Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI:10.21474/IJAR01/4474
DOI URL: http://dx.doi.org/10.21474/IJAR01/4474
ISSN NO. 2320-5407

RESEARCH ARTICLE

PHYSICO-CHEMICAL ANALYSIS OF WATER SAMPLES FROM THREE SELECTED WETLANDS ADRA SAHEBBUNDH, JOYPUR RANIBUNDH AND NIBARAN SAYAR IN PURULIA DISTRICT, WEST BENGAL.

Sujit Kumar Mandal.
Assistant Professor, Deptt. of Botany, Sidho Kanho Birsha University, Ranchi Road, Purulia-723104 , West Bengal, India.

Manuscript Info

Manuscript History

Received: 13 April 2017
Final Accepted: 15 May 2017
Published: June 2017

Key words:-
Physico-chemical characteristics, water samples, Purulia District.

Abstract

The present paper deals with the physico-chemical analysis of water samples in Adra Sahebbundh, Joypur Ranibundh and Nibaran Sayar in Purulia District, West Bengal. Water samples collected from these three wetlands during the post monsoon period (2014-2015) were analyzed for studying as many as 10 important parameters. The study revealed physico-chemical analysis of water of Adra Sahebbundh, Joypur Ranibundh and Nibaran Sayar in Purulia District, West Bengal.

Introduction:-

Wetlands are efficient in trapping pollution and processing waste in human-dominated landscapes (Scholz 2015; Zhao *et al.*, 2016). Wetlands have been found to be important 'sinks' for pollutants moving from upland areas, preventing their movement into surface water and ground water (Ouyang *et al.*, 2014). Artificial wetlands are being used to treat wastewater (Vymazal , 2013; Haydar *et al.*, 2015).

Artificial wetlands are integral part of the global hydrobiological regime and is greatly influenced by both physiographic and climatic conditions. Such wetlands, artificial or natural ,constitute an important component of aquatic ecosystem as they support human civilization, living animals and plant resources and are often characterized by high levels of biodiversity and biological production (Chowdhury and Ahmed, 2012; Gupta and Palit, 2013; 2014a; Mackintosh *et al.*, 2015; Coban *et al.*, 2015, Dixon *et al.*, 2016).

Water quality of wetlands regulates the key biota which prevail in diverse forms (Gupta and Palit 2014b; Mukherjee *et al.*, 2015). In this context, the present study was conducted in selected wetlands of a drought prone region of Eastern India to assess the water quality.

Materials and Methods:-

The sensitive water parameters like Turbidity, Suspended Solids, pH, Acidity, Alkalinity, and Dissolved Oxygen were analyzed on the spot with the help of a 'Surface Water Testing Kit' containing essential reagents and glass wares, whereas water samples for estimation of Specific Conductance, Total Hardness, and Biological Oxygen Demand, were brought to the laboratory for analysis.

Corresponding Author:-Sujit Kumar Mandal.
Address:-Assistant Professor, Deptt. of Botany, Sidho Kanho Birsha University, Ranchi Road, Purulia-723104 , West Bengal, India.

For collection of water sample, water was filled in 500 ml plastic bottles from three portions separately (from periphery to middle) of each of the three wetlands selected. The plastic bottles were washed with source water before filling them up. Four readings of each parameter were taken with each water sample and the values thus obtained with all the sets of collections made from each wetland were added to find out the mean value.

Study sites:-
Purulia District, situated between 23° 19' 50.23 " North latitudes and 86° 21' 46.91 "East longitudes. It extends over an area of 6259.00 sq Km. The soil is of lateritic type and the temperature ranges from 26-44°C during summer and from 11-24°C during winter. Maximum rainfall for the district as far recorded is in the month of July 413 mm (Mandal and Mukherjee, 2012).
Three important artificial wetlands are located in three different blocks and physiographic regions of West Bengal Viz. Adra Sahebbundh (Kashipur) , Joypur Ranibundh (Joypur) and Nibaransayar (Purulia I)**.** Brief description and distinctive physiographic features are as follows.

Adra Sahebbundh [23° 28' 57" N, 86° 42' 35" E]:-
This is a perennial, Government owned, urban-wetland in Purulia District. It spread over a water area of 11 acres of land. This waterbody is infested with macrophytes , bathing and washing of utensils for domestic purposes. This wetland is mainly used for water supply within Adra town.

