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ASSESSMENT OF WATER QUALITY PARAMETERS OF AN ABANDONED OPENCAST COAL PIT (OCP) OF ASANSOL-RANIGANJ COALFIELD (ARCF), PASCHIM BARDHAMAN, WEST BENGAL, INDIA

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Abstract

Coal mining and its auxiliary actions have already been proved to cause potential pollutions to ecosystems. This research work assesses the surface water quality of Samdihi abandoned Opencast Coal Pit (OCP) of Asansol-Raniganj Coalfield Areas (ARCF). Twenty seven water samples were collected maintaining temporal variability and were analyzed for physicochemical attributes. The pH was slightly alkaline with lowest of 7.8 during winter. The water temperature varied between 20 and 35°C. Conductivity was highest during winter (601±3.51 µS/cm) and lowest during monsoon (333±2.8 µS/cm). The Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) ranged from 212 to 2738 mg/L and 170 to 413 mg/L respectively. The low values of TSS (212 mg/L) and TDS (170 mg/L) were observed during winter and the higher values of TSS (2738 mg/L) and TDS (413 mg/L) were observed during monsoon. The dissolved oxygen concentration was moderately high (between 6.89 and 8.43 mg/L) but comparatively higher (8.5 mg/L) in monsoon. The estimated dissolved concentration of phosphate, sulphate, sodium and potassium were 4.2±0.17, 98.6±10.48, 8.6±0.47 and 2.5±0.75 mg/L respectively. Zooplankton population in the OCP was found to be 8±1.76 ind/mL in monsoon and 14±1.12 ind/mL in winter with an impressive abundance of 157/L and 274/L in monsoon and winter respectively. The water chemistry suggests the non-potability compared to prescribed standards but the chemical attributes showed promising traits for pisciculture, aquaculture, horticulture and/or other recreational practices that may assist in improving the socio-economic condition of the community habituating in and around the area.

Keywords: Samdihi OCP, water quality, aquaculture, agriculture, pisciculture

Introduction

In India, coal is the key fuel resource and primary source of energy and the opencast coal mining process is one of the best and economically viable methods of extraction of coal in India. Mining operations usually create an adverse environmental impact, both during the mining activity and subsequently after its closure. Mineral resources are essential materials, because it provides more than 95% of primary energy, 80% of industrial raw materials and 70% of agricultural production materials. After surface mining, it forms a big pit, i.e., void, locally called *khadans*. After coal extraction and dewatering ceases, opencast mining resulting into a void which is eventually filled up by surface runoff and groundwater seepage and becomes a pit-lake or large reservoir. Pit lakes can represent significant liabilities after closing mining activities. These pit lakes are the potential water reservoir for local population of Asansol-Raniganj Coalfield Areas of Paschim Bardhaman (Ghosh, 2012). Transformation of *khadans* into fish ponds or means of aquaculture is one of the most productive processes of ecological restoration and vertical expansion of a productive resource (Pal et al., 2014). Use of mine water for aquaculture is a practical way to avoid pathogens and their hosts and enhance the nutritive value of the concerned fish practised in this pisciculture (Pal et al., 2013). The water scarcity is a major problem in this coalfield area which can be solved by these permanent water reservoir of this area and at the same time these water bodies can be used for different purposes like pisciculture, agriculture, horticulture, recreation,

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aquatic and wildlife conservation, industrial purposes, flood control and waste management (McCullough & Lund, 2006).

