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Assessment of sediment quality in pit-lakes of Raniganj coal fields, West Bengal, India

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ABSTRACT

Pit lakes form when surface-level mines shut down, and water fills the open pit due to active pumping, surface water diversion, or groundwater recharge. In the current study, pit lakes generated by open-cast coal mining have been studied at various mining locations for four years within the Raniganj coalfields, West Bengal, India, focusing on sediment quality. This paper focused on analysing physicochemical parameters such as colour and texture, pH, bulk density, conductivity, particle density, water-holding capacity, organic carbon, available nitrogen and available phosphorus, impacting overall sediment quality from 2020-2023. A quantitative assessment of various sediment parameters showed that pH was 6.41 to 7.96, bulk density 1.21 to 2.08 grams/cm3, conductivity 0.21 to 0.45 µS/cm, particle density 1.02 to 1.96 g/cm3, water-holding capacity 12.09 to 18.50%, organic carbon 2.31 to 6.64%, available nitrogen 19.81 to 50.25 Kg/ha and available phosphorus varied from 10.90 to 17.85 Kg/ha. The overall nutrient content of the sediment was found to be higher to medium range than the standard value. The major objective of the current investigation is to evaluate the sediment quality of a few chosen pit lakes of the RCF region of West Bengal, India.

Keywords: Pit-lakes, Mining, Pit-lakes mines, Raniganj coalfields, Sediment

INTRODUCTION

The surface mining technique changed the landscapes rapidly. Due to open-cast mining techniques, coal mine pit lakes are formed (Palit *et al.,* 2017). For that reason, the value of the natural environment is reduced in the surrounding land. It is used for mining operations until the land surface is reshaped and reclaimed. If mining is permitted, residential people must be moved away from the mining site; commercial endeavours like hunting, fishing and medicinal plants will be terminated (Murphy *et al.,* 2003; Dudgeon *et al.,* 2006). After mining what happens to the land surface is determined by how the mining is conducted. The responsibility of mining companies concerning the proper utilization of their water resources is limited (Palit *et al.,* 2017). Pit lakes surrounding areas consequently receive less attention and make impoverished managerial choices. Over the past few years, Open-cast mining has increased in West Bengal, particularly in the Raniganj Coal Field area, due to advancements in Ore economics and mining technologies (Palit *et al.,* 2017). Moreover, when mining stops, these activities generally leave behind open pits (Palit *et al.,* 2017). A water body soil sediment is known as its "biological engineer" and a nutrient reservoir that directly promotes the autotroph development communities such as Macrophytes (Barko and Smart, 1986; Barko *et al.,* 1991) and the primary food source for other aquatic organisms at eventually consumer levels is phytoplankter (Pal *et al.,* 2014). Therefore, the process of natural Eco restoration in the pit-lake aquatic system may be significantly impacted by the physicochemical composition and characteristics of the bottom sediments, including their nutrient availability (Pal et al, 2014). However, the unavoidable removal of topsoil, the loss and destruction of the natural soil profile, leaching from massive overburden, land degradation and the decline in topsoil fertility are the main causes of the environmental circumstance's degradation of the coal-mined pit-lakes formed following surface mining activities (Kundu and Ghose, 1994). Thus, the nutrients observed in the overburdened top soil—which typically contains fewer nutrients for plant growth—primarily determine the chemical properties of the pit lake sediment, including organic carbon, available phosphorus, nitrogen and potassium (Ghose, 2001; Dutta and Agrawal, 2002; Ghose, 2004; Mercuri *et al.,* 2005; Maiti, 2007; Sheoran *et al.,* 2010). Sediment and soil are closely related but not the same. This study only focused on sediment

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quality but many authors have worked on soil-related studies (Thaker *et al.,* 2023; Bhattacharya *et al.,* 2020; Barik *et al.,* 2017; Poji *et al.,* 2017). The major objective of the current investigation is to evaluate the sediment quality of a few chosen pit lakes of the RCF region of West Bengal, India.