Joypur Ranibundh [23° 26' 00" N, 86° 08' 00" E]:-
This privately owned wetland covers about 120 acres of land. There are 3 concrete bathing places and 2 concrete bath-houses on east of the wetland. On the south-east side, there is a fishery farm for rearing and breeding of carp during rainy season. There are 19 hatcheries and a large breeding chamber. Fish cultivation and marketing is done by a Co-operative Society. The wetland is also used for cremation of dead bodies of the royal family, immersion of image of God and Godess, domestic purposes, washing of vehicles etc.

Nibaransayar [23° 20' 17 '' N, 86° 21' 32 " E]:-
This is a perennial, Government owned wetland which covers an area of 70 acres of land. The Science Centre, a glory of the district, was established beside this wetland. Nibaransayar engulfs two islands located near Purulia bus-stand.

Nibaransayar was designated as a 'national wetland' in February 2001 by Sri Deba Prasad Jana, the District Magistrate of Purulia. Being a nature lover he did a lot for raising greenery around this perennial wetland, reducing eutrophication and removal of excess of water hyacinth and algal bloom from the wetland. This wetland is mainly used for supply of drinking water and aesthetic purposes of Purulia town.

Results and Discussion:-

The physico-chemical characteristics of water samples were determined in case of three wetlands viz, Adra Sahebbundh, Joypur Ranibundh and Nibaran Sayar. Each of the ten parameters considered **(Table 1)** showed certain variations in the three wetlands studied a precise account of which is presented in the following.

pH: Value of pH of water sample was found to be 0.882752 in case of Adra Sahebbundh which in cases of Joypur Ranibundh and Nibaran Sayar or Saheb bundh were 0.81697 and 0.868233 respectively.

Transparency: In case of Adra Sahebbundh transparency of water sample was 2.020498 cm. In case of Joypur Ranibundh its value was 1.942008 cm while for that of Nibaran Sayar it was 1.937819 cm.

Turbidity: So far the values of turbidity are concerned the highest value was scored in case of water samples from Joypur Ranibundh (1.146128 cm) which was followed in the decreasing order by those from Nibaran Sayar (1.12483 cm) and Adra Sahebbundh (1.122216 cm).

Acidity: Values of total acidity of water samples ranged from 1.335658 mg/litre (Adra Sahebbundh) to 1.636789 mg/litre (Joypur Ranibundh) which was 1.477121 mg/litre in case of Nibaran Sayar.

Alkalinity: In case of Adra Sahebbundh, the value of alkalinity of water samples was found to be 1.486572 mg / litre which was higher in case of Joypur Ranibundh (1.539829 mg/ litre) and highest in case of Nibaran Sayar (1.668945 mg/ litre).

Dissolved Oxygen (DO): Values of DO were found to be 0.31133 , 0.340047 and 0.342423 mg/litre for water samples collected from Joypur Ranibundh, Nibaran Sayar and Adra Sahebbundh respectively.

Biological Oxygen Demand (BOD): Biological Oxygen Demand (BOD) values were determined to be 0.4389 , 0.48945 and 0.28735 mg/litre in case of water samples collected from Nibaran Sayar, Joypur Ranibundh and Adra Sahebbundh respectively.

Total Dissolved Solids (TDS): The values of TDS found out in case of water samples collected from Adra Sahebbundh was 2.075766 mg/litre which was somewhat lower in case of Joypur Ranibundh (2.054345) and lowest in case of Nibaran Sayar (2.041393 mg / litre).

Electrical Conductivity (EC): Values of EC were the same (0.15989 µmho/ cm) in case of water samples collected from Adra Sahebbundh and Nibaran Sayar and higher (0.004321 µmho/cm) in case of Joypur Ranibundh.

Total Hardness (TH): Total hardness value of water sample from Adra Sahebbundh was determined to be 0.90309 mg/ litre which in case of Joypur Ranibundh was 0.69897 mg/litre and in case of Nibaran Sayar or Sahebbundh 0.668386 mg/litre.

The quality of fresh water can have a great influence on the ability of growth of aquatic plants and animals in the stream, pond or lake and also those outside (Paka and Rao, 1997). It depends upon several physico-chemical and biological characteristics. The normal range of these characteristics indicates the good water quality. Surface waterbody is the most easily accessible source of fresh water in the rural areas. As the same time, being open lentic water systems, ponds get more easily pollutes than the ground waters and springs (Swaminathan *et al.*, 1997).

Aquatic production in the wetland ecosystem is primarily governed by the important physical factors viz. temperature, transparency, turbidity, wind action, flow and turbulence of water etc. Temperature is not a limiting factor of production in tropical and subtropical India (Banerjee, 1967).