Keeping in mind the constant growth in population with the trailing surge in demand of food, shelter and employment, the present study aimed to investigate the water quality of an opencast pit lake and to explore the possibilities of transformation of these water bodies into a site of specific impoundments for speculated fish farms and other vertical and horizontal developmental probabilities. The hydrological quality obtained from this open cast coal pit is highly variable, depending on the type of mine, the environment or the climate and local geochemistry. The physicochemical properties of pit lake aquatic system depend on the composition and nature of the overburden and bottom sediment, and the growth and development of biological organisms. Several studies on ARCF areas revealed that mining of this area is free from acid mine drainage (Ghosh et al., 2005). The present study undertaken in the Samdihi abandoned OCP of Asansol Coal Block, under Eastern Coal Field Limited (ECL), thus, foreshows the intense possibilities of socioeconomic development of local population based on the safe uses of this large water reservoir through fisheries, agriculture, horticulture and allied purposes.

Materials and Methods

Description of study site

Samdihi khadan (or *dihi/dighi* in Bengali means large reservoir) is located at Samdihi colliery (Samdihi Opencast Coal Mine) in Lohat region of ARCF areas of Eastern Coalfields Limited under Paschim Bardhaman District of West Bengal and around 20.0 km from Asansol. It is about 5.0 km of south east to Rupnarayanpur Railway Station of Eastern Railways and about 8.5 km of north east of Salanpur Railway Station of Eastern Railways within the latitudinal and longitudinal extension of about 23°47'06"N to 23°47'07"N and 86°55'37"E to 86°55'40"E. Total land cover of this area is around 114.0 km² with an outstanding population of around 2.50 lakh according to 2011 census. The nearest human habitat is in Sangramgarh, Samdihi, within 0.5 km from the experimental pit lake.

The Samdihi OCP is very significant in regard to its location and recent closure not more than about 5-7 years ago, it is a perfect experimental site with lowest anthropogenic interventions. The area of this OCP is currently near 1,80,433.62 m² with an irregular perimeter run of about 2,286.25 m and average mean sea level (MSL) of about 14.0 ft. Samples were collected from four distinct sites, named Spot 1 (23°47'06.5"N and 86°55'27.03"E), Spot 2 (23°47'07.02"N and 86°55'37.8"E), Spot 3 (23°47'10.05"N and 86°55'43.75"E) and Spot 4 (23°47'08.49"N and 86°55'40.04"E).

Figure 1. Map of Samdihi OCP with four distinct sampling sites.

Collection of samples and methodology

Water samples were collected in laboratory grade, non-reactive sampling bottles of 1L capacity each from all the four spots in triplicate and were preserved properly for further studies. For dissolved oxygen and biochemical oxygen demand, water samples were collected in clean and clear glass BOD bottles of about 300mL each from four spots.

Zooplankton population and abundance were assessed by collecting by plankton net of mesh size 22 micron by horizontal hauling process and were collected and condensed into 50mL collection tube and were fixed with 5% formaldehyde solution for further studies.

Table 1. Methods of analysis of physicochemical parameters of Samdihi OCP.

Parameters	Methods	Reference (s)
pH	Electrode Method	APHA-AWWA, 2005
Temperature	Electrode Thermometer Method (Total Immersion Thermometer)	APHA-AWWA, 2005
Dissolved Oxygen (DO)	Titrimetric (Winkler's Method)	APHA-AWWA, 2005
Conductivity	Electromagnetic Induction Method	APHA-AWWA, 2005
Biochemical Oxygen Demand (BOD)	Titrimetric (Winkler's Method)	APHA-AWWA, 2005
Alkalinity	Titrimetric (Sulphuric Acid Method)	APHA-AWWA, 2005
Acidity	Titrimetric (Sodium Hydroxide Method)	APHA-AWWA, 2005
Hardness	Complexometric Titration (EDTA Method)	APHA-AWWA, 2005
Combined Carbon Dioxide	Titrimetric (Free CO_2 Method)	APHA-AWWA, 2005
Salinity	Electrical Conductivity Method	APHA-AWWA, 2005
Total Dissolved Solids (TDS)	Gravimetric Method	APHA-AWWA, 2005
Total Suspended Solids (TSS)	Gravimetric Method	APHA-AWWA, 2005

Table 2. Methods of analysis of anions and cations of Samdihi OCP.

