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# SEDIMENT CHARACTERIZATION ON PIT-LAKE WATER BODY OF RANIGANJ COAL FIELDS, WEST BENGAL, INDIA

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**ABSTRACT** Ecological conditions of aquatic environment were very fragile in connection with severe deterioration due to anthropocentric causes. In the present study, open cast coal mining generated pit-lakes at different mining areas under Raniganj coalfields (RCF), West Bengal, India were investigated with special emphasis on the soil-sediment quality. Ten physic-chemical characteristics of soils were measured seasonally from the bottom sediment in lake littoral region during April, 2014 to March, 2015. Mildly acidic to alkaline nature of soil sediment characteristics were recorded where significant positive correlation was noted for organic carbon and bulk density ($r = 0.9$). Moreover, PCA analysis reveals three most important and key influential parameters as Organic Carbon, Bulk Density and Soil available nitrogen content of pitlake soil. Microbial examination of pit lake soil sediment was required to assess the complete nature of this aquatic environment.

**KEYWORDS :** Soil Quality, Pitlakes, Limnology, Raniganj coalfields, India.

## INTRODUCTION:

Surface mining process creates rapid changes in the landscape. Coal mine pit lakes are generated as a consequence of open cast mining process. Large excavated areas bearing vertical walls and enormous quantity of water typically characterize these aquatic systems. Mining companies have limited liabilities regarding the safe usages of their water resources. Subsequently the pitlake adjoining areas receive less attention and improper managerial decisions. In West Bengal, especially in RCF (Raniganj Coal Field) region, open cast mining has become increasingly common over the last few decades through changes in excavation technology and ore economics. Moreover, such operations frequently leave a legacy of open mine pits once mining ceases.

Soil sediment of a water body is considered as the 'biological engineer' as well as reservoir of nutrients which directly supports the growth and development of autotroph community like Macrophytes (Barko and Smart, 1986; Barko et al., 1991). However, Deterioration of ecological condition of the coalmined pit-lakes, created after the surface mining operations, is due to unavoidable evacuation of top soil, destruction and loss of natural soil profile, land degradation, leaching from huge overburden (Kundu and Ghose, 1994) and reduction of fertility of top soil. So, the chemical properties including organic carbon, available nitrogen, available phosphorus and available potassium of the pit-lake sediment are mainly dependent on the nutrients present in the overburden top soil, which is mostly containing less nutrients for the growth of the plants (Ghose, 2001; Dutta and Agrawal, 2002; Ghose, 2004; Mercuri et al., 2005; Maiti, 2007; Sheoran et al., 2010). Ecological conditions are poorly documented in Pitlakes of Raniganj Coal Field area and there are scanty literature with notable works by Palit et al., 2014; Gupta et al., 2013. Thus the present study of selected pit lakes' soil sediment characteristics have been carried out to predict the environmental health and quality of life sustaining nature of Pitlakes in Raniganj Coal Field.

## MATERIALS AND METHODS:

**Study area:**

The Raniganj Coalfield lies in West Bengal and partly in Jharkhand states at the Eastern most part of the Damodar valley coalfield.

Raniganj Coalfield is the birth place of coal mining in the country. Area of Raniganj Coalfield is 1530 $Km^{-2}$ spreading over Burdwan, Birbhum, Bankura and Purulia Districts in West Bengal and Dhanbad District in Jharkhand.Heart of Raniganj Coal Field(RCF)is, however, in Burdwan District bounded by Ajoy River in North and Damodar River in South. On the basis of geographic distribution 10 pitlakes were selected for studying the physico chemical properties of their soil sediment in premonsoon, monsoon and post-monsoon, comprising the three principal seasons of a year (April, 2014 to March, 2015) (Table 1).

