



Geospatial Mapping of Chlorine in NTPC-Linked Coalmines

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Abstract. Chlorine (Cl) is a trace element present in coal which undergoes complex changes when coal is combusted in boiler. Chlorine may combine with iron and sulphur in slag deposits in areas of the boiler where reducing conditions occur to form compounds that can corrode the wall tubes. In the present study, chlorine content mapping of major NTPC linked coal mines has been done using Trace Elemental Instruments (TEI) chlorine analyzer “Explorer-X”. While most of the Indian coal mines exhibit low chlorine levels between 10 and 60 ppm, the Ragavpuram coal deposit stands out with a significantly higher concentration of 146 ppm.

Keywords: Chlorine mapping, iron, sulphur, alkali metals, slag, NTPC linked coal mines

1 Introduction

Thermal power plants have been the backbone of electricity generation for decades while they remain essential for meeting global energy demands, their environmental impact necessitates ongoing technological innovation. Thermal power plants while crucial for electricity generation, pose environmental and operational challenges due to contamination and corrosion [1,2]. These issues arise from various sources including fuel combustion, water use, and the materials involved in plant construction and operation. Chlorine is a significant contributor to high/low temperature corrosion in coal-fired power plants [3]. The chlorine content of coal is influenced by various geological factors, including its proximity to marine environments [4]. Additionally, the migration of groundwater contributes to elevated chlorine levels in coal [5]. Chlorine may be incorporated into the plant material that initially formed the coal [6]. Some plant matter or its residues may assimilate chlorine from the environment, embedding it within the resulting coal formation. Human interventions such as industrial pollution or saline water discharge can potentially introduce chlorine compounds into coal deposits. Nevertheless, these anthropogenic sources are typically less prevalent than naturally occurring chlorine origins. Upon combustion, chlorine combines with hydrogen to form hydrogen chloride gas which is highly corrosive. At high temperatures, chlorine also reacts directly with metals sodium and potassium to form low melting metal chlorides [7]. These metal chlorides can evaporate or form deposits on equipment surfaces leading to chlorine-induced hot corrosion [8]. The presence of sulphur and iron along with chlorine aggravates corrosion by forming a molten corrosive layer on boiler tubes [9]. Iron pyrite decomposes in furnace (from FeS_2 to FeS). Decomposition product is low melting leading to slagging on water wall tubes as shown in Fig.1.

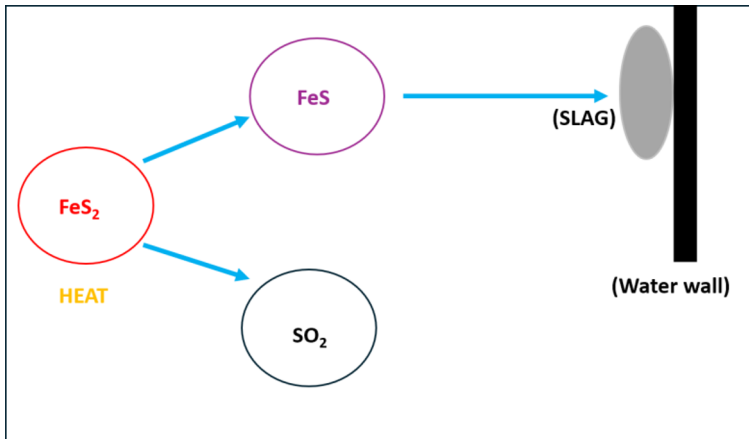


Fig. 1. Water wall slag formation.

A coarse pyrite particle (FeS_2) undergoes thermal decomposition in the flame to iron sulphide (FeS). The molten iron sulphide, accelerated by high velocity gases from the coal pipe or burner, impacts the waterwall with sufficient force to adhere and form slag. At high temperature chlorine leads to the formation of FeCl_2 and FeCl_3 , which can evaporate and redeposit, causing the metal to oxidize and degrade [10]. The process typically occurs in superheater and reheater tubes where temperatures are high. In cooler parts of the flue gas system, chlorine may combine with water vapor to form hydrochloric acid (HCl) leading to acid corrosion of ducts, filters and chimneys. Further, the Gross Calorific Value (GCV), Ash, Moisture and Volatile Matter (VM) varies over a wide range in a coal matrix. Hence the chlorine content was assessed over GCV, ash and VM [11]. Researchers have made effort to study the chlorine content in foreign coals [12-13]. The American, Australian and African coal has high chlorine content 0.02-0.6% [14]. Considering the detrimental effect of chlorine on the power plant equipment, the present study aims at estimation of chlorine content of the various coal mines linked to NTPC.

