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Impact of Opencast Coal Mining on the Quality of Surfacewater, Groundwater and Vegetation: A Case Study in Simlong Coalfield, Sahibganj, Jharkhand

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ABSTRACT: A preliminary study was undertaken to assess the impact of mining activities on surface water, groundwater and vegetation in Simlong coalfield area of Jharkhand. Water samples from the wells, hand pump and Lada river located in the study area were collected and analyzed for hydro-chemical characteristics. The obtained results were compared with ISI (Indian Standard Institution) and WHO (World Health Organization) standards for drinking water. The quality of surface water as well as groundwater was acidic in nature. The results indicate that groundwater was more affected by coalmines than surface water. The groundwater showed high concentration of total solids, total hardness, Ca^{2+} and Mg^{2+} compared to permissible limits of ISI and WHO for drinking purposes. The plants were collected from around the coalmine areas and identified. Altogether 89 species were identified representing 38 angiospermic families. Dicots contributed 87.8% whereas monocots contributed 12.2% of recorded flora. Habit wise tree population contributed of 25 species, shrub of 15 species and herbs of 49 species.

Keywords: Coalmines, hydro-chemical characteristics, potability, water, vegetation

I. INTRODUCTION

Open cast mining on an organized basis began in 1942 as part of the effort made during the Second World War. Technical developments resulted in the extension of the range of economic mining for opencast coal and enabled a continuous expansion of the industry and today major share of the coal production comes from the opencast mining all over the world. Mining results in physical and chemical environmental changes often resulting in water pollution. The relationship between coal mining and water pollution is well established. Spreading of toxic overburden and dirt from coalmines destroys the vegetation in those areas. Flora is very sensitive to environmental pollution by responding to the presence of toxic materials caused by mining operations. Opencast mining activities degrade the vegetative ground cover directly or indirectly. During the construction of infrastructure pit site the tree and vegetation are destroyed. Surface mining has more potential impact on land than deep mining and local people get affected adversely. Surface mining involves the removal of overburden to exploit the underlying valuable coal deposits. Discharge of excessive amount of nutrient rich coal mining effluents results in eutrophication of rivers and streams. The discharge of waste mine waters from Jharia coalfield area in the river Damodar has affected its quality adversely [1]. Coal mining activities significantly cause mineralization of both surface and groundwater. Coal mining causes considerable changes in the amount, distribution and quality of water in mined areas. In fact, coal mining disturbs the hydro-geological system and results in physical, chemical and environmental changes often resulting in pollution of both surface and ground water. The major impact of open cast coal mining are degradation in the water quality due to acid mine drainage, toxic pollutants and change in hydrology and disturbance in groundwater table which results into lowering of ground water table leading to reduced yield of water from the bore-wells. Ghosh [2], Sridharan [3], Dhar *et al*. [4], and Singh [5] studied the effect and impact of coal mining on environment of mined areas. Prasad and Ghosh [6], Prasad and Shrivastava [7], Saha *et al*., [8] and Rawat and Suri [9] studied the impact of coalmining on vegetation of different parts of India.

Jharkhand is the sole producer of coking coal and Jharia coalfields alone contain 53 hundred million tons of prime coking coal. Chuperbita coalfield is about 25 km south of Hura coalfields and contains 14 coal seams ranging in thickness from 1.5 to 9.5 m. The present study relates to the impact study of opencast coal mining on the quality of both surface and groundwater as well as on vegetation in the Simlong coal field area of Jharkhand.

