Impact Assessment of Coal Mining on Ground and Surface Water in Korba Coalfield Region, Chhattisgarh, India

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Doctor of Philosophy

By

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CHAPTER-6

CONCLUSION AND FUTURE SUGGESTION

6.1 Conclusion

The Following conclusion has been drawn from this study as under-

1- On groundwater

- The pH readings ranged from 6.05 to 7.78, with a mean value of 6.76 in the pre-monsoon season, and from 5.32 to 8.11, with a mean value of 6.43 in the post-monsoon season, showing that groundwater from each monsoon has a slightly acidic to alkaline in nature.
- Calcium and sodium were the most abundant cation, accounting for 45% and 43% of all cations in both seasons. The order of mean abundance of major cations is Ca^{2+} > Na^{+} > Mg^{2+} > K^{+} in the pre monsoon and Na^{+} > Ca^{2+} > Mg^{2+} > K^{+} in post monsoon season. While. bicarbonate is the most abundant anion, accounting for 57% and 49% of all anions in both seasons. The order of mean abundance of major anions is HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > F^- in both seasons.
- Based on correlation analysis, the significantly strong positive correlation were observed between different pair of parameters such as EC & TDS (r = 0.999), EC & HCO_3^- (r = 0.898), TDS & HCO_3^- (r = 0.866), TH & Mg^{2+} (r = 0.821), TH & Na^+ (r = 0.968), TH & Cl^- (r = 0.861), Na^+ & Cl^- (r = 0.872), whereas a weak negative correlation existed between pH & Cl^- (r = -0.206), F^- & NO_3^- (r = -0.398), pH & NO_3^- (r = -0.179) in pre monsoon. Moreover, the strong positive correlations were identified

between EC & TDS (r = 0.997), EC & HCO_3^- (r = 0.908), TDS & HCO_3^- (r = 0.910), TH & Mg^{2+} (r = 0.885), and weak negative correlation identified between pH & K^+ (r = -0.178), pH & NO_3^- (r = -0.307), F^- & NO_3^- (r = -0.334) in post monsoon season.

- ❖ The CCME WQI ranged from 48.63 to 100 in pre monsoon season. According to the results of CCME WQI, 27 (62.79%) groundwater samples were categorised as excellent, 13 (30.23%) samples as good, 2 (4.65%) samples as fair, rest 1 (2.3%) sample as marginal and no sample was assigned to the poor class in pre monsoon. However, CCME WQI ranged from 72.79 to 100 in post monsoon season and consequently 28 (65.12%) samples were excellent, 14 (32.56%) samples were good, rest 1 (2.33%) samples were fair and no samples were assigned to marginal to poor category.
- ❖ The dendrogram shows that a total of 43 sampling sites fall into three distinct clusters. Cluster I contain the majority of the 27 sample sites, whereas Cluster II encompasses 15 sampling sites. In contrast, Cluster III consists only of GW-10 during the pre-monsoon season. Whereas, Cluster I consist 28 sample sites, Cluster II consists of 14 sampling sites and only (GW-16) was included in Cluster III in post monsoon season. The change in clusters from cluster 1 to cluster 3 is associated with a noticeable decline in water quality.
- ❖ The piper trilinear diagram is a graphical representation of the major ions that can be used to quickly determine the hydrogeochemical facies of groundwater. The diamond-shaped section of Piper Trilinear diagram shows that 27.91% samples in pre monsoon and 16.28% samples in post monsoon fall into the CaMg-HCO3 category, showing the percolation and dissolution of minerals like calcite and dolomite, which are significant constituents in the geological composition. Similarly, around 72.09% samples in pre monsoon and 74.42% samples in post monsoon fall into the Ca-Mg-

Cl-SO4 category, indicating the existence of anthropogenic activities such as ongoing mining operations and the presence of thermal power plants in the area. The remaining 9.30% samples in post monsoon fall under the NaCl-SO4 category, which shows the process of small minerals dissolving in the area.

