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Comparative study of microbiological and physico-chemical parameters of abandoned coal void of Jharkhand, India

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Abstract
Coal void is a surface pit developed after open cast mining which get filled with rainwater. It has less surface area and great depth as a result poor water mixing and strong thermal and dissolved oxygen stratification. These characteristics make it different from natural water bodies. The physic-chemical and bacteriological parameters studied revealed that water temperature ranges 7 to 27 ^{0}C, pH 7.8 to 8.8, Conductivity 538 to 1446 mhos, TDS 468 to 1258 ppm, Dissolved oxygen 3.6 to 12.4ppm, Carbon dioxide 4.4 to 13.2ppm, Alkalinity 109 to 151 ppm, chloride 22 to 31ppm, Hardness 256 to 860ppm, COD 30 to 42ppm, BOD 1.4 to 2.0ppm, Nitrate 1.1 to 1.98ppm, Ammonical nitrogen 0.18 to 0.29ppm, Phosphate 0.7 to 2.0ppm, Organic carbon 2.8 to 5.7ppm and TSS 81 to 999ppm. The bacterial load ranges from $0.63x10^3$ to $9.222x10^3$. It is more in one of the coal void which receives organic matter from runoff.

Keywords: Coal void, Physic-chemical, Bacteriological, Jharkhand

Introduction
Water is life and abounds on earth, but this vast natural resource has been depleted and turned into scarce commodity with increased usage catering to the needs of ever-expanding population. There is almost a global shortage of water and the world's most urgent and the rank problem today is supply and maintenance of clean drinking water. As per an assessment of the ground Water Board (CGWB) of India most of the Indian States are likely to reach the water stress condition by 2020 and water scarce. The coal void which is created after open caste mining get filled with rain water and surface runoff water. These coal voids have less surface area and more depth. The natural inflow of ground water / rain water converts abandoned void into a pit lake [1]. The mine water in the void is generally used for domestic and industrial purposes and also recharges the nearby water resource naturally [2].
Since, the water contains dissolved and suspended materials in various proportions, its physical and chemical characteristics differ along with its biological characteristics. The water quality is also affected by pollutants which act on elements existing in water, such as dissolved oxygen or produce substances such as ammonia, nitrates etc. It is not possible to understand biological phenomena fully without the knowledge of water chemistry as the limno biological and limnochemical components of the ecosystem. The physico-chemical means are useful in detecting effects of pollution on the water quality, but changes in the trophic conditions of water are reflected in the biotic community-structure including species pattern, distribution and diversity [3]. The present study has provided detailed information on physico-chemical and microbiological parameters of the coal void water and comparison has been made with natural reservoir. The study will be helpful in utilization of the coal void judiciously for the benefit of mankind.
The aim of this work is to analyze the physical, chemical and microbiological characteristics of water to determine its nutrient status.

Materials and Methods
Study Area
Two coal voids were selected for study the details are as follows;

Sangam Coal void: Sangam void is under Saunda Colliery, Bhurkunda, Ramgarh district, of Jharkhand (India). The coal void is 1000m long, 300 m wide, water depth about 44m and free board 15m. It is undrainable and the main source of water is sky feeding and runoff from nearby colonies. The coal void is abandoned since 1995.

Saunda coal void: It is almost square shape of area 10 ha of depth 67 m. The periphery is covered with the natural vegetation and water is used for firefighting in the nearby areas. The void have good catchment area.

The water sample was collected from the different depth by using Kemmerer water sampler for study of Physical, Chemical and Bacteriological parameters. The physical parameters included temperature, conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS). The Chemical parameters include Alkalinity, Hardness, pH, Dissolved oxygen (DO), Chemical oxygen demand (COD), Biological oxygen demand (BOD), Ammonical nitrogen, Chloride, Nitrate, Phosphate. The microbiological parameters include Total plate count (cfu/ml). The physical, chemical and microbiological analysis of various parameters studied following the standard methods [4].

The Physico-chemical parameters was done monthly and microbiological study was done in pre monsoon, monsoon and post monsoon during June 2015-2016.

Results and Discussions

The quality of natural water is generally governed by various physico-chemical and biological Parameters. The Physico-chemical parameters has been presented in Table1.