Study Area: The present study was undertaken in the Simlong area, where coal is being worked since 1981. Rajmahal group of coalfields comprise several isolated patches of coal bearing rocks. Simlong is a part of Chuperbita basin of Rajmahal hills on the latitude of 24º45'50" N and longitude of 87º27'35" E. A manual quarry was worked earlier on the bed of the river Lada situated at about 5 km south west of Chatkam colliery and the present mining operations are being done at Simlong in the main course of river Lada. The Simlong coalmining area is located beneath the dense forest cover where mining activities degrade the environment directly and indirectly. Due to opencast mining the upper cover of the vegetation has been removed and extensive wastelands have been generated leaving many unfilled pits, unreclaimed quarries and overburden dumps spread over large area. The geological formations of the Simlong coalfields belong to Rajmahal formation of Upper Gondwana group with intertrappean sandstones and shales. The out crop of main coal seam is exposed all along the Lada river for a strike length of about 4 km at Simlong. The Lada is a rainfed hilly perennial river which runs through the Simlong coalfield area. More than twenty tribal villages are located on both the banks of river Lada in 10 km^2 area and the inhabitants largely depend on Lada River for various uses of water. The overburden is directly disposed into the river. As a result, the 10 km stretch of the river in the coalfield area seems to be under stress. Five sampling sites were selected for examining the impact of mining on the river water quality i.e. Site I – upstream, no mining activities at this place, Site II – extensive surface mining previously but during present study officially abandoned, Site III – illegal manual mining is carried, Site IV – official mining is being done and Site V – is 3 km downstream from site IV. Local and tribal people settled in and around the Simlong coalfield area use the tube well and well water extensively for domestic purposes. For the study of underground water quality (hand pump as well as dug well), eight villages and one residential colony (Simlong OCP employees colony) located on both the sides (northern and southern) of the river Lada in the mining area were selected. These villages were Japani, Simlong, Lada, Bari Ghaghri, Chhoti Ghaghri, Yogia, Lilatari and Jiazore.

II. MATERIALS AND METHODS

For the study of physico-chemical parameters, the surface (n =5) and ground water (n = 40) samples in the Simlong coalfield area were collected at monthly interval during February 1992 to January 1994. Water samples were collected in 100 ml Pyrex glass specimen bottles, which were cleaned properly. Parameters like pH, dissolved oxygen (DO) and alkalinity were recorded at the spot whereas other parameters were analyzed in the laboratory. Total solids were estimated by the method suggested by Wood[10]. The pH was recorded by battery operated pH meter (Systronics - 327). Dissolved Oxygen was measured by Alsterbergazide modification method, known as Winkler's modified method, described by Welch [11]. Total hardness and calcium and magnesium as cations were recorded by EDTA titration procedure; chloride by argentometric method, Phosphate-phosphorus by stannous chloride method [12] while Nitrate-nitrogen was measured by phenol-disulphonic acid method [13]. The flora growing on degraded land and coalmines spoils including various coal dumps and overburden dumps scattered around and along the main stream of Lada river at Simlong were collected during the study period i.e. February 1992 to January 1994. The collected plant species were identified with the help of Herbarium of Post Graduate Department of Botany, T.M. Bhagalpur University, Bihar and available literature of Duthie [14], Jain and Rao [15] and Verma [16].

III. RESULTS AND DISCUSSION

A. Impact on Surface and Groundwater

Seasonal mean, standard error with minimum and maximum range of hydro-chemical parameters of Lada river water and groundwater samples are shown in Table 1 and 2 respectively.

The pH of surface water (5.20-7.40) as well as groundwater (5.20-7.60) was acidic to neutral throughout the study period. Acid mine water is produced as a result of oxidation of pyritic minerals exposed during coal production. Compared to other sites the most active mining site (IV) seems to be more acidic (6.0). Coalmine wastes seem to be the potential source of acidity in groundwater as well as river water. In acid water heavy metals become soluble in water making it toxic and unsuitable for domestic purposes. Most of the pH values of water samples were below the permissible limit for drinking water quality of ISI i. e. 6.5 to 8.5 and WHO [18] i.e. 7.0-8.5.