- ❖ According to the Gibbs diagram, a majority of the groundwater samples of both seasons fall within the rock water dominance and evaporation crystallisation field in terms of both cation and anion. This suggests that the quality of the groundwater is influenced by the dominance of rock and evaporation crystallisation.
- ❖ The SAR values have been calculated which indicate that a majority of the samples (69.77% in the pre and 74.42% in the post) are classified as C2-S1 category, which corresponds to medium salinity and moderate alkali levels. A smaller proportion of the samples (18.60% in the pre and 19.95% in the post) are categorised as C1-S1, indicating low salinity and low alkali levels. The remaining samples (11.63% in the pre and 11.63% in the post) are classified as C3-S1, indicating high salinity and low alkali levels.
- ❖ The sodium percentage (%Na) is represented by Wilcox plot which indicates that majority of groundwater samples (93.02% in pre and 88.37% in post) belongs to excellent to good while, remaining (6.97% in pre and 11.63% in post) samples classified as good to permitted class.
- ❖ The calculated Kelly's index (KI) indicates that approximately (93.02% in pre and 74.40% in post) of groundwater samples fall into the suitable class for irrigation. The remaining samples (6.98% in pre and 25.60% in post) are categorised as unsuitable class.
- ❖ The Permeability Index values (6.98% in pre and 6.98% in post) of samples belong to Class I, (81.4% in pre and 79.1% in post) samples belong to Class II, showing that

groundwater sampling was suitable for irrigation uses. Whereas, the rest (11.6% in pre and 14% in post) of samples belong to Class III which is not suitable for irrigation.

- ❖ The Magnesium Hazard values (95.3% in pre and 74.4% in post) indicated that samples belong to suitable class (MH < 50), and rest (4.7% in pre and 25.6% in post) of samples belong to unsuitable class (MH > 50) for irrigation.

2-On Surface Water

- ❖ The pH values for surface water ranged from 6.25 to 8.66, with mean value of 7.84 in pre monsoon, and from 6.35 to 8.23, with mean value of 7.66 in post monsoon season respectively. The data indicates that the surface water from both seasons exhibits a slightly acidic to alkaline pH range.
- ❖ Based on ions chemistry, calcium (Ca^{2+}) was the most abundant cation, accounting for 42.10% and 45.8% among cation in pre and post monsoon seasons respectively. The order of mean abundance of major cations was as follow: $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ in both seasons. The bicarbonate ion was most abundant anion that consisted 51.68% and 57.01% of all anions in pre and post monsoon seasons respectively. The order of mean abundance of major anions was as follow: $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^- > F^-$ in both seasons respectively.
- ❖ Based on correlation analysis, significantly strong positive correlations were observed between EC & TDS (r = 0.998), EC & TH (r = 0.852), EC & HCO_3^- (r = 0.862), TDS & TH (r = 0.846), TH & Mg^{2+} (r = 0.828), Mg^{2+} and SO_4^{2-} (r = 0.801), whereas a weak negative correlation existed between pH and EC (r = -0.287), pH and TDS (-0.288), Mg^{2+} and K^+ (r = -0.222), K^+ and SO_4^{2-} (r = -0.303) in pre monsoon season. However, significant strong positive correlations were identified between EC & TDS (r = 0.991), EC & SO_4^{2-} (0.873), TDS & SO_4^{2-} (r = 0.873), Na^+ & Cl^- (r = 0.910), whereas a weak negative correlation identified between pH & TH (r = -0.274), pH &

Ca^{2+} (r = -0.498), K^{+} & SO_4^{2-} (r = -0.195) and F^{-} & NO_3^{-} (-0.252) in post monsoon season.

- ❖ The CCME WQI of surface water ranged from 80.79 to 100 in pre while it ranged from 86.87 to 100 in post monsoon season. As per CCME WQI analysis, 3 surface water samples such as SW-5, SW-10 and SW-14 (17.65%) in pre monsoon and 4 samples such as SW-6, SW-9, SW-10 and SW-14 (23.53%) in post monsoon season were categorized as excellent class. Whereas, the remaining 14 (82.35% in pre) sample and 13 (76.47% in post) samples as good class. No sample was found in the fair to poor class from both seasons.
- ❖ The calculated SAR value of surface water (70.59% in pre and 52.94% in post) classified into the C2-S1 category, (17.65% in pre and 47.06% in post) fall into the C1-S1 category, and the remaining samples (11.76% in pre) under the C3-S1 category are acceptable for irrigation.
- ❖ The sodium percent (%N) is represented by Wilcox plot which indicates that most of the samples (94.12% in pre and 100% in post) fall in the excellent to good category. While, the remaining (5.88% of pre) samples fall in good to permissible class of irrigation.
- ❖ According to Kelly's ratio classification, approximately 94.10% in pre and 74.40% in post monsoon samples fall into the suitable class and the remaining 5.9% in pre and 25.60% in post samples fall into the unsuitable class.

Based on heavy metal analysis of Groundwater

- The groundwater sample was collected during the pre-monsoon period in March 2022 and the post-monsoon period in November 2022 for the purpose of evaluating the groundwater quality in terms of heavy metals. A total of thirty-five (35) groundwater samples were collected during the pre and post monsoon seasons in 2022 from various locations, including bore wells (23 samples), hand pumps (9 samples), and dug wells (3 samples).
- The ICP-MS equipment was used to examine a total of ten heavy elements, including aluminium (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), nickel (Ni), and zinc (Zn).