**Table 1: An inventory of 10 selected pitlakes in Raniganj coalfield area, West Bengal, India**

| Sl. No. | Name of the Pitlakes | Latitude | Longitude | Elevation (m) | Area of mining | Block | Nearest village/town |
|---|---|---|---|---|---|---|---|
| **PL01** | Chora pitlake | 23°40'21.4"N | 87°12'21.9"E | 74.8 | Bankola | Pandabeswar | Chora |
| **PL02** | Joyalbhanga pitlake 1 | 23°41'40.2"N | 87°17'20.3"E | 84 | Bankola | Pandabeswar | Joyalbhanga |
| **PL03** | Jambad pitlake 4 | 23°38'56.5"N | 87°10'30.7"E | 93.7 | Kajora | Andal | Benedi |
| **PL04** | Western Kajora pitlake | 23°40'21.4"N | 87°12'21.9"E | 78 | Kajora | Andal | Kajora |
| **PL05** | Atewal pitlake | 23°36'14.3"N | 87°9'54.6"E | 83.2 | Kajora | Andal | Jogrambati |
| **PL06** | Khadan kali pitlake | 23°35'49"N | 87°9'54.7"E | 79.4 | Kajora | Andal | Polashbon |
| **Pl07** | Babuisol sibmandir pitlake | 23°35'51.4"N | 87°10'189"E | 74.8 | Kajora | Andal | Babuisol |
| **PL08** | Real kajora pitlake | 23°11'9.6"N | 87°11'9.6"E | 106.7 | Kajora | Andal | Kajora |
| **PL09** | Chakrambati pitlake | 23°36'36.3"N | 87°9'32.6"E | 78.3 | Kajora | Andal | Railgate Majhipara |
| **PL10** | Babuisol colony pitlake | 23°35'56.1"N | 87°9'48.2"E | 81.5 | Kajora | Andal | Palashban |

**Assessment of soil-sediment quality:**

Soil samples were collected from 10 pitlakes (PL01, PL02, PL03, PL04, PL05, PL06, PL07, PL08, PL09, PL10) in premonsoon, monsoon and post-monsoon seasons during 2014-2015 using standard field protocols and guidelines (Sutherland 2006; MoEF, 2008).The value of each parameter was expressed as mean with standard deviations in the results. Tests for physicochemical parameters of soil sediment were performed by following standard methods given by American Public Health Association (APHA, 2005) and Black (1965).

**Statistical analysis:**

Statistical analyses were performed using the statistical package XLSTAT (Addinsoft, 2010). Cluster analysis was performed on the basis of measured soil sediment quality for grouping of study sites with similar aquatic environment. Correlation analysis was utilized to assess the interrelationship between soil-sediment quality parameters. PCA was also incorporated to demonstrate the key important factors governing the status of soil sediment quality in this region. All the statistical procedure were performed using a significance level of $p<0.05$.

## RESULTS AND DISCUSSION:

The results of physico chemical analysis of soil samples are presented in Table 2. A mean value of pH 6.8 were recorded which ranged between 4.23 (PL10) to 7.99 (PL03) during the study period. However, conductivity was found to be ranged between 0.003 µS/cm (PL01) to 0.690 µS/cm (PL 04) in RCF pitlakes. Organic carbon value varied between 0.12% (PL03) to 4.58% (PL09) with a mean value of 1.73%. With a mean value of 1.8g/cm$^3$, bulk density of soil varies from 0.1-2.94 g/cm$^3$. Similarly particle density varies from 0.47-9.59 g/cm$^3$ with a mean value of 1.8 g/cm$^3$. Water holding capacity ranges from 2.92 to 22.57 (inch/foot) with a mean value of 8.08 (inch/foot).Phosphate phosphorous varies from 1.17-27.42 mg/Lt with a mean value of 14.17 mg/Lt. In the present study, available nitrogen was found to be ranged from 6.27 mg/Lt to 91 mg/Lt in selected areas of Raniganj coalfield with a mean value of 30.68 mg/Lt. The variation of soil sediment characteristics according to seasonal mean value in different pitlakes are shown in Fig. 1.