Table 1: Physico-chemical characteristics of Lada river water: seasonal mean ± standard error with minimum and maximum range (February, 1992- January, 1994)

Seasons	Pre-Monsoon				Monsoon				Post-Monsoon			
Parameters	**Min**	**Max**	**Mean**	**S. E.**	**Min**	**Max**	**Mean**	**S. E.**	**Min**	**Max**	**Mean**	**S. E.**
pH	6.50	7.00	78	0.06	520	6.60	6.07	0.06	6.80	7.60	7.14	0.17
DO	1.02	3.88	29	0.37	0.41	4.90	2.92	0.22	3.27	6.13	4.57	0.48
Chloride	8.99	66.97	4.79	6.34	7.99	130.95	29.56	3.39	3.99	139.99	11.19	2.82
Total Solid	360.0	2330.0	180.1	207.7	200.0	1900.0	709.5	70.50	450.0	840.0	580.0	70.40
Total Hardness	184.0	288.0	24.0	12.0	62.0	662.0	205.7	17.60	212.00	358.00	272.2	21.18
Total Alkalinity	120.0	365.0	13.0	30.9	70.0	510.0	277.8	15.90	235.0	325.0	284.0	17.30
PO_4-P	0.20	4.89`	45	0.06	0.20	25.01	5.60	0.97	0.20	0.69	0.47	0.08
NO_3-N	0.80	8.90	20	0.04	0.40	27.40	4.40	2.10	0.40	7.10	5.00	2.19
Ca^{2}+	41.68	72.14	).05	3.70	17.64	77.75	46.44	2.67	38.40	86.57	76.41	2.99
Mg^{2}+	10.15	39.32	5.0	3.46	2.41	127.75	21.74	3.54	10.16	34.44	10.33	4.57

All values expressed in mg/l except pH

Table 2: Physico-chemical characteristics of groundwater water: seasonal mean ± standard error with minimum and maximum range (February, 1992- January, 1994)

Seasons	Pre-Monsoon				Monsoon				Post-Monsoon			
Parameters	Min	Max	Mean	S. E.	Min	Max	Mean	S. E.	Min	Max	Mean	S. E.
pH	6.50	7.00	6.78	0.06	520	6.60	6.07	0.06	6.80	7.60	7.14	0.17
DO	1.02	3.88	2.29	0.37	0.41	4.90	2.92	0.22	3.27	6.13	4.57	0.48
Chloride	8.99	66.97	34.79	6.34	7.99	130.95	29.56	3.39	3.99	139.99	11.19	2.82
Total Solid	360.0	2330.0	1180.1	207.7	200.0	1900.0	709.5	70.50	450.0	840.0	580.0	70.40
Total Hardness	184.0	288.0	224.0	12.0	62.0	662.0	205.7	17.60	212.00	358.00	272.2	21.18
Total Alkalinity	120.0	365.0	213.0	30.9	70.0	510.0	277.8	15.90	235.0	325.0	284.0	17.30
PO_4-P	0.20	4.89`	0.45	0.06	0.20	25.01	5.60	0.97	0.20	0.69	0.47	0.08
NO_3-N	0.80	8.90	4.20	0.04	0.40	27.40	4.40	2.10	0.40	7.10	5.00	2.19
Ca^2+	41.68	72.14	50.05	3.70	17.64	77.75	46.44	2.67	38.40	86.57	76.41	2.99
Mg^2+	10.15	39.32	26.0	3.46	2.41	127.75	21.74	3.54	10.16	34.44	10.33	4.57

All values expressed in mg/l except pH

Dissolved oxygen contents varied from 1.08-12.46 mg/l and 0.41-6.13 mg /l in surface and groundwater respectively. It was maximum in winter season and minimum in summer season. Seasonal variation of DO is related to temperature and biological activities [19]. The DO content in both well and hand pump water samples were less than surface water. The average values for both well water (3.20 mg/l) and hand pump water (1.96 mg/l) were below the permissible limit of 4.0 mg/l of ISI [17] and 5 mg/l of WHO [18] for drinking water. Depletion of DO content may not pose health risks to the consumers but it may be prone to microbial contamination leading to degradation of water quality.