  The observed Al content ranged from 0 to 176.57 µg/L with mean value of 12.40 µg/L in pre monsoon, while it ranged from 0 to 153.21 µg/L with mean value of 11.37 µg/L in post monsoon season, indicating that only two samples (GW-4 and GW-29) collected during both seasons exceeded the required limit of 30 µg/L as per BIS (2012).

  The Fe content ranged from 0 to 2889.74 µg/L in pre monsoon, whereas from 0 to 289.49 µg/L in post monsoon season. It shows that only two samples (GW-20 and GW-32) of pre monsoon exceeded standard limit and all samples of post monsoon fall under the permissible limit of 300 µg/L as suggested by BIS and WHO.

  The Mn content ranged from 17.53 to 3687.68 µg/L with mean value of 87.88 µg/L in pre, whereas from 15.03 to 183.65 µg/L with mean value of 57.59 µg/L in post monsoon indicates that ten groundwater samples (GW-1, 3, 5, 8, 20, 21, 24, 28, 31, 32) in pre monsoon and five samples (GW-1, 3, 5, 8, 24, 28) of post monsoon exceeded the suggested required limit of 100 µg/L as per BIS and WHO.

Ni content ranged from 0 to 69.87 µg/L with mean value of 11.37 µg/L in pre monsoon, whereas from 0 to 52.36 µg/L with an average of 10.05 µg/L in post monsoon season. It shows that only six groundwater sample (GW-23, 24, 25, 27, 28, 32) collected during pre monsoon and four samples (GW-25, 28, 29, 33) collected of post monsoon season exceeded the recommended permissible limit of 20 µg/L as per BIS and WHO.

The Zn content ranged from 0 to 11766.92 µg/L with mean value of 485.01 µg/L in pre monsoon, whereas from 0 to 9866.35 µg/L with mean value of 401.76 µg/L in post monsoon season. It suggests that only one sample (GW-32) exceeded the recommended permissible limit of 4000 µg/L, as stated by the WHO (2006), during both the pre-monsoon and post-monsoon seasons.

The rest of the metals analysis of groundwater like Ba, Cd, Cr, Cu and Pb shows that they are within the permissible limits.

- ❖ The Heavy Metal Pollution Index (HPI) is a comprehensive assessment tool that examines the impact of individual heavy metals on the overall water quality. The higher HPI value was shown to be attributable to the increasing concentrations of associated metals in the groundwater.
- ❖ HPI values of the groundwater samples varied between 0.79 to 53.59 during the pre monsoon and 0.79 to 31.72 during the post monsoon season. Out of the total samples collected, 30 (85.71% in pre monsoon) and 30 (85.71% in post monsoon) were categorised under low HPI. Another 5 (14.28% in pre monsoon) samples and 1 (2.86% in post monsoon) sample classified as high class of HPI which need a minor treatment before use. The remaining 4 (11.45% in post monsoon) were classified in medium class of HPI.

- HEI index is recommended as an alternative to the HPI index for assessing the presence of heavy metals in groundwater bodies. The HEI values of groundwater samples have a wide range, varying from 0.53 to 20.25 during the pre and from 0.41 to 5.87 during the post monsoon season. Among the collected samples, 16 (45.71% in the pre monsoon) and 25 (71.43% in the post monsoon) were classified within the low category of HEI. Out of the initial sample, 14 (40.0% in the pre monsoon) and 8 (22.85% in the post monsoon) are classified as medium-class of HEI. The remaining 5 (14.29% in the pre monsoon) samples and 2 (5.71% in post monsoon) samples comes under to the high HEI category which requires the minor treatment before use.
- The metal index (MI) assesses the extent to which heavy metals harm human health in addition to the overall water quality used for drinking. The MI of groundwater samples varied from 0.26 to 15.52 in pre monsoon and from 0.195 to 4.04 in post monsoon season. Overall, 31 (88.57% in pre monsoon) samples and 35 (100% in post monsoon) samples belong to very pure to slightly affected class, making them safe to drink. The rest 4 (11.43% in pre monsoon) samples and (5.71% in post monsoon) samples are classified into moderately to seriously affected class are unsafe to consume.
- Scatter plot has yielded better results in the identification of strong correlation between different indices such as HPI, HEI and MI. Based on scatter plot, there is a strong correlation between HEI and MI (R^2 = 0.9348), a moderate correlation between HPI and HEI (R^2 = 0.5306), as well as between HPI and MI (R^2 = 0.5929) in pre monsoon season. Whereas, a strong correlation between HEI and MI (R^2 = 0.8128), a moderate correlation between HPI and HEI (R^2 = 0.3763), as well as between HPI and MI (R^2 = 0.5228) was found in post monsoon season.