Parameters	Methods	Reference (s)
Chloride	Argentometric Method	APHA-AWWA, 2005
Sodium	Flame Emission Photometric Method	APHA-AWWA, 2005
Potassium	Flame Photometric Method	APHA-AWWA, 2005
Nitrate-nitrogen	UV-Spectrophotometric Screening Method	APHA-AWWA, 2005
Ammoniacal-nitrogen	Titrimetric (Sulfuric Acid Method)	APHA-AWWA, 2005
Phosphate	Spectrophotometric (Stannous Chloride Method)	APHA-AWWA, 2005
Sulfate	Gravimetric (Barium Chloride Method)	APHA-AWWA, 2005

Method for plankton population and abundance

Zooplankton count was done by 'Sedgewickrafter cell count method' and the plankton abundance index was calculated using the formula (Agus Tjahjono & Hartanto, 2020):

$$N = \frac{1}{A} x \frac{B}{C} x \frac{D}{E} xF$$

Where,
N – Plankton abundance/L (ind/L)
A – Volume of filtered water (L)
B – Volume of water in the sample (mL)
C – Volume taken during identification (1 mL)
D – Area of glass cover or preparation space (mm^2)
E – Field of view (25 mm^2)
F – Average number of observed individuals

Results and Discussion

Physicochemical parameters

Table 3. Analysis of Physicochemical parameters of Samdihi OCP water in monsoon and winter.

Parameters	Seasons	
	Monsoon	Winter
pH	08.12±0.79	07.80±0.56
Temperature (^oC)	35.00±2.10	20.00±1.98
DO (mg/L)	08.50±0.13	06.89±0.11
Conductivity ($\mu S.cm^{-1}$)	333.00±2.80	601.00±3.51
BOD (mg/L)	01.90±0.06	01.10±0.01
Alkalinity (mg/L)	180.00±6.60	207.23±4.90
P-acidity (mg/L)	106.00±8.01	106.00±6.97
M-acidity (mg/L)	11.20±4.15	11.20±4.88
Hardness (mg/L)	260.00±2.73	199.90±2.53
Combined CO^2 (mg/L)	171.30±4.60	102.10±3.90
Salinity (mg/L)	00.04±1.20	05.00±2.60

N.B.: Data represented as average value ± standard deviation

pH

pH is the good indicator for determination of the quality of water. For a productive ecosystem, pH ranges from 6.7 to 8.4 and is considered to be safe for aquatic life, and pisciculture can be done under the pH ranging from 6.0 to 9.0 (Swingle, 1967). In this study average pH of all the sampling sites (spot 1 to 4) of Samdihi OCP were between 7.0 and 9.0, with the highest of 8.12±0.79 in monsoon and lowest of 7.80±0.56 in winter. The pH is impacted not just by the response of carbon dioxide yet additionally by the natural and inorganic solutes present in water, thus, any change in water pH is joined by the progressions alongside other physicochemical boundaries (Kulshrestha et al., 1992). Basic nature of pH of the OCP water body of this study communicated its cushioned and high trophic circumstances, which was comparative with the examinations made by Chandrasekhar (1996) on Saroornagar Lake of Hyderabad and Jumbe and Nandini (2010). Kulshrestha et al. (1992) also expressed similar kind of results as in this study, that higher the pH during hot seasons were presumably due to excessive photosynthesis resulting into the precipitation of carbonate of calcium and magnesium from bicarbonates causing higher alkalinity in water bodies. In this manner, the pH in the OCP was found reasonable for endurance and culture of fish in the re-established biological system of water body.

Temperature

Water temperature regulates the biological activity of aquatic organisms like survival, metabolism, physiology, growth, development and reproduction (Welch, 1952). In this study the average temperature was noted as 20±1.98and 35±2.1^oC in winter and monsoon respectively. Temperature around 30^oC is considered to be optimum for biological activities and thus the observed temperature of the Samdihi OCP being in that range can signify the conduciveness of fish culture.

