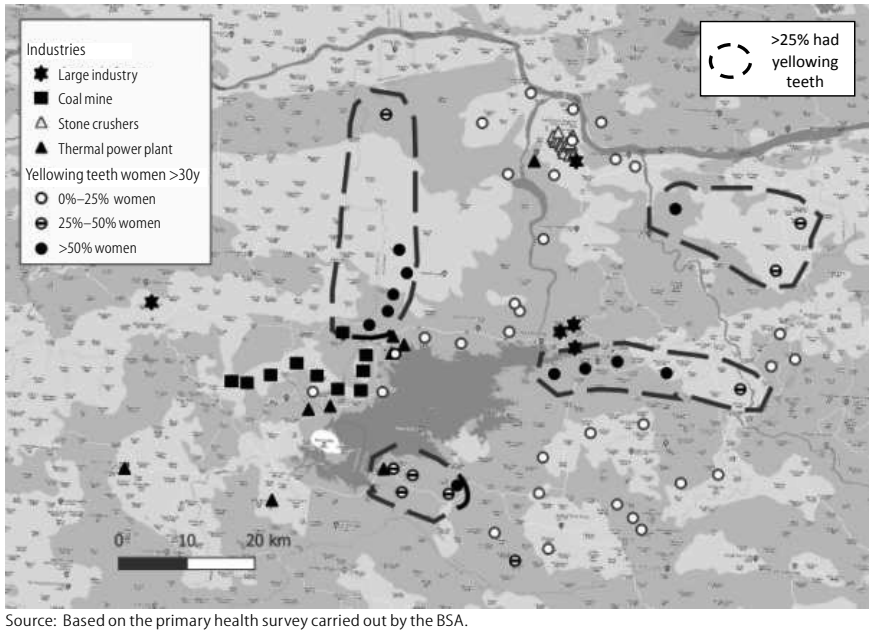
On an average, the lung function of the residents of Singrauli region was 42.7% lesser than that of an average Indian (Kodgule et al 2014). This was slightly more pronounced in women whose lung function showed a decrease of 44% as compared to men whose lung function showed a decrease of 41.6%. The decrease in lung function was also more pronounced in older adults. Figure 8 shows the areas where the decrease in lung function was more pronounced for women older than 30 years. Estimating the actual values of lung function, the PEFR for these women should be at least 290 litres per minute (l/min), and villages where the average PEFR was 175 l/min or less have been highlighted with hatched isolines. The areas of concern are similar for younger women and men whose data is presented in Table 2. As can be seen, the lung function of residents of the entire southern Sonbhadra region is severely affected. Some pockets are more affected being east of the reservoir: the

Table 2: Peak Expiratory Flow Rate of Respondents of Health Survey (l/min)

Village	Women		Men		Village	Women		Men	
Age (years)	15–30	>30	15–30	>30	Age (years)	15–30	>30	15–30	>30
Arjhat	234.3	210.0	318.1	292.6	Kataundhi	207.4	210.1	290.8	262.0
Badi	191.3	203.6	266.8	275.2	Kewal	208.0	202.4	289.0	316.7
Banpaisa				356.1	Khairahi	240.6	205.6	357.8	301.1
Barbe	142.7	140.9	246.4	238.6	Kharhara	200.9	166.5	288.2	284.9
Belwadah	225.7	204.7	247.8	265.1	Koharwal	183.4	193.3	298.2	272.9
Bijpur	192.0	171.7	271.9	241.1	Kubri	126.9	106.1	224.5	194.7
Buda					Kudwa	131.5	94.7	204.8	196.0
Dadihara	197.6	167.9	284.9	239.1	Kurpan	189.7	172.2	312.0	285.4
Dagdauatola	163.9	166.6	287.7	258.1	Lojhara	124.2	124.8	244.7	198.4
Dahkudandi	209.7	194.0	316.8	304.0	Makra	242.9	217.2	286.8	254.6
Dodahar	185.4	161.1	280.9	226.1	Mungadih	174.1	181.0	318.7	264.7
Dumarhar	224.6	207.7	268.2	298.4	Murtwa	130.5	136.0	243.1	191.0
Garbandha	212.5	193.1	283.0	272.3	Nadhira	245.4	207.7	337.6	306.2
Gothani	179.7	145.0	212.4	199.3	Nagwa	177.6	159.4	310.8	281.8
Gulalidih	153.7	144.8	244.9	236.7	Navtoliya	222.8	220.2	338.9	325.6
Gulaljhariya	191.6	190.7	294.5	294.9	Nibhiyadaad	177.2	159.7	314.1	272.9
Jaampani (K)	148.7	138.6	224.0	223.0	Ninga	175.0	163.8	301.5	284.1
Jaampani (B)	133.4	123.5	254.9	229.5	Pachpediya	119.5	113.5	226.1	202.3
Jarha	179.6	180.5	283.9	246.2	Padarwa	150.7	130.4	263.7	243.2
Jogendra	122.4	115.3	181.2	161.6	Padracch	157.3	143.3	226.6	236.2
Kadiya	163.6	145.7	234.6	226.2	Pati			331.3	312.1
Kajrahar	211.3	207.9	266.7	262.3	Pharipan	184.2	184.9	294.1	285.8
Kamhapaan	159.9	144.8	257.1	237.7	Pipri-Sonwani	177.4	165.6	245.8	241.6
Kanacch	221.6	215.7	300.2	304.8	Satbahini	178.0	169.2	283.3	269.1
Karail	115.3	89.2	174.8	151.6	Sirsoti	181.9	161.5	270.0	225.1
Karhiya	164.2	138.5	207.6	199.8	Sukhda	207.4	195.7	283.7	298.1

