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IMPACT OF COAL MINING ON PONDS OF JHARIA TOWN, DHANBAD, JHARKHAND

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Abstract

The geochemistry of ponds was studied around Jharia coal mining areas. The high concentrations of cations and anions revealed the enrichment of pollutants and thick population of E. coli bacteria. The pond waters are alkaline at all sampling sites and control the weathering pattern and availability of dissolved solids in Jharia Pond water. The cations and anions were greater than WHO limits and posing risk to local inhabitants in this region. The abundance of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in the ponds attributed to carbonate and silicate weathering. The molar Mg^{2+}/Ca^{2+} ratio is greater than >0.5, which indicates high saturation, index and carbonate precipitation. Correlation matrix showed a good correlation between total dissolved solids and turbidity/conductivity. Bacteriological parameters of Jharia Ponds showed high population of coliform bacteria with high FC: FS ratio.

1. Introduction:

Aquatic ecosystems contribute to a large proportion of the planet. The earth, two-thirds of which is covered by water, looks like a blue planet-the planet of water- from space (Clarke, 1994). The world's lakes and rivers are most important freshwater resources. Of the earth's fresh water, 69.6% is locked up in the continental ice, 30.1% in underground aquifers, and 0.26% in rivers and lakes. In particular, lakes are found to occupy less than 0.007% of world's fresh water (Clarke, 1994). Natural lake systems were generally formed during the ice ages because of tectonic or volcanic activities. In contrast man-introduced developmental activities are responsible forever increasing number of reservoirs and artificial impoundments. In these cases we have taken advantage of natural topographic characteristics with minor modifications like construction of dams, or embankments lend themselves to large storage facilities of freshwater. Whether artificially or naturally created, all lakes and ponds share several common physical, chemical and biological characteristics.

Wetlands have been drained and transformed due to anthropogenic activities, like unplanned urban and agricultural development, industries, road construction, impoundments, resource extraction, and dredge disposal, causing substantial economic and ecological losses in the long term. Eutrophic water bodies rich in nutrients mainly organic elements carbon, nitrogen and phosphorous. These have usually large populations of plankton and zooplankton, have less diverse populations of fish, and are often depleted of dissolved oxygen during periods of warm temperatures. Humans have altered the nutrient status of many closed water bodies through the addition of nitrates, urea, and phosphates. This process results in physical, chemical and biological changes in the system.

Wetlands filter out sediment and pollution from the surrounding environment so that the water they discharge to closed water bodies is cleaner. Pond, lake or estuary is an ultimate destination of all water running downhill through an area of land, which is referred as watershed. It plays a critical role in the natural functioning of the ecosystem (Ahalya and Ramachandran, 2002) mainly the hydrologic cycle (the capture, storage, release, and eventual evaporation of water) forms the basis of watershed function.

The freshwater wetlands are one of the important productive ecosystems. They play a vital role in the survival of many species of flora and fauna, including human beings. Despite their great values, the wetlands are getting deteriorated all over the world (Maltby, 1986). In recent times, wetlands have become the victim of cultural eutrophication, which is due to increased anthropogenic pressure in the catchments area; increased utilization of domestic articles, agricultural wastes and chokes aquatic life due to excessive growth of algae. In India, about 65,000 freshwater wetlands occur covering 4.5 million hectares (Anon, 900). In TamilNadu, 39,000 irrigation tanks are found, which constitute 17% of their size, have immense economic and ecological values, they have been neglected for a long time. A large number of researchers have worked on the costal wetlands and protected freshwater wetlands in relation to birds in India (Ali and Hussain, 1982; Ali and Sugathan, 1984; Sampath, 1989; Vijayan, 1991; Sampath and Krishnamurthy, 1993; Kar and Sahu, 1993). Makhana (Euryaleferox salisb, family Nymphaeaceae) is cultivated in thousands in the stagnant water bodies in 8 to 10 districts of north Bihar. In this direction, no body has quantified the pollution status of wetlands in Jharkhand state of India. This study emphasizes the environmental significance of wetlands mainly ponds in Dhanbad district of Jharkhand (Jha 2005).

The above review highlights the importance of biological parameters in wetland. Hence, in present study following objectives is being conducted:

- Analysis of physico-chemical parameters (DO, EC, TDS and pH), cations (Na^{+}, K^{+}, Ca^{2+}), anions (Cl^{-}, NO_3^{-}, SO_4^{2-}, and PO_4^{3-}) and bacteriological parameters.