Dissolved Oxygen

Dissolved oxygen concentration plays a key role in aquatic ecosystem and regulates the health of aquatic organisms. Dissolved oxygen (DO) is one of the most important indicators of water quality and is essential for the survival of fish and other aquatic organisms (Santhosh & Singh, 2007). In Samdihi OCP, in winter season DO value was 6.89±0.11 mg/L, but in monsoon it increased upto 8.5±0.13 mg/L. Higher DO in rainy season is suitable for fish culture. Higher DO during monsoon may be because of the effect of downpour water bringing about air circulation and agitation, which was supported by Hannan et al. (1979). Crampton et al. (2003) described that the hotter limnic climate can cause downfall of dissolved oxygen content of the water bodies, but in this study, the DO was noted to increase with rise in temperature, which is due to increased rate of photosynthesis by macrophyte and planktonic

community, and wind action during monsoon. Thus, the observed concentration of DO in Samdihi OCP showed the optimum condition of the OCP for fish culture.

Conductivity

Conductivity is sensitive to variation in dissolved solids, mineral salts dissociation, ion mobility and the temperature. The electrical conductivity values of Samdihi OCP water was under the range of 330.0and 605.0µS/cm. In the current study, highest value of conductance was recorded in winter (601±3.51 µS/cm) and lowest during rainy season (333±2.8 µS/cm). Although, Shariatpanahi and Anderson (1987) described the increased conductance with higher temperature and dissolved solids, the consistency of higher conductance throughout the colder time of year (580 to 601µS/cm) can be explained by the phenomenon of decomposition of organic matter increasing the dissolved solids and ion mobility of the OCP water. Also, the event of low conductance in winter was explained and supported by Salodia (1996).

Biochemical oxygen demand

Biochemical oxygen demand (BOD) can get reduced in heavy oxygen availability and consuming condition. In this study, the BOD was 1.9±0.06 and 1.1±0.01mg/L during monsoon and winter respectively. Higher BOD was seen in rainy season because of oxygen availability and oxygen dissolving capacity is higher in high temperature also; air activity and agitation tend to increase dissolved oxygen in water which then increased the BOD values of Samdihi OCP. The ideal BOD level for fish culture must not be more than 10.0 mg/L (ICAR, 2007) and water with BOD more than 35.0 mg/L are not considered as commodious quality of water for fish culture (Pande & Sharma, 1999). In the present study, BOD of 1.9±0.06 mg/L in monsoon months was due to presence of a load of organic matters coming from degrading aquatic organisms in OCP, and thus provides a great base for pisciculture (Wurts & Durborow, 1992).

Alkalinity, total acidity, total hardness and combined carbon dioxide

Total alkalinity, total acidity, total hardness and combined carbon dioxide (CO_2) are the interrelated biological parameters in an aquatic framework. These parameters can influence the actual stress level of freshwater fishes, oxygen availability in the aquatic system, and other harms.

Total alkalinity is the amount of bases present in natural water and alkalinity comprises carbonate (CO_3^{2-}) and bicarbonate (HCO_3). The present study revealed the alkalinity of the Samdihi OCP as of 180.00±6.60 mg/L and 207.23±4.90 mg/L in monsoon and winter respectively. The average value of alkalinity of the OCP water was 193.62±5.75, ranging a higher value in winter and lower in monsoon because of impact of buffering of pH, copper disintegration and dissociation of other metals which was supported by Boyd & Tucker (2012). An alkalinity value of 20.0 mg/L and more can be sustainable for aquaculture, although a range of 50 - 200 mg/L as $CaCO_3$ is generally suitable for fish culture (Wurts & Durborow, 1992). In this context, it can be established that the OCP water under present condition may be proved reasonable for fish culture and sustainability.