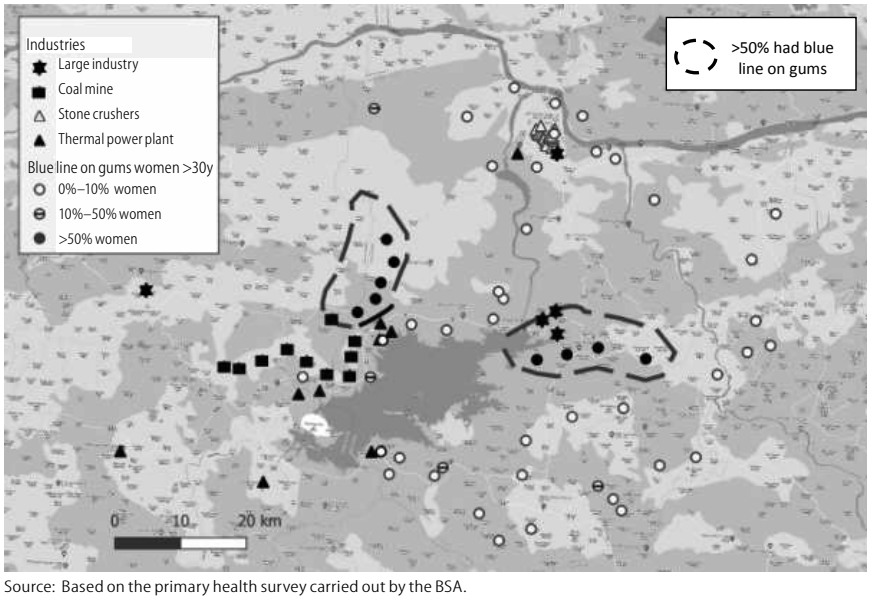
The blank boxes are in cases of insufficient data, that is, smaller than required sample size.
Source: Survey data collected by the BSA.

Figure 9: Prevalence of Yellowing of Teeth in Women Older Than 30 Years



Source: Based on the primary health survey carried out by the BSA.

Figure 10: Prevalence of Blue Line on Gums of Women Older Than 30 Years



Source: Based on the primary health survey carried out by the BSA.

southeast of Hindalco, adjacent and to the north of the coal mines, and the cluster of thermal power plants at Anpara, Vindhyachal, Singrauli and Renusagar, and to the east of the Kanhar river, between Kanhar and Son rivers.

It should be noted that the hatched isolines have been drawn taking into consideration the topographic configuration of the area. Sonbhadra district may be broadly divided into three geographical regions that are separated by two ridges of the east–west Kaimur range. The southernmost region forms the catchment of the south–north Rihand river that has been partly converted into the largest man-made reservoir (Rihand) in India, formed by building a dam at the point where Rihand river pierces the southern ridge. North of this ridge lies the central region formed by the valley of the Rihand until it joins Son river, which is bounded on the north by the northern ridge of the Kaimur. Further north of the Kaimur lies the third region of Sonbhadra, which is a part of the plateau forming the southern boundary of the Gangetic plain. Thus, the two ridges of the Kaimur provide natural boundaries that funnel the winds in an east–west direction, with some air spilling northwards from the high Mainpat plateau south of the district. These winds determine the distribution of air pollution that emanates either from the tall stacks of the thermal power plants in the southern region or the lower-level emissions from the stone quarries and cement plants in the central region.

Figure 9 shows the proportion of women aged more than 30 years with yellowing of teeth that occurs due to fluorosis, and Figure 10 shows the prevalence of blue line on gums that is an indicator of exposure to heavy metals such as lead and mercury. The two areas of concern for both these symptoms are to the north and to the east of the reservoir. There is also a cluster of villages to the southeast of the reservoir, in the vicinity of the Rihand thermal plant, where both lung function is affected and yellowing of teeth is observed. The data of younger women and men for these two parameters are presented in Tables 3 and 4 (p 53).