In view of the foregoing, different physicochemical characteristics of the selected wetlands were studied, a brief discussion of which is made in the following.

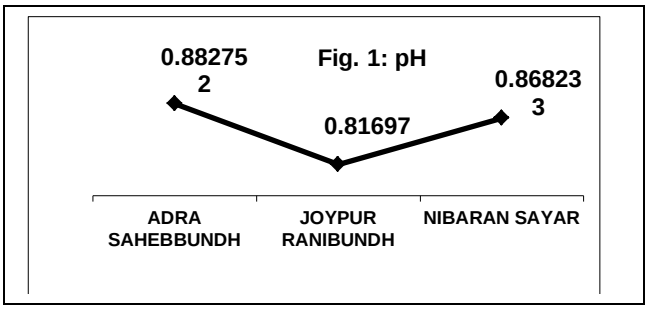
Water in all the wetlands is neutral to moderately alkaline except in Joypur Ranibundh (**Fig.1).** The pH of water of Joypur Ranibundh (0.81697) is indicative of mild acidic nature. The minimum pH value is 0.81697 in Joypur Ranibundh and maximum pH value is 0.868233 in Nibaransayar with the mean value ranging from 0.81697 to 0.882752 .The alkaline nature of certain samples may be due to input of chemical nutrients through agricultural run-off from adjoining crop fields.

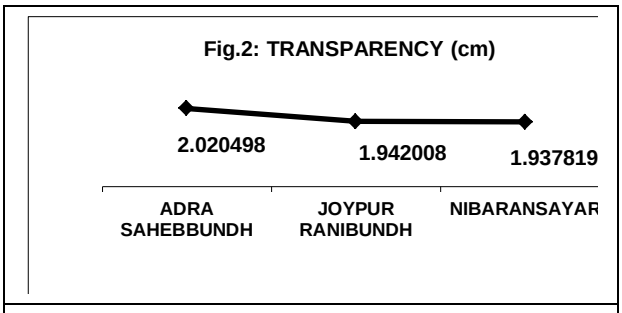
Transparency value of the three wetlands ranges from 1.518514 cm (minimum value recorded for Joypur Ranibundh) to 2.082785 cm (maximum value also recorded for Joypur Ranibundh). However, the mean value of transparency were detected to be lowest (1.937819 cm) in Nibaran Sayar and highest (2.020498 cm) in Adra Sahebbundh (**Fig.2).** The mean value of Joypur Ranibundh is 1.942008 cm. Light penetration of the water in wetlands studied is generally high in Nibaran Sayar which at times reaches up to bottom due to poor abundance of planktons in most part of the year barring monsoon months. This favour the luxuriant growth of submerged macrophytes which maintain the optimum status of primary production.

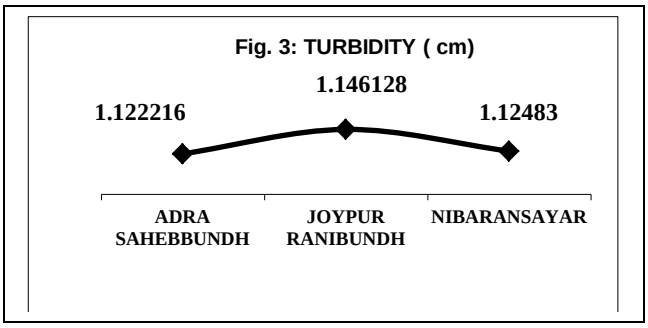
Table 1:-Physico-chemical characteristics of water samples from three selected wetlands.

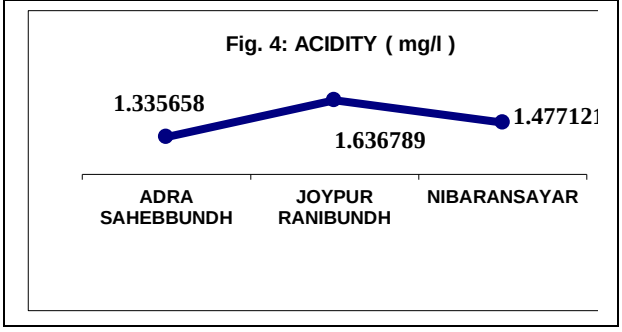
Parameter	**Name of the wetland**								
	Adra Sahebbundh			**Joypur Ranibundh**			**Nibaran Sayar**		
	Mini.	**Maxi.**	**Mean**	**Mini.**	**Maxi.**	**Mean**	**Mini.**	**Maxi.**	**Mean**
pH	0.877026	0.886378	0.882752	0.814714	0.819676	0.81697	0.823344	0.89215	0.868233
Transparency (cm)	1.905796	2.064458	2.020498	1.518514	2.082785	1.942008	1.819544	2.004321	1.937819