Chloride contents fluctuated in between 3.99 to 72.97 mg/l in surface water and 3.99-139.99 mg/l in groundwater samples. Coal mining activities do not appear to have any impact on the chloride contents in the study area. Chloride enters into the surface water as well as groundwater from natural sources like atmospheric deposition of oceanic aerosol and weathering of rock salts. Anthropogenic sources are industrial domestic sewage effluents, and run-off from agricultural fields through fertilizers. Chloride content was well within the ISI [17] and WHO [18] Standard i.e. 250 and 200 mg/l respectively.

Total solids are the sum of total dissolved and suspended solids. The total solids fluctuated from 380 to 21000 mg/l in river water while 200 to 2330 mg/l in groundwater which are beyond the desirable limit prescribed by ISI [17] and WHO [18] i.e. 1500 and 500 mg/l respectively. This has also been observed by Ghosh and Kumar [20], Tiwari [21] and Dutta [22] in water samples from different coal field area in India. The total solids content was invariably higher during summer months, whereas minimum was recorded during monsoon. Higher amount of total solids in warmer months may be attributed to lesser volume of water as well as direct mixing of percolated dissolved substances. Dissolved solids contribute a particular taste at higher concentration and also reduce the water potability, clarity and photosynthetic rate, bind with toxic compounds and heavy metals and lead to increase in water temperature. Groundwater samples were more transparent than the river water as the total solid contents in groundwater samples were 3 to 6 times lower than the river water.

Alkalinity (Bicarbonate) ranged from 40 -160 mg/l in river water and 70-510 mg/l in groundwater. Bicarbonate alkalinity was higher in groundwater than surface water. According to ISI and WHO specifications, bicarbonate content in both surface and Ground water was well within the permissible limit (600 mg/l of ISI [18] and100 mg/l of WHO [18]).

Total hardness ranged from 28-200 mg/l and 62-662 mg/l in surface and groundwater respectively. The total hardness values were well within the Indian Standard Directives [17] of 600 mg/l except for some well water samples but beyond the WHO standards [18] i.e. 100 mg/l in both surface as well as groundwater samples. The range of variation was higher in well water (62-662 mg/l) than hand pump water (108-172 mg/l) i.e. soft to very hard water. Ghosh [23] has also reported hard to very hard groundwater in Jharia coalfield area. In hard water, the concentration of heavy metals reach the level of lethal dosage for aquatic organisms and in this way affect the life of human being [24].

Ca^{2+} and Mg^{2+} varied in the range of 8.01-51.30 mg/l, 1.43-20.84 mg/l and 17.64-86.57 mg/l, 2.41-127.75 mg/l in surface and groundwater samples respectively. The higher values of Ca^{2+} and Mg^{2+} were recorded at the most active mining site IV and downstream site V. The heavy mining operations involved in coal production at site IV and its effect thereafter on site V. Singh [25] also observed the same results at north-eastern coal mines of India. Ca^{2+} and Mg^{2+} values in surface water were well below the ISI [26] and WHO [18] desirable limit, thus indicating the water safe from potability point of view. In groundwater samples, calcium values were found to be well within the ISI[26] and WHO [18] prescribed limit except for few samples which were above the ISI [26] and WHO [18] prescribed limit of 75 and 100 mg/l respectively. About 25 % of the groundwater samples crossed the ISI and WHO prescribed standards of 30 mg/l of Mg^{2+} for drinking water. Higher concentration of Ca^{2+} is not desirable in washing, laundering and bathing due to its suppression of formation of lather with soap.

Compared to surface water (Phosphate: 0.007-0.244mg/l, Nitrate: nil - 7.68 mg/l) higher concentration of phosphate and nitrate were found in the groundwater (Phosphate: 0.20-25.01 mg/l, Nitrate: 0.80-27.40 mg/l). Phosphate and nitrate values were slightly higher at mining and downstream sites in both surface and groundwater sources. The monsoon values for both the nutrients were in higher range compared to summer and winter levels. All the values of PO_4-P and NO_3-N were well within the Indian standard, hence not affecting the potability of water.