2 Geological Formations of the Coalfields

Central Coalfields Limited (CCL) primarily operates in Jharkhand and Bihar, while Eastern Coalfields Limited (ECL) covers West Bengal and Jharkhand. Bharat Coking Coal Limited (BCCL) specializes in high-grade coking coal extraction from the Jharia Coalfield, whereas Northern Coalfields Limited (NCL) operates in the Singrauli Coalfield, spanning Madhya Pradesh and Uttar Pradesh. Mahanadi Coalfields Limited

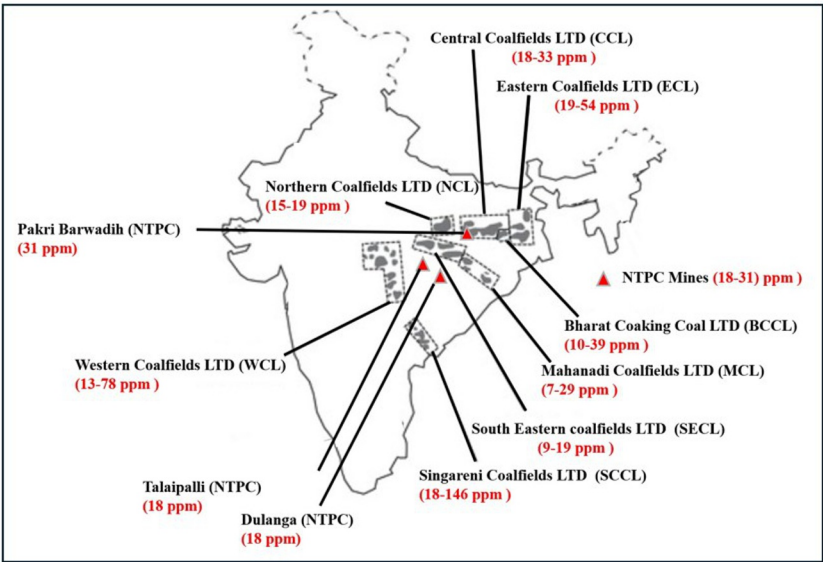


Fig. 2. Chlorine mapping of Indian Coal

(MCL), located in Odisha, lies within the Gondwana sedimentary formation. South Eastern Coalfields Limited (SECL) has its operations concentrated in Chhattisgarh and Madhya Pradesh, while Singareni Collieries Company Limited (SCCL) operates in Telangana. Western Coalfields Limited (WCL) primarily manages coal mines in Maharashtra, with some extending into Madhya Pradesh.

The coal deposits of NTPC, CCL, ECL, BCCL, NCL, MCL, SECL, SCCL, and WCL are part of the Lower Permian Barakar and Raniganj Formations, which belong to the Gondwana Supergroup. The geographical distribution of these coalfields (along with chlorine) is illustrated in Fig. 2.

3 Coal sample acquisition from mines and sidings

The coal samples for this study were collected from various mines and adjacent railway sidings used for shipment. Specifically, samples were obtained from Pakri BNDG NTPC, Tallaipalli KCHP, and Dulanga sidings, corresponding to the Pakri Barwadih, Tallaipalli, and Dulanga coal mines, respectively.

For Eastern Coalfields Limited (ECL), samples were collected from the PSBP, PMCS, CCSJ, SSAP, MCSP, NMCL, PSCE, POCP, and PMCS sidings. Similarly, for Central Coalfields Limited (CCL), primary sidings analysed included PLCP, DCSK, SLSP, BSDC, BLCC, BCBM, CPCS, and CHRI. In Bharat Coking Coal Limited (BCCL) mines, major sidings used for chlorine analysis were KLSK, KKBK, AKKK, TCSB, CCSR, BCSR, NUGP, DRGM, TPST, and POCP.