MATERIALS AND METHODS

Study area

The sampling was completed between 2020 to 2023, using five coal mining-generated pit lakes such as Chora, Joyalvanga1, Dalurbandh, Kumardihi old OCP and Gunjan Ecological Park. The elevation of the pit lakes ranges from 75m to 94.5m. Chora, Joyalvanga1 and Dalurbandh pit lakes are under Pandabeswar block and Kumardihi old OCP and Gunjan Ecological Park are under Jamuria block. Chora pit lakes latitude was 23º40'21.4"N, Longitude 87º12'21.9"E, Elevation 75m and the mining area is Bankola. Joyalvanga1 pit lakes latitude was 23°41’40.2” N, Longitude 87°17’20.3” E, Elevation 85m and the mining area is Bankola. Dalurbandh pit lakes latitude was 23°42’48.4” N, Longitude 87°15’46.4” E, Elevation 79.9 m and the mining area was Pandabeswar. Kumardihi old OCP latitude was 23º39’54.5” N, Longitude 87º1’49.6” E, Elevation 94.5 m and the mining area was Satgram. Gunjan Ecological Park Latitude was 23º39’54.5” N, Longitude 87º1’49.6” E, Elevation 94.5 m and the mining area was Satgram.

Collection of Sample

5 pit lakes (PL1, PL2, PL3, PL4, PL5) collected the sediment samples from 2020 to 2023, utilising standard field methods and protocols (Sutherland, 2006; MoEF, 2008). The physicochemical parameters of the sediment were tested using the standard methods followed by (Saxena MM, 1998), (Olsen *et al.,* 1954), (Subbiah and Asija, 1956), (Blake GR, Hartge K.H., 1986) and (Black CA., 1965).

RESULTS AND DISCUSSION

Texture and Colour

Texture indicates the number of different-sized particles, like clay, silt, and sand in the sediment. The texture of sediment plays a crucial role in determining its workability, water and air retention capabilities as well as the rate of water infiltration and movement through it. Soil texture classification is based on the relative mass of three major size ranges (Hillel, D., 2000), sand, silt and clay. Samples were studied to determine their colour and texture. Chora pit lakes sediment’s colour and texture were brown and clayey loam. Joyalvanga 1 pit lakes sediment’s colour and texture were black sandy and sandy. Dalurbandh, Kumardihi old OCP and Gunjan Ecological Park sediment’s colour and texture were brown and clayey loam.

pH

pH was observed in the range between 6.41 to 7.96 during the study period. 6.41 was the lowest pH value in Dalurbandh pit lake and 7.96 was the highest pH value in Gunjan Ecological Park compared to other selected sites. However, Palit *et al.* (2017) reported the sediment pH value in the Raniganj coal field area was 4.23 to 7.99. However, the sample was supposed to be moderately acidic and have a pH lower than 7 (Brady, 2008). The pH range between 6.5 to 7.5 is very good for nutrients in plants (Brady, 2008) but the selected pit lake's pH was slightly low and high. Research has shown that other environmental factors, pH is important in impacting the soil surface charge, plant nutrient uptake and microorganisms (Escobar and Hue, 2008). The sediment’s pH values are catalogued in Table 1.

Bulk density

Bulk density serves as a valuable metric for evaluating sediment health and sediment compaction. The soil's capacity to move water and solutes, provide structural support and facilitate soil aeration is shown in bulk density. Over-threshold bulk densities indicate compromised function. The sediment's bulk density has affected the density of the sediment's organic and mineral components. It is typically expressed in grams/cm3, which is the dry sediment weight divided by its volume. The densities of the mineral and organic matter components in the sediment and how they are packed, significantly impact bulk density. Bulk density was observed in the range between 1.21

to 2.08 grams/cm3 during the study period. 2.08 grams/cm3 was the highest bulk density value in Gunjan Ecological Park and 1.21 grams/cm3 was the lowest bulk density value in Chora pit lakes compared to other selected sites. However, Palit *et al.* (2017) reported the sediment bulk density value in the Raniganj coal field area was 0.1 to 2.94 grams/cm3. The sediment's bulk density values are catalogued in Table 1.