B. Impact on vegetation

The floristic survey of study area showed a total of 89 species representing 38 angiospermic families (Table 3). Dicotyledonous and Monocotyledonous plants constituted 87.8% and 12.2% respectively (Table 4). Habit wise grouping of flora is presented in Table 5.

The water pollution resistant species i.e. *Polygonum barbatum*, *Cyperus rotundus*, *C. compressus*, *Bergiaammannoides*, *Eclipta alba*, *Rumex dentatus*, *Saccharum spontaneum*, *Malvastrum coromandelianum*, *Ipomoea aquatica* etc. were confined only to Lada river bed and in moist pockets of overburden dumps and abandoned quarries. *Olaxscandens*, a shrub was also found to be dominating in the river bed. *Croton bonplandianum*, *Cynodon dactylon*, *Xanthium strumarium*, *Blumea lacera*, *Aerualanata* sp., *Evolvulus alsinoides*, *Phyllanthus fraterness* etc. had universal occurrence on abandoned mine spoils and overburden dumps.

Number of grasses found was very few probably due to the non-availability of soil and requisite moisture contents on the dumps or slopes for the better retention of rainwater. The wind dispersed species were rich and the herbaceous species appeared in the early successional stages. Plant succession on abandoned mine land is greatly affected by soil conditions and proximity of seed sources for plant invasion[27].

Pennisetum pedicellatum, *P. purpureum*, *Heteropogon contortus*, *Andrographis paniculata*, *Tinospora malabarica*, *Pleopeltislinearis* and *P. simplex* were noticed closely adhering to rocky wastes. *Lantana camara*, *Carissa opaca*, *Eupatorium odoratum*, *Ipomoea carnea*, *Calotropis gigantean*, *Vitex nugundo* etc. were some of the shrubby species that were found to have the inhibiting effect on herbaceous species. The species of *Butea*, *Cressa*, *Zizyphus*, *Acacia*, *Ficus* etc. were found to be growing well on rocky and barren coal spoils, whereas saplings of *Shorea robusta*, *Terminalia tomentosa*, *T. arjuna*, *Borassus flabellifer* and *Phoenix sylvestris* showed common appearance and were found struggling for its existence in the area. Compared to the tree species of abandoned mines and overburden dumps, the trees on forest edge and river bank showed dominance. *Acacia auriculiformis*, *Oryx lumindicum*, *Diospyro smelanoxylon*, *Garugapinnata*, *Gardenia latifolia* etc. had a high density in the area.

Table 3: List of angiospermic plants in Simlong coal mining areas (February 1992 to January 1994).

Family	Botanical Name	Common Name	Status	Occurrence
A. HERBS			A	
Acanthaceae	*Andrographis paniculata* Nees.	Kalmegh	A	Rocky OBD/WL
	Ruellia suffruticosa Roxb.			
Amaranthaceae	*Achyranthes aspera* Linn	Charpatu	P	Rocky OBD
	Achyranthes cordifolia Linn.	Latjira	P	OBD/RS
	Aerua lanata Juss.	-----	A	OBD/RB/RS
	Amaranthus spinosus Linn.	Silwari	A	OBD/RS
Ampelidaceae	*Vitis trifolia* Linn.	Katili Chaulai	P	OBD/WL
Boraginaceae	*Heliotropium indicum* Linn.	Amarlati	A	OBD/RB
Caesalpinaceae	*Cassia tora* Linn.	Hathi Soorh	A	OBD/RB
Compositae	*Ageratum conyzoides* Linn.	Chakunda	A	OBD/WL
	Blumea lacera DC.	Uchunti	A	OBD/RB
	Eclipta alba Hassk.	-----	A	OBD/RB/RS
	Echinops echinatus Roxb.	Bhangra	A	OBD/RS
	Enhydra fluctuans Linn.	-----	A	OBD/RB/RS
	Parthenium hysterophorus Linn.	Harhuch	A	RB
	Tridax procumbens Linn.	-----	P	OBD/WL/RS
	Vernonia cinerea Less.	-----	P	OBD/RB
	Xanthium strumarium Linn.	Jhurjhuri	A	OBD/WL
Convolvulaceae	*Evolvulus alsinoides* Linn.	Chhota gokhru	P	OBD/WL/RS
	Ipomoea aquatica Forssk	-----	P	OBD/WL
	Ipomoea uniflora Roem.	Baghandi	P	RB/Ditch
Cyperaceae	*Cyperus compressus* Linn.	Baghandi	A	OBD/FE
	Cyperus rotundus Linn.	-----	A	RB/OBD
		Motha		RB/OBD