2. Materials and Methods:

2.1 Study Area

Jharia coalfield is situated in Eastern India at the heart of Damodar Valley, mainly along the northern bank of the river. It is situated about 260 Kms northwest of Kolkatta in the Dhanbad district of Bihar. The chief mining centre is Jharia, the eastern part of the field, after which it is named. The Jharia has undergone a tremendous development and transformation in the last 25 years, so that the old topographic details are no longer there at many places". The infield underground voids are giving rise to surface subsidence.

Geologically it is a part of the East-West trending chain of the Gondwana basin in Eastern India. The rocks of the Gondwana Formation make up the coalfield the geology of which has been studied in detail by Fox (1930) and later by Mehta (1957). The field is approximately sickle-shaped; covering an area of about 450km. Jharia coalfield is main storehouse of metallurgical coal in India. Intensive mining started here about 1925 but proceeded in a completely unplanned manner, without any attempt at reclamation. The quarries overburden dumps and even the underground voids were all left. Sometimes underground fires also develop due to prolonged auto-oxidation of the remaining low-grade coal underground. All these actions of the past are disturbing the environment, ecology and land use of the area today and threatening the future safely of its urban development. Unplanned mining has disturbed the potential of the area and polluted the water bodies mainly ponds, which are recreation centres for local people.

2.2 Water Sampling:

Surface water samples (n=6) were collected from six different ponds in month of March 2007. For each pond, the water samples were filtered (0.45 m membrane filter, Millipore) and stored in acid washed polypropylene bottles. Cleaning of plastic bottles and plastic bags was carried out by soaking in 5 % (v/v) HNO_3 for 24 hours and then rinsing with milli-Q water. Water samples taken for the analyses of cations were preserved by acidification with 2 M HNO_3 acid. High purity reagents (Merck) and milli-Q water (Model Milli-Q, Biocel) were used for all the analyses.

The total dissolved solids (TDS), electrical conductivity (EC); redox potential (ORP), dissolved oxygen (DO) and pH were measured at the site within a few hours of collection of samples using a portable Cyber Scan Con 10/100/200 kit.

2.3 Laboratory methods for water analysis:

Phosphate was determined by the Ascorbic Acid Method (APHA, 1995). Chloride was determined by using Mohr's Titration Method. Sulphate was determined by turbidimetric method (APHA, 1995). Concentrations of nitrate in water samples were determined by brucine-sulphanilic acid method. The concentration of Ca^{2+} and Mg^{2+} was determined by Atomic Absorption Spectrophotometer and Na^{+} and K^{+} by Flame Photometer (APHA, 1995). High purity reagents (Merck) and milli-Q water (Model Milli-Q, Biocel) were used for all the analyses. The double strength EC medium was used for E.coli test as per Standard Methods (APHA, 2000). The MPN test also conducted as per standard methods (APHA, 2000).

3. Result and discussion:

3.1 Geochemistry of Jharia Water

The physico-chemical properties of ponds varied spatially. The water quality parameters for each sampling sites are given in Table 1 and 2. The analytical precision for the measurement of major ions is better than 5%. The results reveal that all the physico-chemical parameters including major ions are higher at all sampling sires. Water characteristics are relatively not stable in shallow ponds, which are mixed by winds. However, deeper ponds exhibit patterns of vertical gradients for temperature (Anshumali and Ramanathan, 2007). Other factors responsible for the abundance and variation in major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (HCO_3^{-}, SO_4^{2-}, PO_4^{3-}, NO_3^{-} and Cl^{-}) in surface water can be controlled by weathering and atmospheric precipitation, and possible anthropogenic activities, which are discussed below.

The pond waters are alkaline at all sampling sites and control the weathering pattern and availability of dissolved solids in Jharia Pond water ((Table 1). Electrical conductivity (EC) is a measure of the ionic strength, which is higher at Jiyal Garha Talab (W3; 1708 s/cm), Bhulan Barai Talab No1 (W5; 1613 s/cm), Karbala Talab (W4; 1602 s/cm), Raja Talab (W1; 1420 s/cm) and Jharia Railway Station (W2; 1132 s/cm) while Mada Water Tank showed relatively less EC (W6; 406s/cm) (Table 1). The EC value in surface water depends on the concentration, volume and rate of movement of ionic species (Das and Kaur, 2001). Similar trend were observed for turbidity and TDS (Table 1). Dissolved oxygen (DO) is a measure of gaseous oxygen present in aqueous solution. The DO concentration was higher in fresh water samples of Mada Water Tank (W6; 7.9 mg/l) while other ponds showed DO <7mg/l (Table 1) indicating that surface water of Dhanbad Ponds are not healthy and well oxygenated. BOD and COD demands were high in polluted ponds (W1-W5) while low values of BOD and COD in Mada water Tank indicates the healthy nature (Table 1). The relative hardness of all ponds is high, which reveal the prevalence of calcium and magnesium hardness in pond ecosystems of Dhanbad district.