The sample sources for Northern Coalfields Limited (NCL), included Aryan IPAT, Amelia THDC, Nighai, Dudichua, and Nighai WW. In Mahanadi Coalfields Limited (MCL), samples were obtained from sidings at Kulda MCLK, Basundhara MFSJ, Garjanbahal MFSJ/MCLK/K/MCLF, IB Valley BOMB, Lajkura LOCM, Laxhanpur BOCM/BOCB, Jagannath SBCT/ACTR, Lingaraj, Hingula, Bharatpur, Siarmal MFSJ, Samleshwari LOCM, and Talcher KT.

For Southeastern Coalfields Limited (SECL), sidings analysed for chlorine content included Gevra GPCK, New Kusmunda NKCR, Dipka SCDG, Kusmunda KMKA, Baroud BOMK, Chhal SLCC, Manikpur MCK, and Old Kusmunda OKSR. In Western Coalfields Limited (WCL), chlorine analysis was conducted on samples from Pouni-II GGPP, Penganga GGS, Gourideep PRPI, Gokul UMSG, Umrer UMSG, Dhuptalla MBCB, Ballarpur MBCB, Kolar WANI, Bellora GGS, Sasti MBCB, Mungoli GSG, Makardhokra-I UMSG, Makardhokra-III UMSG, Neeljay GGS, Ukni WANI, and Dumrikhurd.

For Singareni Collieries Company Limited (SCCL), coal samples for analysis were collected from JVR CHP JVRB, GDK GXSG, RCHP RUSG, GDK CHP GOSG, as well as sidings at Ramakrishna, Singareni, Godavari, Jalagam, Ragavapuram, Deoragam, and BPA CHP.

4 Method

In the present study, chlorine measurement in coal has been done using TEI make chlorine analyser, model “Xplorer-X”. The instrument is based on standard ASTM D -6721. The same standard has been used for chlorine assessment globally [15]. Sample containing halides is introduced into the furnace using introduction module “Solid Module for solids and petrochemical products with a final boiling point > 420 °C”. The schematic of Xplorer- X is presented as Fig. 3.

The sample containing chlorides is oxidized at high temperature (1000°C). After conditioning the gas stream so produced by removing water and any other interference compounds in the sulfuric acid scrubber, the dried and clean gases are led into a temperature-controlled titration cell where the chloride ions react with the silver ions. The amount of charge (the integral of the regeneration current over the measuring time) used to generate the lost silver ions, is directly related to the chlorine (Cl) content of the sample.

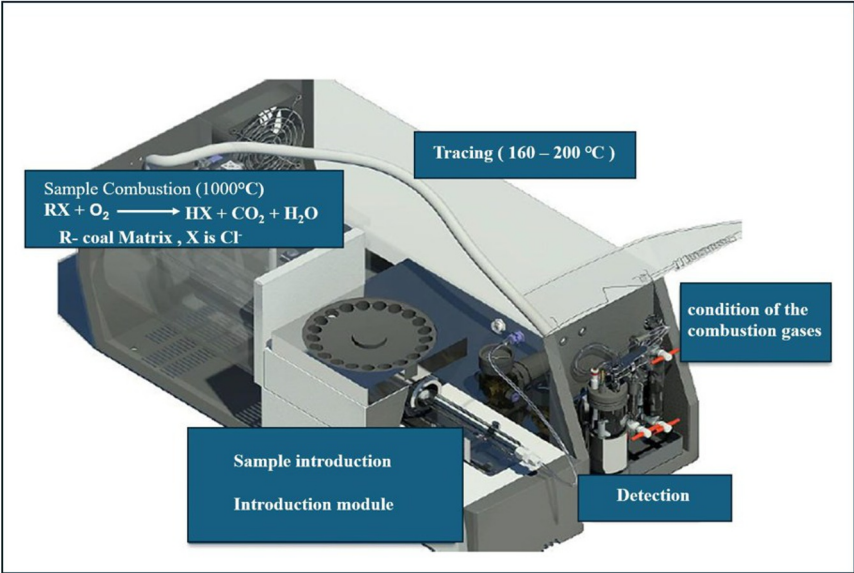


Fig. 3. TEI “Xplorer -X along with its components (Courtesy of Trace Element Instruments)