Likely, total acidity is the sum total of titrimetric value of phenolphthalein acidity (P-acidity) and methyl orange acidity (M-acidity). Hydrolyzing salts and mineral acids can contribute in increasing the acidity of a water body (Apha, 2005). In this study, the concentrations of P- and M-acidity were 106±6.97 and 11.2±4.15 respectively, which defines the total acidity range to be in favour of pisciculture (Wurts, 2000). Also, there was no significant change in the values of acidity during the winter and monsoon seasons.

Total hardness is a significant parameter in determining the probability for fish culture and is a significant viewpoint of estimating water quality. In this OCP water, total hardness was maximum in monsoon (260±2.73 mg/L as $CaCO_3$) because of less retention by aquatic plants and degradation of organic materials, while in winter, the value decreased upto199±2.53 mg/L as $CaCO_3$ due to increased bioabsorption and same was explained by Silva et al. (2003). However, Wurts (1993) described the availability and dissociation of calcium and magnesium in higher temperature to be the factor behind the variations of hardness.

In Samdihi OCP, monsoon season bears greatest measure of carbon dioxide load (171.3±4.6 mg/L) and winter showed the low value of CO_2 (102.1±3.9 mg/L). Aquatic combined CO_2 appears mainly from the respiratory course of aquatic organisms, some elemental dissolution and organic matter decomposition (Mandal et al., 2021). Thus, heavy organic load and greater algal bloom in higher temperature causes rise in aquatic carbon in monsoon as compared to winter (Hargreaves et al., 1996).

Salinity, total dissolved solids and total suspended solids

Salinity of water is a significant factor in deciding numerous aspects of water chemistry and organic cycles inside it. In the present study, during winter the salinity of the OCP was much higher (5±2.6 mg/L) compared to that of monsoon (0.0318±1.2 mg/L) due to lower temperature and higher conductance of the water in winter (Mondal et al., 2015).The total dissolved solids (TDS) and total suspended solid (TSS) refer to the solid matter substances dissolved and suspended in water respectively, both of which significantly define the productivity, particulate load and water quality. In this study, the TDS and TSS values of the samples were higher in monsoon (413±6.3 mg/L and 2738±2.1 mg/L, respectively) due to high rate of water drainage and overburden runoff, while in winter, the values were much lower (170±4.7 mg/L and 212±2.3 mg/L, respectively). Similar results were denoted by Pal et al. (2013).

Anions and cations

Table 4. Analysis of anions and cations of Samdihi OCP water in monsoon and winter.

	Seasons	
Parameters	Monsoon	Winter
Chloride (mg/L)	16.99±5.70	16.90±7.10
Sodium (mg/L)	08.60±0.47	06.66±0.55
Potassium (mg/L)	01.27±0.53	02.50±0.75
Nitrate-nitrogen (mg/L)	00.81±0.16	00.16±0.29
Ammoniacal-nitrogen (mg/L)	00.25±0.19	00.19±0.08
Phosphate (mg/L)	04.50±0.17	00.02±0.21
Sulfate (mg/L)	98.60±1.48	23.25±2.00

N.B.: Data represented as average value ± standard deviation

Chloride (Cl)

Chloride is a significant parameter of water quality and is helpful to fish in keeping up with their osmotic equilibrium. In the OCP, the chloride concentration was found to be in a steady minimum average of about 16.99±5.7 mg/L. Though, there is no particular standard of chloride content for freshwater fish culture, but value near 100.0 mg/L is suitable (Ghosh et al., 2005). This low concentration (16.99±5.7 mg/L) of chloride in this OCP may be due to the lack of the chloride rich rocks which were the primary providers of the chloride in OCP water.