The concentration of NO_3^- was high in Raja Talab (W1; 12.27 mg/l) and low in Jiyal Garha Talab (W3; 2.79mg/l) (Table 2). These values indicate that ponds are enriched in nutrients. The high concentration of NO_3^- indicates the mineralization of N-containing compounds by micro organism (Hankinson, 1984). The NO_3^- in ponds indicates possible influence of atmospheric deposition and/or the leaching of fertilizers in the agriculture dominant catchment's areas. The occurrence of PO_4^{3-} in the Dhanbad pond water varied from 0.10 mg/l in Mada Water Tank (W6) to 1.45 mg/l in Jharia Railway Station (W2) (Table 2). This is contributed by anthropogenic activities mainly input of fertilizers applied to farmland, detergents, sewage effluents, disposal of solid waste, and decomposition of organic matter. The sulphate (SO_4^{2-}) concentration ranges from 136.16 mg/l in Mada Water Tank (W6) to 375.50 mg/l in Bhulan Barari Talab No1 (W5). Sulphate in the Jharia Ponds is derived from atmospheric deposition and oxidation of sulfur compounds in the boundary layers between aerobic and anaerobic environments. Such processes are common at the surface of reduced sediment that becomes superimposed by oxygenated water (Jones, 1982)). Another very important source is leaching from abundant coalmines. In this study, Cl^- varied from 22 in Mada Water Tank (W6) to 233 mg/l in Raja Talab (Table 2). The origin of chloride is mostly from rainfall and pollution sources, as rock sources for chloride are minimum unless halite deposits are present in the Dhanbad region. The enrichment of Cl^- indicates high salinity in Jharia Ponds.

The major cation that characterizes the surface water is Ca^{2+}. It varies from 19.25 mg/l in Karbala Talab (W4) to 57.71 mg/l in Raja Talab (W1) (Table 2). In ponds, calcium and magnesium together account for 40- 50 % of cations. The contribution of Na^+ and K^+ is between 40 and 50% of the major ion budget of the ponds. Further the Ca^{2+}/SO_4^{2-} ratio is <1 indicating that sulphuric acid replaces the carbonic acid as a source of proton for rock weathering (Stallard and Edmond, 1983). The abundance of Ca^{2+}, Mg^{2+}, Na^+ and K^+ in the ponds attributed to carbonate and silicate weathering. The molar Mg^{2+}/Ca^{2+} ratio is greater than >0.5, which indicates high saturation, index and carbonate precipitation. The quantities of cations and anions released to solution are determined by proton source, composition of parent rock and secondary minerals produced during chemical weathering (Das and Kaur, 2001). The chemical compositions of high salinity waters are controlled by the amount of dissolved salts furnished by atmospheric precipitation and weathering (Gibbs, 1970). Weathering plays a major role in controlling the composition of natural waters (Bricker and Garrels, 1967; Garrels, 1967; Hem, 1985; White, 2002)

.The correlation matrix of the physico-chemical parameters is given in Table 3. Correlation was observed between various physico-chemical parameters indicating strong tendency to regulate the ionic strength of pond waters in Jharia. This also infers that sources of these parameters are similar in nature. The matrix shows data analysis that is how parameters are related with each other. From the correlation table we get a good correlation between Turbidity and Total Dissolved Solids. Similarly, Conductivity shows a correlation with Total Dissolved Solids. It means that the increase and decrease in Total Dissolved Solids affect Conductivity and Turbidity directly. Here, we found that Biological Oxygen Demand (BOD) is very much related with the Conductivity and Total Dissolved Solids present in the samples. Major ions do not show any correlation with physical parameter, Such as pH, TDS, Turbidity etc, except Lead. However, all ions are directly related with the Total Hardness of the samples. Chemical parameters are not very much correlated with other parameters and show independent affect for any water sample. The negative (-) sign indicate poor correlation between the various parameters.