Exposure to heavy metals, such as mercury, is known to affect the nervous system, lungs, kidneys as well as foetuses, and has been linked to miscarriages (Bernhoft 2012; Bjørklund et al 2019; Kumar et al 2019). Figure 11 (p 54) shows the occurrence of miscarriages for every 100 live births, where the most affected is the region in the northeast of the district, and an area to the east of the reservoir. There are 5.6 miscarriages per 100 live births nationally, whereas in Sonbhadra, there are 8.75 miscarriages per 100 live births (IIPS and ICF 2017). UP has 8.6 miscarriages per 100 live births, which is much higher than the national average, but is still lower than the levels in Sonbhadra. Thus, women in Sonbhadra had 1,700 excess miscarriages as compared to women in UP, and nearly 36,000 more abortions as compared to pan India.

Figure 12 (p 54) gives the predominant surface wind direction over all three regions of Sonbhadra district as per the reanalysis of the National Centre for Environmental Prediction data (Urban Emissions.info nd), and the three main directions are from the northwest, west, and east. It is possible that due to the winds blowing from the southern Mainpat plateau towards

the thermal power plants and a saddle in the ridge north of these plants, the impacts are seen on the lungs of villagers residing to the north of the industries. Historically, the wind direction in the region, especially at the altitude of 300 metres, up to which height the chimney stacks of the thermal power plants extend, are predominantly westerly and to a small extent easterly. This might be the reason for the extensive impact to the east of the reservoir.

Economic Loss

The average health indicators of the population of Sonbhadra as compared with those of the Indian population show that their lung function is poorer, they are severely afflicted by fluorosis, and that women suffer greater miscarriages as compared to the national average. The notional economic loss of villagers due to the adverse impacts on their health was computed according to the following methodology:

Lung function: Economic losses were calculated on the basis of the compensation amounts mandated by the Employee's Compensation Act, 1923 (amended in 2017). This act provides for compensation to be paid by an employer for an injury or health impact on account of work.

Compensation for permanent disability = 60% of monthly wage × Rf as per age of worker × % reduction of earning capacity

Rf: relevant factor given in the act as based on the age of the worker.

For each worker, the percent decrease in lung function was taken as the percent reduction of earning capacity, the assumption being that they would be substitutable. Separate calculations were undertaken using the following three income figures. (i) The average income of households in UP in 2013 (as the health survey was carried out in 2012–13) of ₹4,923 per month (NSSO 2013). (ii) The minimum wage of ₹3,692 per month (assuming 26 working days in a month) paid to agricultural labourers in UP in 2013 (Labour Bureau 2013). (iii) The UP minimum wage for unskilled labour of ₹9,078 per month (Office of the Labour Commissioner 2021) as stipulated in 2021 to capture inflation effect. The sum arrived was then multiplied by three or four, depending on how many families were surveyed in the village, and this was then multiplied to obtain the reduction in the earning capacity of all the residents of 1,429 villages in the district.

Fluorosis: The National Human Rights Commission had ordered MP to compensate a sum of