Water Temperature

The maximum and minimum temperatures of coal void water were observed in the months of June and January respectively. The values ranged between 7 ^{0}C to 27 ^{0}C. There is a very close similarity between the temperature of atmosphere and water due to the depth of the reservoir. High summer temperature and bright sunshine accelerate the process of decay of organic matter resulting into the liberation of large quantities of CO_2 and nutrients. The water temperature variation was less in different depth in coal void in comparison to natural dam may be due to fire zone in the area

pH

The pH is affected not only by the reaction of carbon dioxide but also by organic and inorganic solutes present in water. Any alteration in water pH is accompanied by the change in other physic chemical parameters. pH maintenance (buffering capacity) is one of the most important attributes of any aquatic system since all the biochemical activities depend on pH of the surrounding water. In the present study, pH ranged 6.8-8.0 in Sangam, 7.8-8.8 in Saunda and 7.6-8.9 in Patratu. The pH was more alkaline in a void in comparison to Patratu dam may be due to inherent characteristics of the coal. pH increased during the summer months and decreased during monsoon and winter months. Maximum values during the summer may be due to increased photosynthesis of the algal blooms resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates. The decrease in pH during the winter may be due to decrease in photosynthesis, while during monsoon it may be due to greater inflow of water.

Conductivity

Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The Conductivity was more in coal voids, it ranged from 538 - 1446 µmohs. The conductivity of the natural reservoir was found 159 µmohs. The high conductivity value is due to dissolution of minirals from exposed coal in the surface area [2].

Total Dissolve Solids

Total dissolved solids (TDS) combine the sum of all ion particles that are smaller than 2 microns Depending on the ionic properties, excessive total dissolved solids can produce toxic effects on fish and fish eggs. Dissolved solids are also important to aquatic life by keeping cell density balanced. In distilled or deionized water, water will flow into an organism's cells, causing them to swell. In water with a very high TDS concentration, cells will shrink. These changes can affect an organism's ability to move in a water column, causing it to float or sink beyond its normal range.TDS can also affect water taste, and often indicates a high alkalinity or hardness.

The TDS in the reservoir ranged from 136 -139 mg/l whereas in the coal void 468 – 1258 mg/l which is more than the ideal range. This may be due to poor flushing and runoff, high evaporation, low rainfall, small ground water inflows[2] and low organic bed in the bottom[6].

Dissolved oxygen (DO)

DO is a very important parameter of water quality and an index of physical and biological process going on in the water. In the present study, the maximum concentration of dissolved oxygen was observed in the month of June. It may be due to heavy rainfall, which favours solubility of oxygen among the study sites. The highest concentration (8.8-14.4 mg/l) was recorded in patratu dam, there is wide variation in the DO concentration (3.6 to 12.4 mg/l) in the coal voids may be due to poor growth of phytoplankton.

Carbon dioxide

The free carbon dioxide is the product of living organism and also used by the phytoplankton for photosynthesis during day time, it becomes more harmful when the dissolved oxygen is less and fishes are under stress. The free carbon dioxide concentration in the selected water bodies ranged from 4.4 to 13.2 mg/l depending upon aquatic animals available in the water bodies. The carbon dioxide concentration becomes more harmful when the dissolved oxygen concentration decreases.

Alkalinity

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them. Alkalinity plays an important role in controlling enzyme activities. Maximum andMinimum values of alkalinity on different sites of the present study showed variations in different months. There is an indication to suggest that alkalinity concentration is affected directly by rainfall [7]. Similar effect has been noticed in the present investigation immediately often the onset of rains. The alkalinity of the water bodies indicates the productive nature of water as also shown in findings in a man-made reservoir of India [8]. Man-made water bodies usually show wide range of fluctuation in alkalinity values depending upon a number of factors. Alkalinity concentration is affected directly by rainfall [9]. In the present investigation alkalinity was more in Saunda (151 ppm) followed by Sangam (109ppm) and Patratu (72ppm). Higher level of alkalinity was observed during the summer months and has also been reported by other workers [10].

Chloride

Chloride is one of the important indicators of pollution. Chlorides are present in sewage, effluents and farm drainage. The value of chloride concentration in the present study was highest in coal void (22-31 ppm) and in Patratu (8-10ppm). These values are usually in the lower range of values for different rivers of India [11]. The low value in the Patratu study may be attributed to the absence of major pollutants.

Hardness

The water hardness in the reservoir was higher. During the summer months which might have caused the increased concentration of salts by excessive evaporation [12]. The hardness increases in the polluted waters mostly by the deposition of calcium and magnesium salts. Calcium and Magnesium salts are main reason for hardness. The hardness was more in Sangam (860ppm) followed by Saunda (256ppm) and Patratu(85ppm).