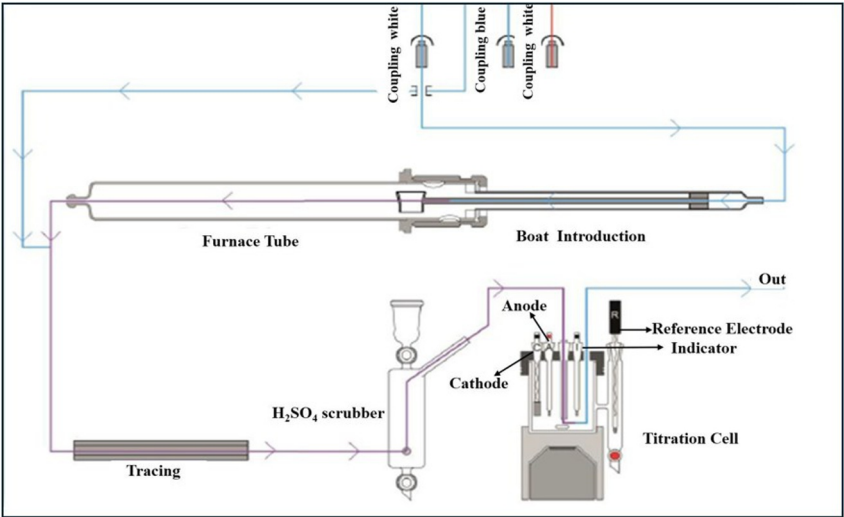


Fig. 4. Flow path - This diagram shows flow path of chlorine containing sample from boat introduction up to detection by coulometric cell (by courtesy of Trace Element Instruments)

5 Test Procedures

The test procedure of the coal samples for the trace of chlorine is presented as Fig. 4. A sample quantity of 10-20 mg is introduced through boat into furnace tube. The sample is subjected to oxidation at high temperature around (1000°C). The reaction among the products of combustion leads to formation of HCl gas which is conditioned through sulphuric acid scrubber. Furthermore, the conditioned sample is detected through micro coulometry.

6 Results

The chlorine concentration of NTPC, ECL, CCL & BCCL mines lies in the range of 10-50 ppm. There is not much significant variation in the coal chlorine content of NTPC, ECL, CCL & BCCL mines as coal formation belongs to Gondwana era with Barakar and Raniganj as the major coal bearing formation. The chlorine content of NTPC, ECL, CCL & BCCL mines presented as Fig. 5.

The chlorine content of SECL, SCCL & SECL is presented as Fig. 6. It lies in the typical range of 10-60 ppm except for Raghavpuram coal mine. The higher chlorine content of Raghavpuram mines is associated to its presence in the vicinity of coastal area.

The chlorine concentration of WCL & MCL mines typically ranges from 10 to 60 ppm, Fig. 7. Coal from these mines shows minimal variation in coal chlorine, as they originate from the Gondwana era, primarily within the Barakar and Raniganj coal-bearing formations. However, there were slight variations of Makardhokra-I UMSG (78 ppm) and Makardhokra-III UMSG (72 ppm) which could be attributed due to the heterogeneity of organic matter at the time of deposition.