4.2 Coliform test:

Bacteriological parameters of Jharia Ponds show high population of coliform bacteria, which is threat to local inhabitants (Table 4). The ratio of faecal coliform to faecal streptococci gives an idea of the source of faecal Contamination. If FC: FS < 1 suggests that the contamination is of non-human origin i.e. animals and birds; if FC:

FS > 4, it is implied that faecal contamination may be of human origin, which could also be secondary. Primary contamination by human excreta may however be ruled out where the roof is inaccessible to humans. It may be noted that in water samples, streptococci can produce enough lactic acid and other organic acids from sugar fermentation as a result medium becomes acidic and their growth is inhibited. This may lead to faster reduction in streptococci as compared to coliform, thus raising the FC: FS ratio.

Conclusion:

Generally, the physico-chemical quality of water in terms of colour, odours and taste, pH, Total Dissolved Solids (TDS) and Total Hardness (TH) are greater than the prescribed standards (WHO). Total coliform (TC), Faecal coliform (FC) and Faecal streptococcus (FS) are used as indicators of faecal contamination. Total coliform test is rendered difficult in the presence of large counts of other bacteria. Hence, E.coli is considered a better indicator. The COD is slower and involves the use of wet chemicals with higher waste chemical disposal costs. The COD and BOD provide different but complementary information on the carbon in the water sample. It is critical to note that these measurements, concerned with the carbon and carbon removal, do not directly address concerns for the removal of inorganic compounds such as nitrate, phosphate, and sulphate from water. These nutrients are having large impact on cynobacterial and algal growth in ponds.

Further research is needed to understand the aerobic self-purification sequence that occurs when organic matter is added to ponds can be carried out under controlled conditions in which natural processes are intensified. This often involves the use of large basins (conventional sewage treatment) where mixing and gas exchange are carefully controlled. The proceeding purification process effectively removes or inactivates disease-causing bacteria and indicator organisms (coliforms).

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Table 1: Physico-chemical parameters of Jharia Ponds.

	pH	T (°C)	EC (/µ S)	Tur (NTU)	TDS (/µS)	DO (mg/l)	BOD (mg/l)	COD (mg/l	TH (mg/l)	CaH (Mg/l)	MgH (mg/l
W1	8.11	27	1420	12.58	710	5.5	112	150	212	144	68
W2	7.42	26	1132	20.85	566	4.7	66.5	81	326	76	250
W3	8.05	28	1708	2.33	854	5.6	6.2	99	434	66	368
W4	8.61	27	1602	46.17	801	5.8	30.0	92	328	48	280
W5	8.45	26	1613	31.52	806.5	6.3	1.8	87	404	88	316
W6	8.51	26	406	2.6	203	7.9	6.2	75	80	58	22

W1: - Water sample 1, RAJA TALAB, (FATEHPUR)
W2: - Water sample 2, JHARIA RAILWAY STATION, (GHANUADIHNALA)
W3: - Water sample 3, JIYAL GARHA TALAB, (BAGDIGHI)
W4: - Water sample 4, KARBALA TALAB, (BAGDIGHI)
W5: - Water sample 5, BHULAN BARARI TALAB NO.1
W6: - Water sample 6, MADA WATER TANK, R.S.P. COLLEGE, (JHARIA)

Table 2: Concentrations (mg/l) of major cations and anions in Jharia Ponds.

Site	Ca^{2+} mg/l	Mg^{2+} mg/l	Cl^{-} mg/l	Na^{+} mg/l	K^{+} mg/l	SO_4^{2-} mg/l	PO_4^{-} mg/l	NO_3^{-} mg/l	Pb mg/l	Cu mg/l	Fe mg/l	Zn mg/l
W1	57.71	16.59	233	72	53	168.15	0.78	12.27	0.11	0.03	0.04	0.11
W2	30.40	61.00	95	36	26	221.42	1.45	3.07	0.08	0.03	0.12	0.06
W3	26.45	89.79	104	47	40	306.66	1.29	2.79	0.15	0.03	0.04	0.04
W4	19.25	68.32	129	64	57	351.84	1.37	3.99	0.17	0.03	0.06	0.06
W5	35.27	72.10	65	32	33	375.5	0.22	2.15	0.11	0.03	0.04	0.07
W6	23.25	05.37	22	11	4	136.16	0.10	6.68	0.07	0.03	0.04	0.01

W1: - Water sample 1, RAJA TALAB, (FATEHPUR)
W2: - Water sample 2, JHARIA RAILWAY STATION, (GHANUADIHNALA)
W3: - Water sample 3, JIYAL GARHA TALAB, (BAGDIGHI)
W4: - Water sample 4, KARBALA TALAB, (BAGDIGHI)
W5: - Water sample 5, BHULAN BARARI TALAB NO.1
W6: - Water sample 6, MADA WATER TANK, R.S.P. COLLEGE, (JHARIA)

Table 3: Correlation matrix of physico-chemical parameters.