Chemical oxygen demand (COD)

COD is a measure of pollution in aquatic ecosystems. It estimates carbonaceous factor of organic matter. The range of values of COD in the present study was 18-42 ppm. The maximum values of COD Sangam (42.5ppm) indicated the higher degree of pollution compared to that of Saunda (30.4ppm) and Patratu (18ppm). Higher concentration of COD in the summer and rainy months may be due to high temperature and higher concentration of suspended and dissolved solids.

Biochemical oxygen demand (BOD)

BOD is the amount of oxygen required by the living organisms engaged in the utilization and ultimate destruction or stabilization of organic water. It is a very important indicator of the pollution status of a water body. The values of BOD clearly showed higher concentrations during most of the summer and rainy months and comparatively low during winter months. Many workers [13, 14, 15] showed higher BOD during summer due to low level at river discharge. In the present investigation the BOD ranges from 1.4 to 2.0 ppm.

Nitrate

Nitrate concentration depends on the activity of nitrifying bacteria which in turn get influenced by the presence of dissolved oxygen. In the present study the values of nitrate ranged from 1.1 to 1.98 ppm showing highest values in summer months and early monsoon. The nitrate value was maximum in Saunda. This may be due to the higher phytoplanktonic production, decaying macrophytes and concentration of nutrients owing to the evaporation of reservoir water with subsequent increase in nitrate value. Such observations have also been found by other workers [16]. Decrease in nitrate content during the winter months was probably due to its utilization as nutrient by the algal community as evidenced by the luxuriant growth of algae particularly in the winter months.

Ammonical nitrogen

Ammonical nitrogen reaches the reservoir through diverse sources, major contributor being domestic wastes. A significant amount of ammonical nitrogen was recorded during March, April and May. The concentration is more in Patratu (0.41ppm) followed by Sangam (0.29ppm) and Saunda (0.18ppm).

Phosphate

The amount of phosphate is observed probably due to the presence and decomposition of aquatic vegetation which releases phosphate. The phosphate is an important constituent not only for the aquatic vascular plants but also for the growth of phytoplankton. Phosphate was found only in smaller amount on all sites. The low concentration of phosphate affects the growth of aquatic flora as it is a very essential plant nutrient. The concentration of phosphate was more in the summer during which the blooms of algae were observed, while the minimum value in the winter months was possibly due to its immediate utilization by the overgrowth of phytoplankton.The concentration was more in Sangam (2.0ppm) followed by Patratu (1.4ppm) and Saunda(0.7ppm), it may be due to low utilization by vegetation in Saunda.

Organic carbon

The organic matter found in the aquatic ecosystems consists of dissolved organic carbon (DOC) and particulate organic carbon (POC) [17]. In lakes, DOC alone represents the largest reservoir of organic carbon in the water column, followed by heterotrophic bacteria that are estimated to be 40 times smaller [18]. Two major sources of DOC are generally considered in lake ecosystems: autochthonous production by autotrophic organisms including phytoplankton, benthic algae and macrophytes [19] and allochthonous. The organic carbon water was found more in Patratu (5.71ppm) followed by Sangam (5.27ppm) and Saunda (2.8ppm).

Total suspended solids (TSS)

The value of TSS ranged between 81-999 mg/l on different sites of the present investigation.

Suspended solids cause ecological imbalance in the aquatic ecosystem by mechanical abrasive action. Suspended solids may be in the form of coarse, floating, fine or colloidal particles as a floating film. Maximum values reported in the present study during the monsoon months at all study sites were due to increased surface runoff from nearby catchments [20]. Most of the Indian reservoirs and rivers showed a similar tendency with respect to fluctuations of suspended solids.