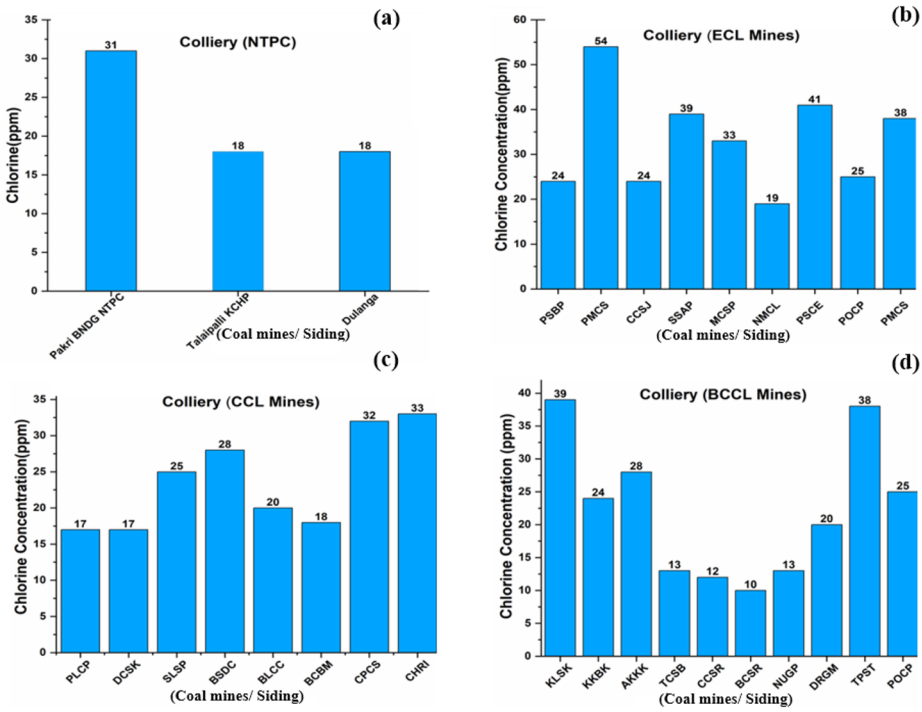
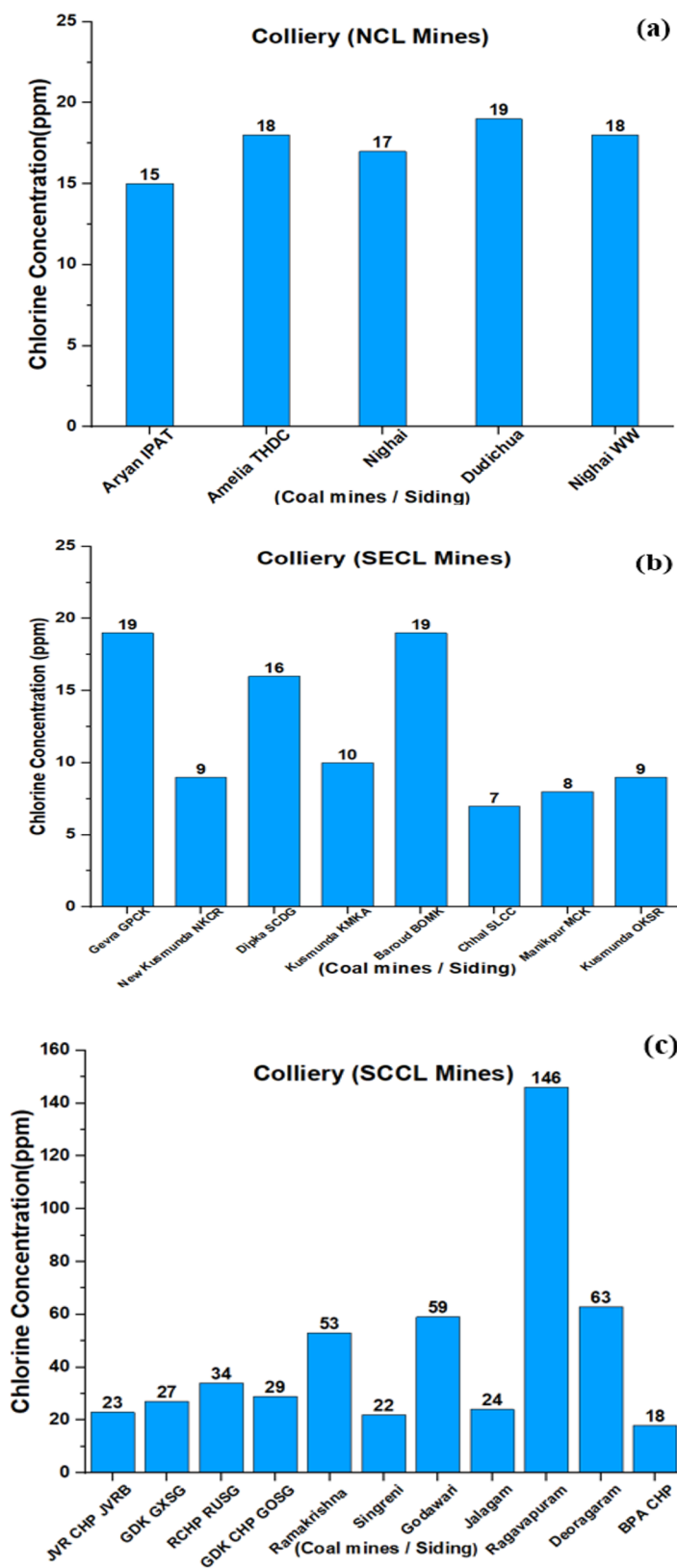