Family	Botanical Name	Common Name	Status	Occurrence
Elariaceae	*Bergia ammanoides* Roxb.	-----	A	RB/OBD
Euphorbiaceae	*Atylosia scarabaeoides* Benth.	Bankulthia	A	OBD/WL
	Croton bonplandianum Linn.	-----	A	OBD/WL/RS
	Euphorbia hirta Linn.	Bara Kerui	A	OBD/WL
	Phyllanthus fraternees Linn.	-----	A	OBD/WL
	Tragia involucrata Linn.	Barhanta	A	OBD/WL
	Ricinus spp.	------	P	OBD/WL
Lemnaceae	*Lemna paucicostata* Hegelm.	-----	A	RB
	Wolffia arrhiza Wimm.	-----	P	RB
Nyctaginaceae	*Boerhaavia diffusa* Linn.	Arak	P	OBD/WL
Papaveraceae	*Argemone Mexicana* Linn.	Pila Kantaila	A	OBD/RS
Poaceae	*Aristida adscencionis* Linn.	Kharag-Jonsk	P	OBD/WL
	Cynodon dactylon Pers.	Dub	P	OBD/WL/RB
	Dichanthium annulatum Stapf.	Grass	P	FE/OBD/Slopes
	Heteropogon contortus Roem.	Kher	P	OBD/RB
	Pennisetum pedicellatum Trin.	Grass	A	Rocky OBD/WL
	Pennisetum purpureum Pers	Bajri	A	Rocky OBD/WL
	Saccharum spontaneum Linn.	Kans	P	OBD/RB
Polygonaceae	*Polygonum barbatum* Linn.	-----	P	RB
	Rumex dentatus Linn.	Jangali Palak	A	RB
Polypodiaceae	*Pleopeltis linearis* Bedd.	-----	P	Rocky OBD/RB
	Pleopeltis simplex Bedd.	-----	P	Rocky OBD/RB
Solanaceae	*Datura metel* Linn.	Datura	A	OBD/RS
	Datura stramonium Linn.	Datura	A	OBD/RS
	Solanum surattense Burm.	-----	P	OBD/RS
Typhaceae	*Typha angustata* Chaub.	Hugla	A	RB

Family	Botanical **Name**	Common Name	Status	Occurrence
B. SHRUBS				
Apocynaceae	*Carissa opaca* Stapf.	-----	R	OBD/WL/FE
Asclepidaceae	*Calotropis gigantean* Br.	Madar	F	OBD/RS
	Calotropis procera Br.	Akona	F	OBD/RS
Convolvulaceae	*Ipomoea carnea* Jacq.	Beshram	F	OBD/RS/WL
Euphorbiaceae	*Breynia rhamnoides* Muell.	Karki	F	FE/RB
Lythraceae	*Woodfordia fruticosa* Kurz.	Dhaiphul	F	OBD/FE
Olaceae	*Olax scandens* Roxb.	Badalia	D	RB
Papilionaceae	*Butea superba* Roxb.	Dorang	C	FE
	Dalbergia tamarindifolia Roxb.	-----	F	OBD/FE/RB
	Tephrosia purpuea Pers.	Sarphuka	D	OBD/WL/RB
Rhamnaceae	*Zizyphus oenoplia* Mill.	Katber	F	OBD/RS
Rubiaceae	*Wendlandia exserta* DC.	Tilia	F	FE/RB
Sterculiaceae	*Eriolaena stocksii* H.I. & T.T.	Banta	F	FE/RB
Verbenaceae	*Vitex negundo* Linn.	Sinoar	D	OBD/RB
	Lantana camara Linn.	Putus	D	OBD/RS
C. TREES				
Apocynaceae	*Holarrhena antidysentrica* Wall.	Kurchi	C	RB/FE
Araliaceae	*Heteropanax fragrans* Seem.	Rengebanam	C	RB/FE
Bignoniaceae	*Oroxylum indicum* Vent.	Sona	C	RB/OBD/WL
Caesalpiniaceae	*Tamarindus indica* Linn.	Imli	C	FE/WL/RS
Combretaceae	*Terminalia arjuna* W. & A.	Arjun	C	FE/OBD/WL
	Terminalia tomentosa W. & A.	Asan	C	FE/OBD/WL
Cornaceae	*Alangium lamarckii* Thw.	Akar-kanta	A	RB/OBD/WL