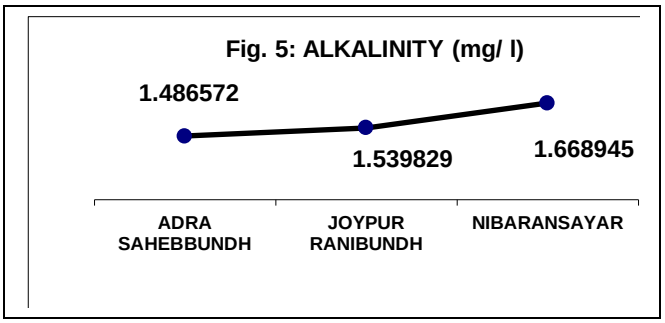
Turbidity (cm)	0.90309	1.255273	1.122216	0.954243	1.30103	1.146128	0.954243	1.342423	1.12483
Acidity (mg/l)	1.176091	1.477121	1.335658	1.60206	1.653213	1.636789	1.39794	1.544068	1.477121
Alkalinity (mg/l)	1.477121	1.50515	1.486572	1.477121	1.579784	1.539829	1.591065	1.70757	1.668945
DO (mg/l)	0.30103	0.380211	0.342423	0.30103	0.342423	0.31133	0.30963	0.401401	0.340047
BOD (mg/l)	0.39794	0.22185	0.28735	0.4437	0.4437	0.48945	0.55284	0.22185	0.4389
TDS (mg/l)	2.070038	2.082067	2.075766	2.049218	2.060698	2.054345	2.033424	2.049218	2.041393
Electrical conductivity (µmho/cm)	0.18046	0.12552	0.15989	0.00877	0.0086	0.004321	0.18046	0.12552	0.15989
Total hardness (mg/l)	0.845098	0.954243	0.90309	0.60206	0.845098	0.69897	0.477121	0.778151	0.668386