**Table 2: Descriptive statistics on soil-sediment parameters measured in pit lakes during the study period.**

| SOIL PARAMETER | CODE | MIN | MAX | MEAN | SD |
|---|---|---|---|---|---|
| **pH** | PH | 4.23 | 7.99 | 6.8 | 0.64 |
| **Conductivity (µS/cm)** | CON | 0.003 | 0.69 | 0.145 | 0.186 |
| **Organic Carbon (%)** | ORC | 0.12 | 4.58 | 1.87 | 1.73 |
| **Bulk Density (g/cm$^3$)** | BUD | 0.1 | 2.94 | 1.8 | 0.78 |
| **Particle Density (g/cm$^3$)** | PDE | 0.47 | 9.59 | 2.33 | 2.43 |
| **Water holding capacity (inch/ft)** | WHC | 2.92 | 22.57 | 8.08 | 5.22 |
| **Phosphate phosphorous (mg/Lt)** | PHO | 1.17 | 27.42 | 14.17 | 7.72 |
| **Soil available nitrogen (mg/Lt)** | SAN | 6.27 | 91 | 30.68 | 22.66 |

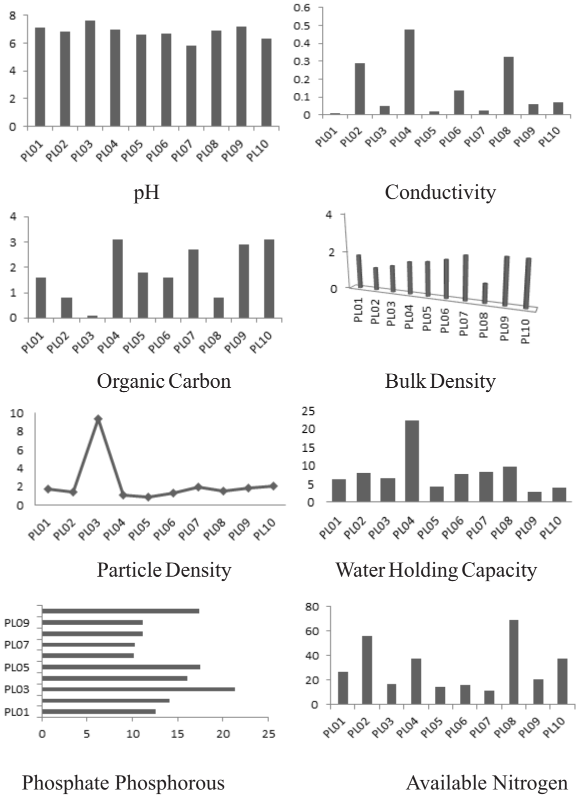


**Fig. 1: Variation of different physico-chemical parameters within 10 pitlakes of Raniganj coalfields**

Correlation Coefficients computed among the chemical parameters of ten pit lakes showed in Table 3. Significant positive correlation was noted within organic carbon and bulk density. Conductivity is also positively correlated with water holding capacity in pit lakes. Principal components analysis is a multivariate data analytic technique. It reduces a large number of variables to a small number of variables, without sacrificing too much of the information. The PCA was used to reduce soil chemical parameters (variables).The contribution of the variables (%) and squared cosines of the variables of PCA analysis is represented in Table 4 and 5. PCA reveals three most important and key influential parameters – Organic Carbon, Bulk Density and Soil available nitrogen content of pitlake soil.