P	pH	T	EC	Tur	TDS	DO	BOD	COD	TH	CaH	MgH	Ca2+	Mg2+	Cl	Na	K	SO4	PO4	NO3	Pb	Fe	Zn
pH	1																					
T	0.02	1																				
EC	0	0.59	1																			
Tur	0.29	-0.2	0.45	1																		
TDS	0	0.59	1	0.45	1																	
DO	0.72	-0.3	-0.6	-0.3	-0.6	1																
BOD	0	0.64	0.99	0.36	0.99	-0.6	1															
COD	-0.3	0.51	0.77	0.21	0.77	-0.7	0.75	1														
TH	-0.2	0.41	0.86	0.36	0.86	-0.6	0.88	0.45	1													
CaH	-0.2	0.03	0.18	-0.2	0.18	-0.3	0.18	0.7	-0.1	1												
MgH	-0.1	0.38	0.77	0.39	0.77	-0.5	0.78	0.25	0.97	-0.4	1											
Ca2+	-0.2	0.03	0.18	-0.2	0.18	-0.3	0.18	0.7	-0.1	1	-0.4	1										
Mg2+	-0.2	0.41	0.76	0.37	0.76	-0.5	0.78	0.26	0.96	-0.4	1	-0.4	1									
Cl	-0.2	0.47	0.49	0.11	0.49	-0.6	0.46	0.91	0.07	0.73	-0.1	0.73	-0.1	1								
Na	0	0.61	0.69	0.36	0.69	-0.6	0.66	0.89	0.29	0.46	0.16	0.46	0.18	0.92	1							
K	0.08	0.61	0.83	0.52	0.83	-0.6	0.79	0.86	0.48	0.33	0.37	0.33	0.38	0.8	0.96	1						
SO4	0.27	0.23	0.78	0.67	0.78	-0.3	0.76	0.23	0.85	-0.3	0.88	-0.3	0.86	-0.1	0.22	0.5	1					
PO4	-0.5	0.51	0.48	0.25	0.48	-0.8	0.47	0.44	0.5	-0.2	0.51	-0.2	0.55	0.39	0.56	0.5	0.24	1				
NO3	0.07	0.08	-0.3	-0.3	-0.3	0.11	-0.3	0.35	-0.7	0.73	-0.8	0.73	-0.8	0.66	0.4	0.2	-0.7	-0.2	1			
Pb	0.35	0.76	0.79	0.46	0.79	-0.3	0.78	0.47	0.59	-0.2	0.61	-0.2	0.63	0.36	0.67	0.8	0.7	0.52	-0.2	1		
Fe	-0.8	-0.4	-0.1	0.24	-0.1	-0.6	-0.1	-0.04	0.14	-0.2	0.17	-0.2	0.19	-0.1	-0.1	-0	-0.08	0.59	-0.3	-0.3	1	
Zn	-0.2	0.12	0.57	0.34	0.57	-0.6	0.52	0.91	0.23	0.82	0.01	0.82	0	0.86	0.78	0.7	0.11	0.19	0.47	0.2	0	1

Table 4: MPN test for E. coli bacteria

Site No.	Combination of Positive tubes	MPN index In 100ml	Lower limit	Upper limit	FC/FS Ratio	Surrounding/Use of water
Raja Talab	5-4-3	280	120	690	10	Washing, Waste drainage, Bathing
	FC: 5-3-2	140	60	360		
	FS: 3-2-0	14	6	35		
Jharia Railway Station No. 1	5-5-2	500	200	2000	4.33	Water outlet (Highly polluted)
	FC: 5-4-0	130	50	390		
	FS: 5-1-0	30	10	120		
Jiyal Garha Talab	5-3-2	140	60	360	4.12	Drinking, Washing cloths and animals
	FC: 5-2-1	70	30	210		
	FS: 4-1-0	17	7	46		
Karbala Talab	5-4-1	170	70	480	4.25	Drinking, Washing cloths and animals
	FC: 3-2-1	17	7	40		
	FS: 2-0-0	4	1	17		
Bhulan Barari Talab no. 1	4-3-1	33	15	77	0.47	Drinking, Washing cloths and animals, Bathing
	FC: 3-2-0	14	6	35		
	FS: 5-1-0	30	10	120		