- Based on scatter plots, it is evident that the groundwater recharge in post monsoon season dilutes heavy metal concentrations and lowering the metal index (MI) in groundwater.
- The PCA analysis revealed that groundwater quality was governed through large loading with an absolute value ≥ 0.40. The water quality parameters under PC1, PC2, and PC3 have total variance of 37.71%, 14.98%, and 12.69% in the pre monsoon as well as 25.71%, 18.18%, and 13.26% in the post monsoon respectively.

  The three factors with eigenvalue of 3.772, 1.498, 1.269 in pre monsoon season and 2.569, 1.818 1.326 in post monsoon season were extracted from principal factor matrix after varimax rotation.

Land Use and Land Cover (LULC)

- The remote sensing & GIS application were applied to analyse LULC changes in the study area. A total of six classes of LULC such as Forest, Habitation, Water bodies/river, Mining Area, Crop land/vegetation and Fallow land were considered. The present findings revealed a pattern of significant changes in the LULC classifications between 2001 and 2021.

  The Mining area and Habitations were experienced the most positive changes of 138.27% and 75.48% whereas water bodies and Crop land/vegetation were experienced maximum negative changes -25.84% and -22.80% in the area from 2001 to 2021 respectively. The majority of these two classes has been harmed by the expansion of mining blocks.

  The Forest area and Fallow land also shows declining trend with very low negative change (-7.39%) & (-1.53%) in the area from 2001 to 2021 respectively.

  As a result of the rapid expansion of coal mining and industrial activity over the last twenty years, there have been major changes in the LULC. The expansion of mining sites throughout the study period has been seen to have a direct major impact on Water bodies, Crop land/vegetation.

Moreover, the prepared LULC map have undergone an accuracy assessment in the area. The accuracy of the generated LULC map for the years 2001, 2011, and 2021 demonstrates overall accuracy rates of 90.5%, 92.1%, and 94.5% respectively, along with corresponding Kappa coefficient accuracy values of 88.2%, 90.5%, and 93.3% indicating that the LULC analysis of the study area was very precise.

Correlation of LST with NDVI and NDWI

- The correlation study result between LST with NDVI and NDWI revealed a significant correlation, providing evidence of how mining and urbanisation influence the environment, water bodies, and vegetation coverage over time.

It aims to investigate the trend of spatiotemporal relationship of LST with NDVI and NDWI for the study area using five (2001, 2006, 2011, 2016, 2021) cloud-free Landsat data sets from 2001 to 2021.

This analysis shows that mean LST of the study region has been increased with a very significantly from 28.40℃ in 2001 to 38.27℃ in 2021. Total increased in surface temperature in last two decade are maximum 9.87℃ from 2001 to 2021.

An exponential increase in surface temperature over the past 20 years is evidence of dynamic coal mining operations in the Korba region.

The continuous rise in surface temperature cause decline in water body demonstrate the steady decline in water (-0.43 between 2001 and 2021) during the study period.

This analysis demonstrates that vegetation cover of the area has also been decreased at a quite significant rate of -0.1 between 2001 and 2021.

A negative correlation has been observed between LST & NDVI and LST & NDWI.

The correlation study shows low negative correlation between LST and NDVI for the selected year of 2001, 2006, 2011, 2016 and 2021 are as follows: r = 0.061, r = 0.054, r = 0.119, r = 0.011 and r = 0.230 respectively. Whereas, low to very low negative correlation exists between LST and NDWI for the year of 2001, 2006, 2011, 2016 and 2021 are as follows: r = 0.039, r = 0.113, r = 0.047, r = 0.037 and r = 0.0.268 respectively.

6.2 Suggestions for future work

- Mine water is a valuable resource for local society, but it is a hindrance to mining operations. The conversion of mine water into portable water under the nation's Jal Shakti Abhiyan is the future work related with this thesis.
- It is possible to develop a more effective monitoring programme for water quality parameters in the study area by combining remote sensing, GIS, and conventional in-situ sampling.
- There is a need to study water level fluctuations as well as compute the groundwater potential zone in the Korba coalfield region.
- Future works may develop new strategies to reduce toxic pollutants from large volumes of work, ands new techniques to absorb such metals.
- Further study on LULC forecasting in the Korba coalfield region will help with policy interventions for future development of that region.