Family	Botanical Name	Common Name	Status	Occurrence
Dipterocarpaceae	*Shorea robusta* Gaertn.	Sal	F	FE/OBD/WL
Ebenaceae	*Diospyrus melanoxylon* Roxb.	Kendu	A	RB/OBD/WL
Lythraceae	*Lagerstroemia parviflora* Roxb.	Sidha	C	FE/OBD/WL
Mimosaceae	*Acacia arabica* Willd.	Babul	F	OBD/RB/RS
Moraceae	*Ficus glabella* Blume	Putkul	C	OBD/WL
	Ficus glomerata Roxb.	Gular	C	OBD/WL/FE
	Ficus infectoria Roxb.	Pankar	C	FE/RB
	Ficus religiosa Linn.	Pipal	C	OBD/WL
	Ficus tomentosa Roxb.	Barun	F	OBD/WL
Ochnaceae	*Garuga pinnata* Roxb.	Kekar	C	FE/RB
Oleaceae	*Nyctanthes arbor-tristis* Linn.	Haringhar	C	FE/OBD
Palmae	*Borassus flabellifer* Linn.	Tar	C	OBD/WL/FE
	Phoenix acaulis Buch.	Khajur	F	OBD/WL/RS
	Phoenix sylvestris Roxb.	Khajuri	C	FE/WL/RS
	Diospyrus melanoxylon Roxb.	Kendu	A	RB/OBD/WL
Papilionaceae	*Butea frondosa* Roxb.	Dhak	C	OBD/WL
Rubiaceae	*Adina cordifolia* Hook.	Karam	C	FE/RB
	Gardenia latifolia Aiton.	Papara	F	RB/FE

N.B. – RB = River Bank and Bed, OBD = Over Burden Dump, WL = Waste Land, FE = Forest Edge, RS = Road Side, P = C = Common, F = Frequent, A = Annual, P = Perennial, D = Dominant

Our study suggests that groundwater was more polluted than surface water. Coalmining activities significantly cause mineralization in groundwater. Compared to surface water, groundwater samples were rich in cations like calcium and magnesium, anions like chloride and nutrients like phosphate and nitrate. Total solids and total hardness concentration were also higher in groundwater than surface water. Thus, groundwater was not potable in regards to total solids, total hardness and calcium and magnesium cations because their values crossed the ISI and/or WHO standards for drinking water. pH and DO concentrations were below the ISI and WHO standards in both surface as well as groundwater samples. Comparatively less plant species density on abandoned mines and overburden dumps and the low frequency of trees and dominance of thorny shrubs around the disturbed areas were recorded.

Table 4: Frequency of different plant taxa in Simlong coalfield area.

Taxa	Monocot		Dicot	
	Number	Percentage	Number	Percentage
Family	5	12.50	33	87.50
Genera	12	16.64	60	83.36
Species	15	16.85	74	83.15

Table 5: Habit wise grouping of plant species and their percent composition in Simlong coalfield area.

Habit	Number of Species	Percentage
Herbs	49	55.056
Trees	25	28.089
Shrubs	15	16.853

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