Table 3: Percentage of Respondents with Yellowed Stained Teeth

Village / Age (years)	Women 15–30	Women >30	Men 15–30	Men >30	Village / Age (years)	Women 15–30	Women >30	Men 15–30	Men >30
Arjhat	5.8	17.4	8.6	5.5	Kataundhi	20.9	65.1	28.1	76.8
Badi	1.4	1.9	0.0	1.7	Kewal	0.0	2.3	0.0	0.0
Banpaisa	0.0	0.0	0.0	1.7	Khairahi	35.1	64.4	19.7	65.0
Barbe	20.3	18.8	14.6	16.7	Kharhara	2.1	4.8	0.0	11.4
Belwadah	0.0	11.3	8.8	22.8	Koharwal	5.5	21.6	7.0	28.8
Bijpur	39.3	31.6	31.8	39.3	Kubri	86.2	92.0	49.2	65.5
Buda	21.4	70.5	25.7	70.9	Kudwa	40.0	50.0	27.5	43.8
Dadihara	31.7	84.0	24.2	80.2	Kurpan	16.7	14.0	17.6	26.8
Dagdauatola	4.6	9.3	1.6	5.1	Lojhara	88.0	86.6	60.2	75.0
Dahkudandi	1.8	1.6	3.2	6.8	Makra	0.0	0.0	3.9	4.3
Dodahar	31.3	37.7	46.8	21.1	Mungadih	4.5	1.8	1.4	6.5
Dumarhar	11.8	31.8	24.5	21.6	Murtwa	13.5	10.4	1.7	6.8
Garbandha	5.8	9.7	4.3	9.9	Nadhira	8.5	14.8	16.9	42.0
Gothani	13.7	13.1	0.0	19.7	Nagwa	10.0	26.3	7.1	35.6
Gulalidih	60.2	71.9	41.2	56.1	Navtoliya	0.0	0.0	0.0	0.0
Gulaljhariya	35.0	56.9	37.0	67.2	Nibhiyadaad	2.3	1.6	2.9	5.0
Jaampani (B)	13.9	10.7	6.2	6.9	Ninga	0.0	1.9	0.0	1.7
Jaampani (K)	0.0	0.0	0.0	0.0	Pachpediya	24.7	27.0	37.8	60.9
Jarha	57.4	48.5	63.0	67.4	Padarwa	77.3	86.8	59.0	81.3
Jogendra	73.0	91.7	43.2	72.7	Padracch	46.8	80.3	20.8	74.3
Kadiya	10.0	14.5	7.9	12.3	Pati	0.0	0.0	0.0	0.0
Kajrahar	0.0	0.0	0.0	1.6	Pharipan	3.3	1.6	4.5	2.6
Kamhapaan	2.0	0.0	1.3	0.0	Pipri–Sonwani	1.5	3.0	3.6	10.5
Kanacch	0.0	2.0	0.0	0.0	Satbahini	0.0	2.5	0.0	15.2
Karail	13.6	26.3	3.5	4.2	Sirsoti	34.5	35.7	32.2	34.0
Karhiya	8.8	19.2	0.9	3.1	Sukhda	0.0	0.0	0.0	0.0

Source: Survey data collected by the BSA.

Table 4: Percentage of Respondents with Blue Line on Gums

Village / Age (years)	Women 15–30	Women >30	Men 15–30	Men >30	Village / Age (years)	Women 15–30	Women >30	Men 15–30	Men >30
Arjhat	0.0	2.2	0.0	0.0	Kataundhi	23.1	63.9	28.1	80.5
Badi	0.0	0.0	0.0	1.7	Kewal	0.0	0.0	0.0	0.0
Banpaisa	0.0	0.0	2.0	5.2	Khairahi	36.1	64.4	20.5	64.1
Barbe	1.3	12.5	1.1	1.7	Kharhara	0.0	3.2	1.1	3.8
Belwadah	4.2	3.8	0.0	1.8	Koharwal	9.1	13.5	8.8	15.3
Bijpur	1.6	0.0	0.0	1.6	Kubri	86.2	92.0	47.7	67.2
Buda	11.4	54.5	14.3	52.7	Kudwa	1.4	0.0	2.3	0.0
Dadihara	35.6	85.3	24.2	82.7	Kurpan	5.6	7.0	5.9	12.5
Dagdauatola	1.5	2.3	0.0	1.7	Lojhara	80.4	89.6	58.0	71.6
Dahkudandi	0.0	3.2	1.6	1.4	Makra	0.0	0.0	0.0	1.4
Dodahar	0.0	3.3	0.0	0.0	Mungadih	1.5	0.0	0.0	0.0
Dumarhar	0.0	2.3	2.0	7.8	Murta	2.2	2.1	1.7	3.4
Garbandha	0.0	0.0	4.3	1.4	Nadhira	1.7	1.6	0.0	0.0
Gothani	3.9	7.1	1.9	5.6	Nagwa	1.0	3.8	3.0	0.0
Gulalidih	52.8	67.2	34.3	36.6	Navtoliya	0.0	2.0	1.7	1.9
Gulaljhariya	40.0	56.9	41.1	68.9	Nibhiyadaad	3.4	3.1	2.0	1.3
Jaampani (B)	0.0	0.0	0.0	0.0	Ninga	0.0	0.0	0.0	0.0
Jaampani (K)	0.0	0.0	0.0	0.0	Pachpediya	30.6	41.3	40.0	59.4
Jarha	2.9	4.5	0.0	2.3	Padarwa	77.3	82.4	54.2	77.5
Jogendra	73.0	91.7	43.2	72.7	Padracch	2.1	2.6	0.0	2.8
Kadiya	2.0	8.1	1.6	7.7	Pati	0.0	0.0	0.0	0.0
Kajrahar	0.0	0.0	0.0	0.0	Pharipan	5.0	3.1	1.5	2.6
Kamhapaan	0.0	0.0	0.0	0.0	Pipri–Sonwani	0.0	7.5	2.4	9.3
Kanacch	0.0	0.0	0.0	0.0	Satbahini	0.0	0.0	0.0	0.0
Karail	0.0	0.0	0.0	0.0	Sirsoti	0.0	0.0	0.0	0.0
Karhiya	0.0	1.9	0.0	0.0	Sukhda	0.0	0.0	0.0	0.0

Source: Survey data collected by the BSA.