Fig. 5. Chlorine content of NTPC(a), ECL(b), CCL(c) & BCCL(d) mines



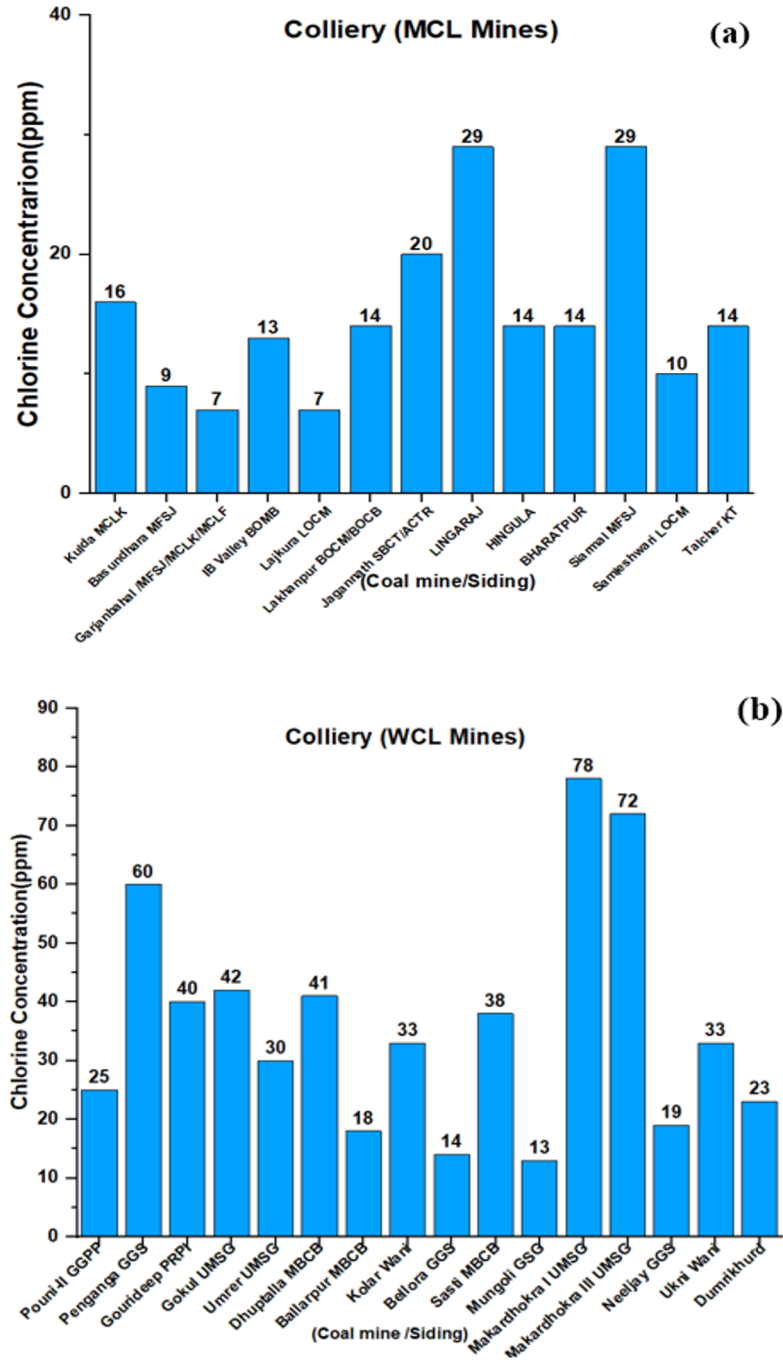


Fig. 7. Chlorine content of MCL(a) & WCL mines(b)

7 Conclusions

Indian coal typically contains chlorine levels ranging from 10 to 60 ppm, with few exceptions. The primary coal-bearing formations, Barakar and Raniganj, are found across all coalfields within the Gondwana subgroup. NTPC-owned coal mines have chlorine concentrations between 18 and 31 ppm. Most Indian coal mines, including those operated by ECL, CCL, BCCL, NCL, SECL, and MCL, generally feature chlorine content below 50 ppm, with the exception of SCCL and WCL mines. Notable locations with slightly higher chlorine levels include SCCL sidings such as Godavari (59 ppm) and Deoragram (63 ppm), as well as WCL sidings like Penganga GGS (60 ppm) and Makardhokra (72–73 ppm). The Rhagavpuram siding of WCL, situated near the coastal region, exhibits a significantly higher chlorine level of 146 ppm. In general, Indian coal mines are characterized by relatively low chlorine content.

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