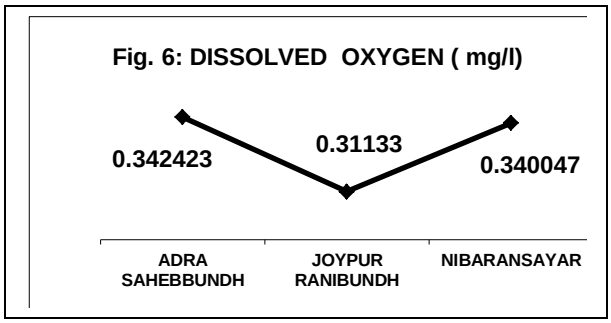


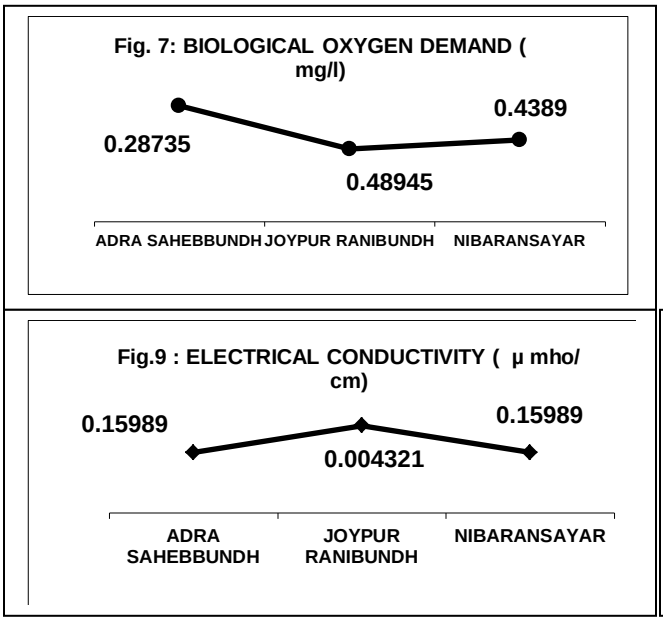


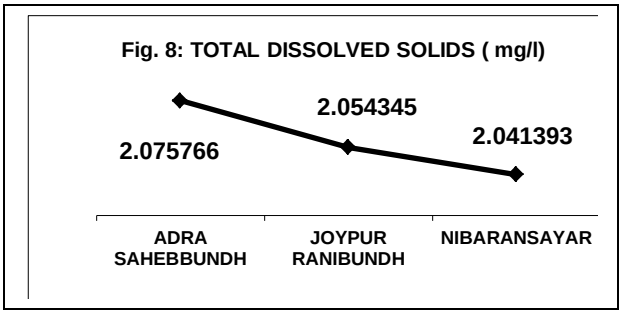


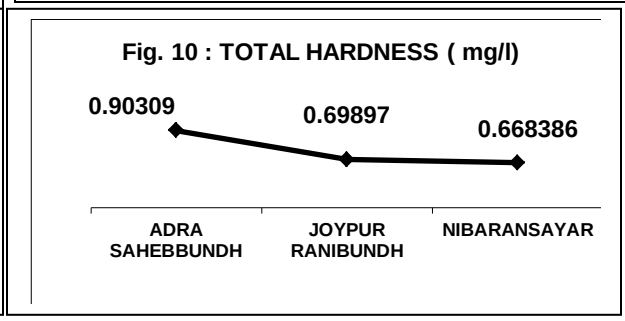












Graphical representation of different parameters observed in three selected wetlands:-

The turbidity value of the three wetlands ranges from 0.90309 cm (minimum value was recorded for Adra Sahebbundh) to 1.342423 cm (maximum value recorded for Nibaran Sayar). However, the mean values of turbiditwere detected to be lowest (1.122216 cm) in Adra Sahebbundh and highest (1.146128 cm) in Joypur Ranibundh (**Fig.3).** The mean value of turbidity of water in Nibaran Sayar is 1.12483 cm. Light obstruction of the wetland water i, e, turbidity is highest in Joypur Ranibundh which might be due to the abundance of planktons. In case of Adra Sahebbundh and Nibaran Sayar the water is quite turbid with their mean value as 1.122216 NTU and 1.12483 NTU respectively.

Acidity value was found to be minimum in the sample from Adra Sahebbundh (1.176091 mg / l) and maximum in case of Joypur Ranibundh (1.653213 mg/l) with the mean value ranging from 1.335658 mg /l (Adra Sahebbundh) to 1.636789 mg/l (Joypur Ranibundh). Somewhat intermediate value was registered in case of Nibaransayar which is also familiar as Sahebbundh **(Fig.4).**

Alkalinity of water is a measure of its capacity to neutralise acid and is characterised by the presence of hydroxyl ions capable of combining with hydrogen ions in the solution. Such value was detected to be minimum in the samples from both Adra Sahebbundh and Joypur Ranibundh (1.477121 mg/l) and maximum in case of Nibaran Sayar (1.70757 mg/l) with the mean value ranging from 1.486572 mg/l (Adra Sahebbundh) to 1.668945 mg / l (Sahebbundh). The highest mean value slightly exceeds the optimum value of 40mg/l as per Das (2003).The low value of alkalinity observed in most of the samples **(Fig.5)** indicates the absence of weak and strong bases. It results in lowering of ion exchange capacity of water.

The DO (Dissolved Oxygen) level was found to be minimum (0.30103 mg/l) in Adra Sahebbundh as well as Joypur Ranibundh and maximum (0.401401 mg/l) in Nibaran Sayar /Sahebbundh. The mean value was found to range from 0.31133 mg/l to 0.342423 mg/l (**Fig. 6).** Higher DO level was observed throughout the 3 wetlands which can be attributed to the direct diffusion of air across the air-water interface. In addition, it may be due to penetration of direct sunlight across the wide surface of wetlands which is capable of supporting photosynthetic activities of phytoplankton and help in maintaining the DO level (Raja *et al.*, 2002).

BOD level was found to be minimum in samples from Adra Sahebbundh (0.39794 mg/l) and maximum in case of Joypur Ranibundh (0.4437 mg/l) with the mean value ranging from 0.28735 mg/l to 0.48945 mg/l **(Fig. 7).** Higher BOD value may be due to high quantity of biologically oxidisable organic matter and large number of microbes.

It may also be due to unethical practice of open defecation in the adjacent agricultural land, discharge of contaminated waste water containing decayed organic matter and agricultural residues. High BOD value may also be attributed to the stagnation of a sublentic water system as wetland leading to absence of self purification cycle.