Figure 11: Reproductive Health of Women—Number of Miscarriages per 100 Live Births

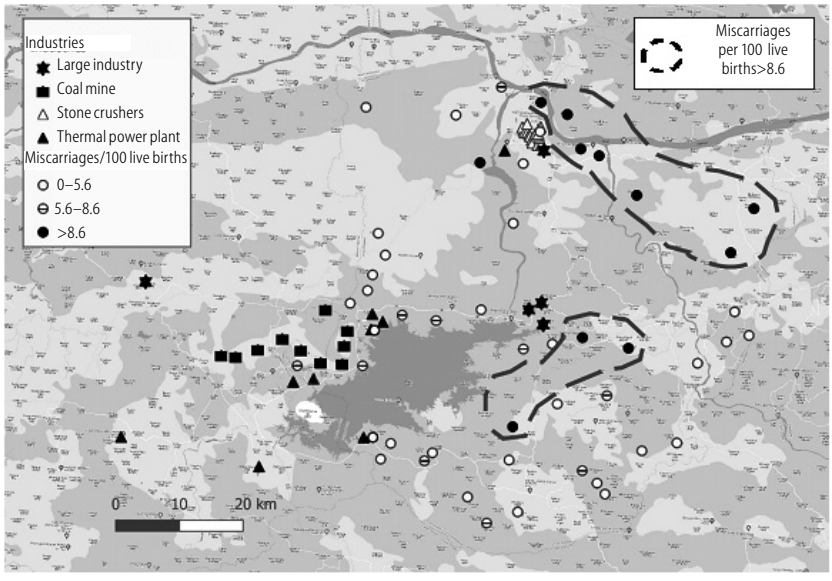


Figure 12: Wind Direction for Sonbhadra District

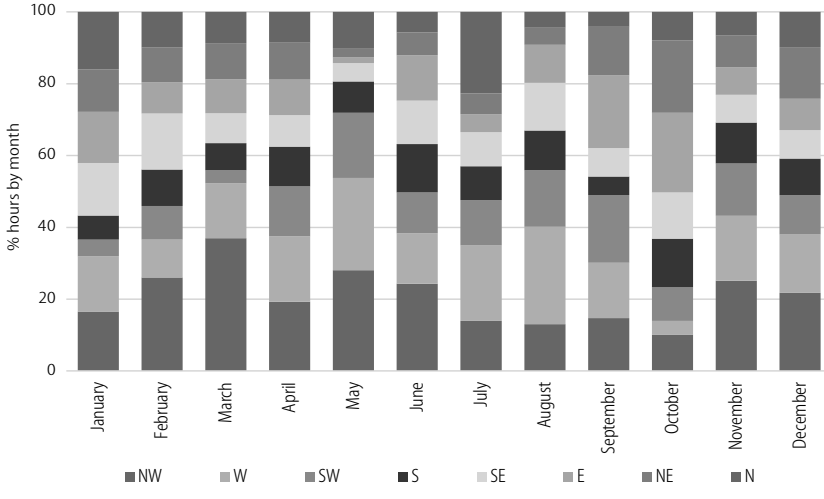


Table 5: Health Damages of Residents of Sonbhadra

Health Impact	Wage/Location	Respondents in 52 Villages (₹)	All Residents of 52 Villages (₹)	1,429 Villages of Sonbhadra (₹)
Lung function	2013 household income ₹4,923*	79,96,70,679	2,39,90,12,038	65,92,66,96,202
	2013 minimum wage (agriculture) ₹3,692*	1,80,25,50,165	5,40,76,50,495	1,48,60,63,95,347
	2021 minimum wage (unskilled) ₹9,078*	4,43,21,64,247	13,29,64,92,740	3,65,39,78,48,580
Miscarriage	Calculating excess miscarriages using miscarriage rate in Uttar Pradesh as a base	51,97,500	1,55,92,500	42,84,93,894
	Calculating excess miscarriages using pan-India miscarriage rate	10,82,10,000	32,46,30,000	8,92,10,82,115
Fluorosis		3,32,70,000	9,98,10,000	2,74,28,55,577
Range of totals	Lower	83,81,38,179	2,51,44,14,538	69,09,80,45,674
	Upper	4,57,36,44,247	13,72,09,32,740	3,77,06,17,86,272

* Figures are specific to Uttar Pradesh.
Source: Calculations based on the primary survey conducted by BSA.