Total plate count

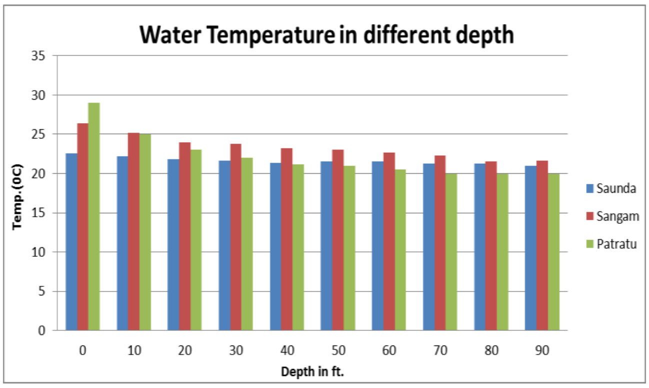
It has been found that, the bacterial population was in decreasing order from Pre monsoon to Post Monsoon, this variation is clearly seen in the Sangam void. Some Workers has correlated that bacterioplanktonic growth is positively correlated with temperature, particularly at relatively low temperature of ranges <10 ^{0}C to 15 ^{0}C [21, 22]. Above this temperatures, bacterial growth is not as much of strong associated and apparently in the seasonally warmer upper part of the water column, temperature-adapted bacterial communities develop and are limited to a greater extent by other parameters and resources, particularly organic substrates and nutrients [23]. The maximum bacterial load (1.28 x 10^3 cfu/ml) has been found at Sangam coal void during summer season in comparison to Saunda coal void (0.825 x 103 x 10^3 cfu/ml) and Patratu dam (0.51 x 10^3 cfu/ml) is due to domestic waste water discharge near by the colony. The microbial contamination in different water sources is significantly affected with seasonal variations, waste disposal and various socio-biological activities like bathing, cloth washing, defecations and domestic and as well as industrial garbage dumping effluents from various sources, like municipal sewage, industries, agriculture lands and others, affect the microbial quality of water sources in various ways [24].

Like temperature, pH also plays a very vital role in shaping the ability of bacteria to grow or succeed in particular environments. Most of the, bacteria grow optimally within a narrow range of pH between 6.7 and 7.5. Many biological activities can occur only within a narrow pH range. Any variation beyond acceptable range will affect the growth and density. In the present study, the pH value ranged from (7.24 to 8.46) and such condition may be suitable for the growth of microorganisms.

In Monsoon at Saunda coal void has been found maximum (9.22 x 10^3 cfu/ml) bacterial load in comparison to Patratu dam (2.01 x 10^3 cfu/ml) and Sangam coal void (0.90 x 10^3 cfu/ml) may be due to organic matter from catchment area, it is supported by the findings of other workers [25, 26]. The luxurious growth of bacterial population during the summer and monsoon months is the outcome at the influx of washed organic matter in the reservoir from the surrounding forest areas. It is natural that the incoming nutrient load finds its way first to the surface, thereby encouraging bacterial proliferation during monsoon. The rains bring in particulate matter, which serves as sites of adsorption for bacteria, thereby increasing the bacterial load [27].

Even though land washing organic matter and animal manure added by runoff rain water, due to the dilution effect reduce the bacterial count in the monsoon season. And minimum in the rain may be the lower part of the water column, temperatures can directly control bacterial growth.

In winter season the minimum (0.63 x 10^3 cfu/ml) bacterial load has been obtained at Sangam coal void in comparison to Patratu dam (1.68 x 10^3 cfu/ml) and Saunda coal void (3.1 x 10^3 cfu/ml) is due to the lower temperature and low organic matter. The depth wise Cfu /ml decreases uniformly in Saunda and Sangam upto 30 ft but in Patratu it is up to 50 ft.