**Table 3: Correlation matrix of soil parameters measured in RCF Pitlakes during the study period**

| | pH | Conductivity | Organic Carbon | Bulk Density | Particle Density | Water holding capacity | Phosphate phosphorous | Soil available nitrogen |
|---|---|---|---|---|---|---|---|---|
| **pH** | 1 | 0.16 | -0.22 | -0.21 | 0.34 | 0.05 | 0.14 | -0.002 |
| **Conductivity** | 0.16 | 1 | 0.19 | -0.03 | -0.24 | **0.69** | 0.12 | 0.18 |
| **Organic Carbon** | -0.22 | 0.19 | 1 | **0.90** | -0.27 | 0.10 | 0.43 | -0.40 |
| **Bulk Density** | -0.21 | -0.03 | **0.90** | 1 | -0.12 | -0.16 | 0.42 | -0.58 |
| **Particle Density** | 0.34 | -0.24 | -0.27 | -0.12 | 1 | -0.15 | 0.27 | -0.19 |
| **Water holding capacity** | 0.05 | **0.69** | 0.10 | -0.16 | -0.15 | 1 | 0.01 | 0.22 |
| **Phosphate phosphorous** | 0.14 | 0.12 | 0.43 | 0.42 | 0.27 | 0.01 | 1 | -0.25 |
| **Soil available nitrogen** | -0.002 | 0.18 | -0.40 | -0.58 | -0.19 | 0.22 | -0.25 | 1 |

**Table 4: Squared cosines of the variables after Varimax rotation derived from PCA of soil parameters. [Values in bold correspond for each variable to the factor for which the squared cosine is the largest]**

| | D1 | D2 | D3 |
|---|---|---|---|
| **pH** | 0.1846 | **0.4064** | 0.0079 |
| **Conductivity** | 0.0930 | 0.0131 | **0.8614** |
| **Organic Carbon** | **0.7335** | 0.1275 | 0.0600 |
| **Bulk Density** | **0.7999** | 0.0385 | 0.1045 |
| **Particle Density** | 0.0250 | **0.7504** | 0.0695 |
| **Water holding capacity** | 0.0021 | 0.0045 | **0.8870** |
| **Phosphate phosphorous** | 0.0016 | **0.7169** | 0.0061 |
| **Soil available nitrogen** | **0.4623** | 0.0877 | 0.2324 |

**Table 5: Contribution of the variables (%) after Varimax rotation**

| **derived from PCA of soil parameters** | D1 | D2 | D3 |
|---|---|---|---|
| **pH** | 8.0193 | 18.9454 | 0.3556 |
| **Conductivity** | 4.0386 | 0.6109 | 38.6476 |
| **Organic Carbon** | 31.8622 | 5.9437 | 2.6898 |
| **Bulk Density** | 34.7487 | 1.7952 | 4.6904 |
| **Particle Density** | 1.0839 | 34.9838 | 3.1199 |
| **Water holding capacity** | 0.0930 | 0.2112 | 39.7971 |
| **Phosphate phosphorous** | 0.0715 | 33.4194 | 0.2743 |
| **Soil available nitrogen** | 20.0829 | 4.0904 | 10.4253 |

Fig. 2 depicts the dendogram plot derived from AHC analysis depending on the soil sediment quality parameters. Three clusters shows the similarity above 90% among the pitlakes they include i.e. Cluster 1and 2 contain PL 07, 06, 04 and PL 10, 09, 08, 02, 01 having similar soil-sediment environment whereas Cluster 3 constituted only PL 05 and 03. These may be due to the site specific complex hydrological and biological interactions which naturally occur in these ecosystems (Rai et al., 2011; Soni, 2007).

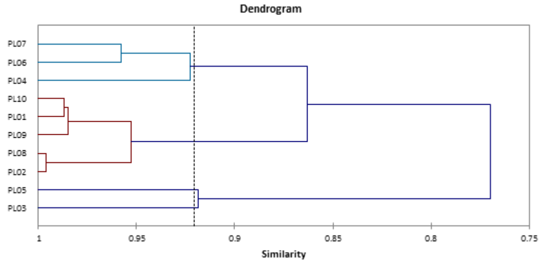


**Fig. 2: Dendrogram derived from Agglomerative Hierarchical Cluster (AHC) analysis showing the Piltlakes associations depending on soil parameters measured during the study period**

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