Sodium (Na^+) and potassium (K^+)

Sodium and potassium, the micronutrients are very important for aquatic life. In this study, the sodium concentration in OCP water was high in rainy season (8.60±0.47 mg/L) and low in winter (6.66±0.55 mg/L). But, the potassium concentration followed opposite traits with higher value of 2.50±0.75 mg/L in winter and as low as 1.27±0.53 mg/L in monsoon. Being micronutrients, the concentrations of sodium and potassium are usually low in freshwater but value near 5.0 mg/L is suitable for the sustainability and proper cellular metabolism of aquatic organisms (Tepe & Mutlu, 2004).

Nitrate-nitrogen (NO_3-N) and ammoniacal-nitrogen (NH_3-N)

In the present study, the nitrate-nitrogen (N-Nitro) was recorded within the normal range, measuring highest in monsoon (0.807±0.16 mg/L) and lowest in winter (0.16±0.29 mg/L). Nitrate is the most non-harmful of the major inorganic nitrogen compounds and is found as the finished result of the nitrification interaction of the aquatic system. For pisciculture <80 mg/L nitrate can be the suitable as reported by Svobodová (1993), but according to Pillay (2008) and Zweig et al. (1999) <3.0 mg/L nitrate is admissible for aquaculture.

In this study, the values of ammoniacal-nitrogen (A-Nitro) were found 0.25±0.19 mg/L as the highest in monsoon and 0.19±0.08 mg/L as lowest in winter. Unlike nitrates, ammonia is the underlying result of the deterioration of nitrogenous natural materials, organic substances and digestion of microorganisms, and may demonstrate the presence of decaying urea, excrement, and organics. Accordingly, the present study indicated the availability of phytoplankton and water plants to absorb those as also evidenced by Wurts (2003). Zweig et al. (1999) proposed that the value of ammoniacal-nitrogen within 0.1 mg/L is suitable for fish culture practices which were later additionally supported by Pillay (2008).

Phosphate (PO_4^{3-}) and sulfate (SO_4^{2-})

Phosphate permits plants and animals to develop and keep up with the proper physiological functioning. From the current study, in OCP water, higher phosphate value was recorded during monsoon as 4.5±0.17 mg/L, while in winter, it was lowest 0.019±0.21 mg/L. Sayre et al. (1983) and USEPA (1986) recommended that for sustainable freshwater fish cultivation, the phosphate-phosphorus value should be less than 5.0 mg/L, otherwise excess of it might cause eutrophication in water body which is most unsafe for fish culture.

Sulfate adds to osmotic tension, and sulfur is a part of protein in organisms' body. In the present study, OCP water portrayed greatest sulfate content in rainy season (98.6±1.48 mg/L) and lowest in winter (23.25±2 mg/L). Sulfate in OCP water is mostly coming from sulphur containing rocks, though there is no such evidence found in this case. Nonetheless, freshwater fish evidently don't have any explicit prerequisite for sulfate in water and they get sulphur mostly from their food. Sulfate had positive relation with EC, thus, higher EC may be the conceivable justification for the higher sulphate content in OCP water bodies during rainy season (Cole, 1979).

Plankton

Zooplankton population count

Plankton is the different assortment of life form tracked down in water that can't drive them against a water current momentum. In the aquatic system, they give an urgent wellspring of food to numerous little and huge aquatic living beings, like bivalves, fish, whales and other aquatic organisms. In this study, the average zooplankton count of samples was 8±1.76 and 14±1.12 ind/mL in monsoon and winter respectively. Zooplankton plays an important role in bio-diminishing pollutants and other contaminating metals due to their high rate of bioaccumulation, and thus is a very important factor for health of any aquatic system consideration (Rossi & Jamet, 2008). Zooplankton of the order Cladocera and Calanoida was found to be plentiful in Samdihi OCP dominated by *Cyclops* sp. along with the community abundance of 7.91±0.21 U/L.