₹10,000 for children who drank fluoride-laden water (NHRC 2013) and got sick, stating that it was the responsibility of the state to provide clean drinking water. The number of respondents who showed signs of yellowing and staining of teeth was multiplied with ₹10,000 to arrive at the figure in Table 5.

Miscarriages: Multiple high courts have considered the unborn foetus as a child and, in case of an accident leading to miscarriage, have ordered for the affected woman to be compensated. The high courts of MP (*Shraddha v Badresh and Ors* 2006) and Delhi (*Prakash and Ors v Arun Kumar Saini and Anr* 2010) have ordered compensation of ₹2,50,000 in different orders. The number of excess miscarriages suffered by the women of Sonbhadra as compared to the women of UP was multiplied by ₹2,50,000 to arrive at the figure of ₹42,84,93,894 in Table 5. Similarly, the number of excess miscarriages suffered by women pan-India was multiplied by ₹2,50,000 to arrive at the figure of ₹8,92,10,82,115.

Table 5 summarises these calculations, which suggest that the residents of Sonbhadra district have suffered cumulative damages over the past three decades due to the above-mentioned three parameters' adverse impacts on their health estimated between ₹70 billion and ₹380 billion. This does not include the impact on the health of the residents of the neighbouring district of Singrauli, which falls in MP and lies outside the area of the BSA's operations.

In 2013, the average household income of agricultural families in UP was less than ₹5,000 per month or less than ₹60,000 per year. However, these impoverished residents of Sonbhadra district have suffered further economic damages due to adverse health impacts up to the tune of ₹380 billion, that is, nearly ₹1.15 million per household. The earlier 2011 pilot survey among 1,613 respondents in 21 villages in Sonbhadra also showed significant health damage. As per that study, each individual had suffered health damages in the range of ₹1,23,899–₹6,09,017.[5] This survey did not cover all family members, instead only one to two respondents from 1,184 families were surveyed.

The estimated damages would be even higher if the impact on crops and fruiting trees was to be considered. In 1997, a study was conducted to look at the fruit and crop production in the region (BSA and PSI 1997). A survey was conducted among farmers in 22 villages of Sonbhadra, inquiring into the productivity of fruit trees, such as mango, jackfruit, and lemon, lac (shellac) as well as cereals

such as wheat, mustard, and potato, between 1975 and 1996, and carried out an ambient air monitoring. Lac had been severely affected then and now, it has nearly completely disappeared from the region. Between 1975 and 1996, a loss of ₹121.4 million was estimated to have been borne by 996 families. Thus, each family suffered an average economic loss of ₹1,21,874 due to the decreased production of just the major fruits and lac. Twenty-five years have passed since.

The Courts

Multiple cases related to environmental impacts in the Singrauli region have been filed in the NGT. In each of these, the court has acknowledged the environmental pollution by the industries, and has ordered compensations to be deposited as fines and towards remediation. The judgment in *Ashwani Kumar Dubey v UoI and Ors* (2022) gives a description of some of these cases. The *Anjani Jaiswal v UoI and Ors* (2019) case sought directions on environmental pollution by the industries, and the NGT ordered an environmental compensation of ₹790 million. In January, the NGT gave its judgment on eight petitions filed for remedial action against the violation of environmental norms by thermal power plants, including the Ashwani Kumar case that specifically sought directions for thermal power plants in the Singrauli region. The industries in Singrauli have been ordered to deposit a total environmental compensation of ₹2.24 billion. Other than this, a three-member committee constituted by the NGT calculated an environmental compensation of ₹1.55 billion for Grasim Industries' chemicals division (which falls under the Aditya Birla Group) for storing mercury-bearing brine sludge in its premises and immediately shifting it to a treatment, storage and disposal facility. However, Grasim Industries as well as most other thermal power plants have filed appeals in the Supreme Court against these penalties.

In April 2020, a breach at the Sasan thermal power plant's ash dyke led to the death of six people and loss of property, cattle, and crops. The district administration ordered Sasan to pay a compensation of ₹6.94 million for the loss of life and treatment costs, and ₹27.72 million for the loss of property (house, crops, cattle, motor pump, and so on) (Affidavit of Sasan Power Ltd in the matter of *Hiralal Bais v UoI and Ors 2021*). Thus, the NGT and district administration recognise the damages to health due to accidents such as the ash dyke breaches, and have ordered compensation for the same. The NGT has also recognised the impact on the health of the people of Singrauli region; however, it has not deemed the need for compensation on this count.

In Conclusion

Burning 3,00,000 tonnes of coal daily, the industries of Singrauli region release significant amounts of toxic heavy metals into the environment. Whereas 99.96% of this generated electricity goes out into the national grid, leaving Singrauli as one of the most dark and toxic regions despite being under the very lamp of development.