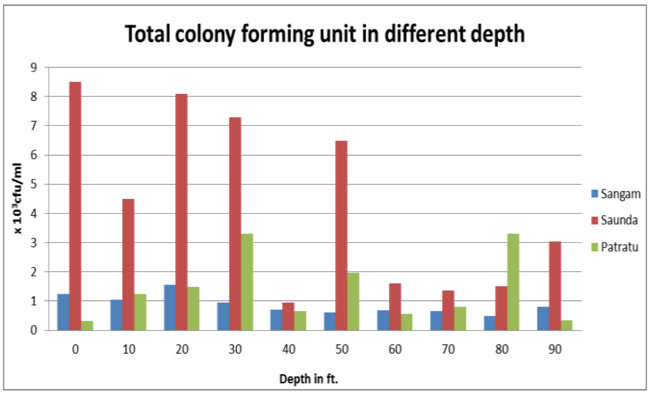


Table 1: Physic-chemical parameters of water

Sl .no	Parameters	Patratu dam			Sangam			Saunda		
		Range	Annual mean	S.D	Range	Annual mean	S.D	Range	Annual mean	S.D
1	pH	7.6-8.9	8.36	0.35	6.8-8.0	7.3	0.42	7.8-8.8	8.2	0.45
2	Conductivity	156-204	164.5	15.18	1401-1726	1561	96.0	516-639	553	43.7
3	TDS	136.19	145.12	19.0	1122-1456	1312.8	97.7	415-469	453.2	20.03
4	Dissolved oxygen	8.8-14.4	11	15	3.6-12.4	6.75	2.5	4.8-10.8	7.2	2.16
5	Free CO2	0-4.4	0.88	1.5	0-17.6	11	5.71	0-11	6.16	5.09
6	Alkalinity	32--92	72	18	48-136	109	25.1	120-216	151	35.06
7	Chloride	8..5--11	10.06	1.21	22-31	28.25	4.38	22-31	27.4	2.93
8	Total hardness	72-104	85	10.72	796-900	860	31.31	244-264	256	6.69
9	COD	0-64	18	21.81	0-96	42.5	30.52	4-64	30.4	19.69
10	BOD	1.0-2.8	1.8	0.65	1.4-2.4	2	0.6	1.0-2.4	1.48	0.49
11	NO_3	0.78-1.7	1.25	0.32	0.24-2.9	1.1	0.91	0.6-3.8	1.98	1.17
12	Amm. Nitrogen	0-1.1	0.411	0.317	0.05-0.37	0.297	0.12	0—0.47	0.182	0.16
13	PO_4	0—2.0	1.4	1.03	0.2-1.4	2.0	0.8	0-2.0	0.7	0.79
14	OC	0-11	5.71	3.05	0-10.4	5.27	3.63	0—5.4	2.8	2..0

Table 2: Turbidity, Total Suspended Solids and Total Dissolved Solids in different depth

	Sangam			Saunda			Patratu		
	TDS (mg/l)	TSS(mg/l)	Turbidity(NTU)	TDS (mg/l)	TSS(mg/l)	Turbidity(NTU)	TDS (mg/l)	TSS(mg/l)	Turbidity(NTU)
Surface	1237	97	3.4	459	48.8	6.4	160	115.6	4.2
10	1239	163	6.1	457	81.2	6.2	157	127.7	6.0
20	1231	128	6.8	517	68.4	6.8	157	115.4	5.2
30	1198	143	13.9	483	58.2	7.3	155		41.3
40	1249	162	9.2	481	14.4	6.7	157	149.2	10.4
50	1205	143	11.4	480	71.6	3.0	157	158.7	9.9
60	1208	162	7.5	482	81	4.2	1533	102.2	8.0
70	1204	209	11.5	472	104.6	3.0	159	81.9	8.7
80	1251	138	21.4	480	69.4	4.9	157	272.6	27.3
90	1251	162	36.6	478	81.2	2.7	157	999	95.8

Table 3: Bacterial population in different season

Site	Premonsoon (summer season)	Monsoon (rainy season)	Postmonsoon (winter season)
Sangam void	1.28 x 10^3 cfu/ml	0.90 x 10^3 cfu/ml	0.63 x 10^3 cfu/ml
Saunda void	0.825 x 103 x 10^3 cfu/ml	9.22 x 10^3 cfu/ml	3.1 x 10^3 cfu/ml
Patratu dam	0.51 x 10^3 cfu/ml	2.01 x 10^3 cfu/ml	1.68 x 10^3 cfu/ml

Conclusion

The findings of the present investigation revealed that the physic-chemical parameters are within the favorable range for the fish culture, Temperature ranges 7 to 27 ^{0}C (15-35 ^{0}C), pH 7.8 to 8.8(6.8-8.6) Dissolved oxygen 3.6 to 12.4ppm (>5ppm) Carbon dioxide 4.4 to 13.2ppm (0-10ppm), Alkalinity 109 to 151 ppm(50-200ppm) Chloride 22 to 31ppm (<100ppm), Hardness 256 to 860ppm(50-150 ppm), COD 30 to 42ppm (40-80ppm), BOD 1.4 to 2.0ppm (3-6ppm), Nitrate 1.1 to 1.98ppm (<2 ppm), Ammonical nitrogen 0.18 to 0.29ppm (<0.5 ppm), Phosphate 0.7 to 2.0ppm(<2 ppm), and TSS 81 to 999ppm (80 ppm). The Conductivity 538 to 1446 mhos (60-2000 mhos), TDS 468 to 1258 ppm is higher. The bacterial load ranges from 0.63x10^3 to 9.222x10^3 which is within permissible limit. It may be concluded that this water bodies can be utilized for commercial fish culture with little management of organic carbon application

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