Table 1: Yearly changes in sediment parameters

Sediments Parameters	Name of the pit lakes	2020	2021	2022	2023
pH	C	7.21	6.70	7.35	7.31
	J	7.80	7.28	6.66	7.18
	D	6.99	6.99	6.41	6.79
	K	7.67	7.67	7.48	7.46
	G	7.96	7.92	7.85	7.90
Bulk density (grams/cm3)	C	1.21	1.34	1.42	1.30
	J	1.33	1.48	1.46	1.33
	D	1.8	1.81	1.72	1.52
	K	1.90	1.85	1.39	1.79
	G	1.91	1.91	2.08	1.68
Conductivity (µS/cm)	C	0.29	0.412	0.4410	0.351
	J	0.43	0.39	0.40	0.45
	D	0.21	0.23	0.22	0.29
	K	0.28	0.22	0.29	0.25
	G	0.35	0.27	0.24	0.39
Particle Density (g/cm3)	C	1.22	1.26	1.25	1.23
	J	1.92	1.96	1.91	1.79
	D	1.21	1.14	1.17	1.18
	K	1.03	1.06	1.08	1.02
	G	1.18	1.14	1.13	1.14
Water-holding capacity (%)	C	17.02	17.25	17.06	16.90
	J	18.04	18.09	18.50	18.15
	D	16.01	16.50	16.90	16.65
	K	12.09	13.02	12.90	12.66
	G	14.08	15.01	15.55	15.32
Organic Carbon (%)	C	2.91	3.10	3.09	3.11
	J	2.37	2.31	2.32	2.39
	D	6.61	6.55	6.58	6.64
	K	3.90	3.59	3.70	3.46
	G	4.90	5.52	4.01	5.55
Available Nitrogen (Kg/ha)	C	38.09	39.12	39.18	39.0
	J	48.07	48.90	49.10	49.15
	D	43.01	42.08	42.25	42.31
	K	50.12	48.90	49.10	50.25
	G	19.81	19.85	19.86	19.90
Available Phosphorous (Kg/ha)	C	17.11	17.75	17.40	17.25
	J	17.52	16.90	17.10	17.85
	D	13.95	15.25	15.90	16.0
	K	11.20	10.90	11.50	12.12
	G	13.66	14.22	14.10	14.25

C represents Chora pit lake; J represents Joyalvanga 1 pit lake; D represents Dalurbandh pit lake; K represents Kumardihi Old OCP and G represents Gunjan Ecological Park

Conductivity

Measurements of sediment properties such as sediment texture, cation exchange capacity, organic matter content and salinity characteristics are correlated with sediment electrical conductivity. It is a crucial sign of the sediment's health. The conductance specific to sediment (µs/cm) indicates the number of free ions or electrolytes, throughout the sediments. The conductivity range was found between 0.21 to 0.45 µS/cm during the study period. 0.45

µS/cm was the highest conductivity value in the Joyalvanga 1 pit lake and 0.21 µS/cm was the lowest conductivity value in the Dalurbandh pit lakes compared to other selected sites. However, Palit *et al.* (2017) reported the sediment conductivity value in the Raniganj coal field area was 0.003 to 0.69 µS/cm. The sediment's conductivity values are catalogued in Table 1.

Particle Density

Sediment particle density is the most crucial factor in sediment properties utilized for computing void ratio and porosity. Usually, the sediment particle density is not measured but taken as given a constant (for example, particle density = 2.65 Mg m3). In soil mechanics, the void ratio is frequently utilised (Keller *et al.,* 2011) and soil mechanical behaviours' accurate estimates are crucial for understanding. Sediment particle density was observed in the range between 1.02 to 1.96 g/cm3 during the study period. 1.96 g/cm3 was the highest particle density value in the Joyalvanga 1 pit lake and 1.02 g/cm3 was the lowest particle density value in the Kumardihi old OCP compared to other selected sites. However, Palit *et al.* (2017) reported the sediment particle density value in the Raniganj coal field area was 0.47 to 9.59 µS/cm. The sediment's particle density values are catalogued in Table 1.