This study in Sonbhadra found that the consequent industrial pollution has led to a general deterioration in the health of its residents. A methodology to estimate the damages due to adverse health impacts was derived, based on three health parameters: lung function that was found to be 42.7% lesser than that of an average Indian, increased rate of miscarriages found to be 56% higher than the national average, and widespread occurrence of fluorosis in the region. These damages were estimated to be between ₹70 billion and ₹380 billion, depending on the notional income value. Damages due to other health issues, such as neurological disorders and infertility as well as crop and agricultural losses, need to be assessed to get a more comprehensive estimate of people's losses due to this pollution.

The NGT has found industries in violation of environmental norms, and has ordered them to pay environmental compensation to the state agencies for remediation of the environment. These total to ₹3.03 billion. Yet, nearly all the industries have appealed to the Supreme Court, which has, in turn, ordered a stay. On the other hand, the losses that people have borne are orders of higher magnitude. Who will compensate the people for these damages that have conveniently been written off as externalities?

NOTES

1 The data on renewable energy produced in Delhi between April 2019 and March 2020 was accessed from the CEA dashboard.

2 Region-wise, statewise and station-wise monthly generation reports of thermal power for November 2021 were accessed from the National Power Portal. The renewable energy generation data was accessed from the CEA dashboard.

3 These figures were calculated from the monthly fuel consumption of thermal power plants available at the CEA website and the environmental statements of Renusagar Power Plant, Hindalco and UltraTech Cement Limited (aka Dalla cement factory).

4 This quote is from page 22 of the Subcommittee-2 on Potential Impact of Pollution on Water Resources in Singrauli Area under the Core Committee (2014). There were five subcommittees, each of whose reports are paginated discretely.

5 Calculations are based on the survey of 1,613 respondents of 21 villages undertaken by the BSA in 2011.

REFERENCES

Affidavit of Sasan Power Ltd in the Matter of *Hiralal Bais v UoI and Ors* (2021): 148/2020, National Green Tribunal.

Anjani Jaiswal v UoI and Ors (2019): 453/2019, National Green Tribunal.

Ashwani Kumar Dubey v UoI and Ors (2022): 164/2018, National Green Tribunal.

Banerjee, N N, B Ghosh and A Das (2000): *Trace Metals in Indian Coals,* Dhanbad: Central Fuel Research Institute.

Bernhoft, R A (2012): "Mercury Toxicity and Treatment: A Review of the Literature," *Journal of Environmental and Public Health,* doi: 10.1155/2012 /460508.

Bjørklund, G, S Chirumbolo, M Dadar, L Pivina, U Lindh, M Butnariu and J Aaseth (2019): "Mercury Exposure and its Effects on Pregnancy Outcome," *Basic and Clinical Pharmacology and Toxicology,* Vol 125, No 4, p 317.

Bharadwaj, S, R Soni, S K Gupta and D P Shukla (2020): "Mercury, Arsenic, Lead and Cadmium in Waters of the Singrauli Coal Mining and Power Plants Industrial Zone, Central East India," *Environmental Monitoring and Assessment,* Vol 192, No 4, p 251.

BSA and PSI (1997): "Air Pollution and its Effect on Agricultural Productivity in Sonbhadra Region," unpublished report, Banwasi Seva Ashram and People's Science Institute.

BSA (2010): *Environmental Quality Monitoring in Singrauli Problem Area,* Central Pollution Control Board, New Delhi.

Census of India (2011): *District Census Handbook,* Government of India.

CEA (2020): "Energywise Performance Status All India: Regionwise," *National Power Portal,* Central Electricity Authority, https://npp.gov.in/public-reports/cea/monthly/generation/18%20col%20act/2020/MAR//18%20col%20act-16_2020-MAR.pdf.

Chaudhary, Archana and Bibhudatta Pradhan (2021): "Six Thermal Plants around Delhi to Shut Down to Curb Air Pollution," *Business Standard,* 17 November, https://www.business-standard.com/article/current-affairs/six-

thermal-plants-around-delhi-to-shut-down-to-curb-air-pollution-121111700306_1.html.

Core Committee for Monitoring of Potential Hazards of Industrial Development in Singrauli (2014): Final Report, Core Committee Constituted by the National Green Tribunal, New Delhi.

Government of India (2017): *The Employee's Compensation Act, 1923,* Amended in 2017, Ministry of Labour, New Delhi.

IIPS and ICF (2017): *National Family Health Survey (NFHS-4) 2015–16: India,* Mumbai: International Institute for Population Sciences.