Plankton abundance

Plankton abundance of the present study attributes highest in winter (274/L) and lowest in monsoon (157/L). Thus, with the higher value of plankton abundance, the rate of bioaccumulation of heavy metals gets increased due to the special ability of plankton to take up metals much faster than other organisms, which results into a steady aquatic system suitable for aquaculture (Saygı & Yiğit, 2012). Maintenance of the nutrient cycle through polyculture is the new era of sustainable aquaculture and for that maintaining a feed pool of zooplankton and phytoplankton is necessary even though they don't have any market value, but still contributes a lot to the aquatic ecosystem (Wurts, 2000).

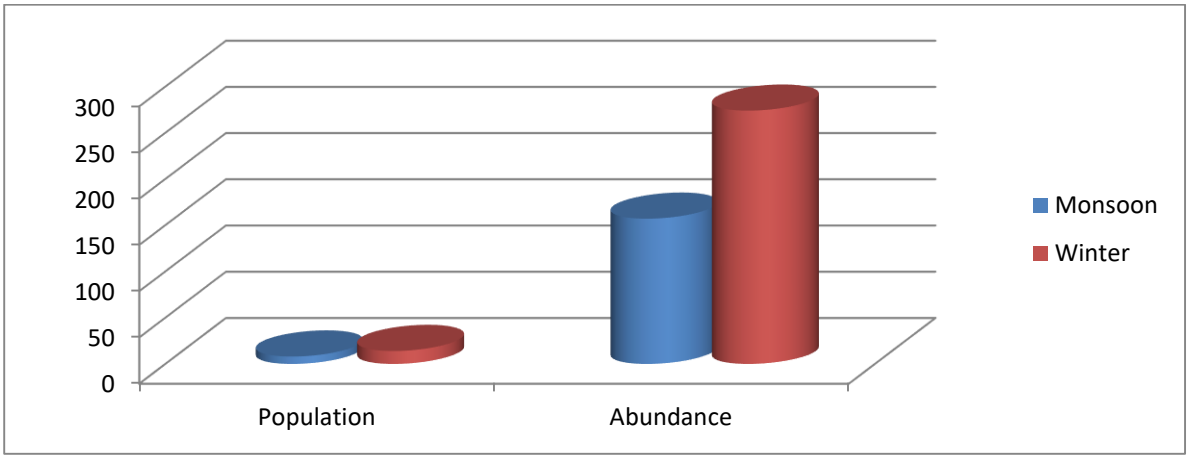

Figure 2. Graph showing zooplankton population and plankton abundance in monsoon and winter.

Conclusion

Present study intended to assess the nature of mine water comparing with a standard portrayal. This study includes assurance of physical, natural and compound boundaries of surface water of Samdihi OCP. Outcome of this

investigation revealed that, the water is substantially unsuitable for the end goal of drinking, but for other different utilization, actually could be thought of as very satisfactory. The water was viewed as marginally basic in nature, suitable level of alkalinity and DO, and low range of BOD values showed the evidence of commodious productivity. Because of high pace of precipitation nearby during rainy season and with dispersed, irregular, and heavy rain practically all the year round, the agitation caused the OCP water to be more turbid in monsoon than in winter. The other physicochemical parameters being either within prescribed limits or only somewhat more, alongside the suitable concentrations of sodium, potassium, nitrate, sulfate, phosphate, ammonia and chloride and higher planktonic overflow, the water probably won't be appropriate for drinking, but may be an excellent base for hydroponics, pisciculture, agriculture and horticulture. The increased water quality parameters in monsoon showed that during the rainy season the pit lake water is more impacted than winter. This could be because of the way that the microbial movement get diminished because of low temperature, consequently keeping higher DO during whole winter season, and higher DO indicates the higher productivity. Thus, the non-consumable OCP water (according to BIS standards) can be utilized in different purposes, such as pisciculture, agriculture and horticulture, which will help in development of financial state of the area, and furthermore dealing with abandoned and deserted mines for recovery, restoration and natural reclamation as much as possible and also makes valid toward sustainability and conservation of biological system.

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Conflict of Interests

It is hereby declared that the authors have no such conflict of interests.

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