Water holding capacity

The ability to store water depends on the organic matter and sediment texture. Water-holding capacity usually rises with a higher percentage of silt and clay-sized particles. Sediment texture and organic matter are pivotal factors that strongly influence water retention capacity. Porosity is the most crucial aspect of sediment that affects its ability to hold water. Sediment water holding capacity was observed in the range between 12.09 to 18.50 % during the study period. 18.50 % was the highest water-holding capacity in the Joyalvanga 1 pit lake and 12.09 % was the lowest water-holding capacity in the Kumardihi old OCP compared to other selected sites. However, Palit *et al.* (2017) reported the sediment water-holding capacity in the Raniganj coal field area was 2.92 to 22.57 inches/ft. The sediment's water-holding capacity values are catalogued in Table 1.

Organic Carbon

The organic carbon content within sediment is the pivotal factor in determining soil fertility and influences its physical, chemical and biological fertility characteristics. Different minerals are produced by the breakdown of soil organic matter and other nutrients are necessary in plant development. Organic carbon is developed when different animals and plants decompose and are stored within the soil (Dekka *et al.,* 2008). Soil carbon predominantly denotes the carbon content existing within the soil in organic form. The most abundant terrestrial group of carbon is soil carbon (Batjes, 1996). Sediment organic carbon was observed in the range between 2.31 to 6.64% during the study period. 6.64 % was the highest organic carbon value in the Dalurbandh pit lake and 2.31 % was the lowest organic carbon value in the Joyalvanga 1 pit lake compared to other selected sites. Palit *et al.* (2017) reported the sediment organic carbon value in the Raniganj coal field area was 0.12 to 4.58 % but present study organic carbon value was high. However, Soil organic carbon concentration has an enormous effect on available nitrogen in sediment (Saha, 1991). The sediment's organic carbon values are catalogued in Table 1.

Available Nitrogen

Since the amount of nitrogen in the sediment changes not just between species but also with the growth phase and season, chemical analysis of the sediment is less appropriate when estimating the amount of nitrogen required over an extended time. Consequently, the chemical test for NH_4+ and NO^3 denotes unstable circumstances when the sample is obtained, requiring immediate action. Sediment available nitrogen was observed in the range between 19.81 to 50.25 Kg/ha during the study period. 50.25 Kg/ha was the highest available nitrogen value in Kumardihi Old OCP and 19.81 Kg/ha was the lowest available nitrogen value in the Gunjan ecological park compared to other selected sites. However, Palit *et al.* (2017) reported the sediment available nitrogen value in the Raniganj coal field area was 6.27 to 91 Kg/ha. The sediment's available nitrogen values are catalogued in Table 1.

Available Phosphorous

Due to the high phosphorus needed for plant growth, phosphorus is a necessary element catalogued in the macronutrient category. The primary function of phosphorus in the sediment is mainly to utilise microorganisms for energy transfer. Since energy is required for this process, phosphorus in organic compounds can help in the transmission of energy inside the cells. However, Sediment available phosphorus was observed in the range between 10.90 to 17.85 Kg/ha during the study period. 17.85 Kg/ha was the highest available phosphorus value in Joyalvanga 1pit lake and 10.90 Kg/ha was the lowest available phosphorus value in the Kumardihi old OCP compared to other selected sites. However, Palit *et al.* (2017) reported the sediment available phosphorus value in the Raniganj coal field area was 1.17 to 27.42 Kg/ha. The sediment's available phosphorus values are catalogued in Table 1.

CONCLUSION

The assessment of the sediment quality in the pit lakes of the Raniganj Coal Fields indicates that the activities related to coal mining led to a significant reduction in the value of sediment quality. A diverse array of sediment quality parameters is analysed, yet certain outcomes show unsatisfactory results. The sediment quality impacts the aquatic system both ways directly or indirectly. If restore ecosystem health then it is crucial to undertake remediation measures such as habitat restoration and sediment dredging.

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