Industrial Toxicology Research Centre (1998): "Monitoring and Analysis of Mercury Contamination in Singrauli Region," the Centre has since been renamed Council of Scientific and Toxicology Research–Indian Institute of Toxicology Research, Lucknow, India.

Kodgule, R R, V Singh, R Dhar, B G Saicharan, S J Madas, J A Gogtay, S S Salvi and P A Koul (2014): "Reference Values for Peak Expiratory Flow in Indian Adult Population using a European Union Scale Peak Flow Meter," *Journal of Postgraduate Medicine,* Vol 60, pp 123–29.

Kumar, S, S Prasad, K K Yadav et al (2019): "Hazardous Heavy Metals Contamination of Vegetables and Food Chain: Role of Sustainable Remediation Approaches: A Review," *Environmental Research*, Vol 179 (Part A): 108792, doi: 10.1016/j.envres.2019.108792.

Labour Bureau (2013): "Report on the Working of Minimum Wages Act, 1948 for the Year 2013," https://paycheck.in/salary/minimumwages/uttar-pradesh/minimum-wages-in-uttar-pradesh-w-e-f-april-1-2013-to-september-30-2013.

Livemint (2022): "Delhi to Roll Out First DTC Electric Bus Today," 17 January, https://www.livemint.com/news/india/delhi-to-roll-out-first-dtc-electric-bus-today-check-routes-and-other-details-11642386835442.html.

Ministry of Coal (2021): *Provisional Coal Statistics 2020–21,* Kolkata: Government of India.

NHRC (2013): "NHRC Sets aside MP Government's Contention and Recommends ₹70,000/- as Monetary Relief to 7 Child Victims of Fluorosis," 6 February, National Human Rights Commission, https://nhrc.nic.in/press-release/nhrc-sets-aside-mp-governments-contention-and-recommends-rs-70000-monetary-relief-7.

NSSO (2013): *Key Indicators of Situation of Agricultural Households in India, NSS 70th Round,* Ministry of Statistics and Programme Implementation, Government of India.

Office of the Labour Commissioner (2021): "Notification No 336/61 MW15," Government of India, http://uplabour.gov.in/MediaGallery/DA%20In%2074%20Emp%2011-05-2021.pdf.

Planning Department (2022): *Economic Survey of Delhi 2020–21,* Government of National Capital Territory of Delhi, http://delhiplanning.nic.in/sites/default/files/11.%20Energy.pdf.

Prakash and Ors v Arun Kumar Saini and Anr (2010): MAC, APP, 602/2009.

PSI (2018): *Global Strategic Communications Council Grant Final Report,* Dehradun, India: People's Science Institute.

PSU EcoMerge (nd): *The Cycle of Mercury*, https://mercurytox.weebly.com/the-cycle-of-mercury.html.

Roychowdhary, Anumita and Avikal Somvanshi (2021): "Winter Air Pollution in Cities of Madhya Pradesh and Chhattisgarh," *Centre for Science and Environment,* 23 December, https://www.cseindia.org/Central-India-air-pollution-analysis-note-Jan3.pdf.

Sahu, R, P Saxena, S Johnson, H B Mathur and H C Agarwal (2014): "Mercury Pollution in the Sonbhadra District of Uttar Pradesh, India and Its Health Impacts," *Toxicological and Environmental Chemistry*, Vol 96, No 8, pp 1272–83.

Schweinfurth, S P (2003): "Coal: A Complex Natural Resource," United States Geological Survey, circular no 1143.

Sharma, Abhishek (2021): "Sonbhadr mein NCL ki Khadiya Pariyojana ke paas Hadsa, Do Bacchon sahit Teen ki Maut," *Jagran,* 23 June, https://www.jagran.com/uttar-pradesh/varanasi-city-three-killed-including-two-children-in-an-accident-near-ncl-khadiya-project-in-sonbhadra-21765210.html.

Sharma, B M, G K Bharat, K Sebkova and M Scheringer (2019): "Implementation of the Minamata Convention to Manage Mercury Pollution in India: Challenges and Opportunities," *Environmental Sciences Europe,* Vol 31, p 96.

Shraddha v Badresh and Ors (2006): ACJ 2067.

UPPCB (2018): *Draft Action Plan for Critically/Severely Polluted Area Singrauli, District Sonbhadra,* Uttar Pradesh Pollution Control Board, Government of Uttar Pradesh.

UrbanEmissions.info (nd): *Visualization of Weather Patterns in India by District*, https://urbanemissions.info/blog-pieces/india-meterology-bydistrict/.

Vasudha, A and Ragini Prem (2015): "Singrauli: Development, But At Whose Cost?" *India: Social Development Report 2014: Challenges of Public Health*, Council for Social Development (ed), New Delhi: Oxford University Press, pp 255–68.