TDS content signifies inorganic pollution load of any waterbody. Its variation from one source to other is due to variation in siltation, rainfall, wind and biota. Surface run-off from adjacent agricultural land may be another cause of variation in TDS content in different wetlands. Excess TDS influences taste, hardness and corrosive property of the water, disturbs the ecological balance and causes imbalance in osmotic regulation and suffocation in aquatic fauna even in the presence of fair amount of DO. Minimum TDS value (2.033424 mg/l) was determined in case of Nibaran Sayar and maximum TDS value (2.082067 mg/l) in case of Adra Sahebbundh with the mean value ranging from 2.041393 mg/l to 2.075766 mg/l **(Fig.8).**

EC level was found to be minimum (0.00877 µmho/cm) in water samples from Joypur Ranibundh and maximum (0.12552 µmho/cm) in Adra sahebbundh and Nibaransayar with the mean value ranging from 0.004321 µmho/cm to 0.15989 µmho/cm **(Fig.9).** EC value of water samples is a measure of ionic constituents present in the waterbody. The variation of EC value from one source to another is attributed to the contents of total dissolved solids and salinity.

Hardness level was found to be minimum (0.477121 mg/l) in case of Nibaran Sayar and maximum (0.954243 mg/l) in Adra Sahebbundh. The mean value ranged from 0.668386 mg/l (Nibaransayar) to 0.90309 mg/l (Adra Sahebbundh) **[Fig.10].** All wetlands were found to have water with hardness values > 100 mg/l. It is indicative that all the wetlands contain hard water. This accounts for scale formation in the distribution as well as prior scum formation (Singanan *et al.,* 1996).

The alkalinity value varied in the range from 1.477121 mg/l to 1.70757 mg/l. This value indicated that Nibaran Sayar had the best capacity to neutralize acidity and it is below the optimum value of 40mg/l (Das, 2003). Joypur Ranibundh showed the highest transparency value (1.942008 cm). Nibaran Sayar has the highest 1.12483 cm) turbidity value among others and Adra Sahebbundh the lowest (1.122216 cm). Adra Sahebbundh possessed lesser amounts of suspended particles to allow more sunlight to penetrate than other wetlands studied.

It was detected that all the minimum values of pH (0.814714),Transparency (1.518514 cm) were shown by Joypur Ranibundh and those of Turbidity (0.90309 cm), Acidity (1.176091 mg/l) were shown by Adra Sahebbundh. The minimum values of BOD (0.55284 mg/l),Total Hardness (0.477121 mg/l),TDS (2.033424 mg/l) were shown by Nibaran Sayar. The Minimum value of DO (0.380211 mg/l) and Akalinity (1.50515 mg/l) were shown by Adra Sahebbundh as well as Joypur Ranibundh and Electrical Conductivity (0.18046 µmho/cm) was shown by Adra Sahebbundh and Nibaran Sayar.

Characteristically maximum values of pH (0.89215), Turbidity (1.342423 cm), Alkalinity (1.70757 mg/l), DO (0.401401 mg/l) were shown by Nibaran Sayar and those of Transparency (2.082785 cm), Acidity (1.653213 mg/l), Electrical Conductivity (0.0086 µmho/cm) were shown by Joypur Ranibundh. The maximum value of Total Hardness (0.954243 mg/l) and TDS (2.082067 mg/l) were shown by Adra Sahebbundh, and BOD (0.22185 mg/l) was shown by both Adra Sahebbundh and Nibaran Sayar.

Acknowledgement:-

The author is grateful to Ambarish Mukherjee, Professor, UGC Centre for Advanced Study in Botany, Burdwan University, Burdwan for constant encouragement and valuable supervision.The author is grateful to Nandadulal. Sannigrahi, Head, Department of Botany, Nistarini College, Purulia and Priyabrata Mukherjee of the Department of Environmental Science of the same institution for providing laboratory facilities during this work.

References:-

1. Ahmad, S. and Mishra, A., (2014). A study on physic-chemical properties of ground water quality of various locations of Kanpur city. *IJSR*. 3(3):177-179.
2. Banerjee, S. M., (1967). Water quality and soil conditions of fish ponds in states of India in relation to fish production *Indian J. Fish*. 14 (1 & 2): 115-144.

3. Coban, O., Kuschk, P., Kappelmeyer, U., Spott, O., Martienssen, M., Jetten, M. S. & Knoeller, K., (2015). Nitrogen transforming community in a horizontal subsurface-flow constructed wetland. *Water research*. 74: 203-212.
4. Chowdhury, A. H. and Ahmed, R., (2012). Water, sediment and macrophyte quality of some shrimp culture ponds and freshwater ecosystems of Koyra. In *Bangladesh J. Bot.* 41 (1):35-41.
5. Das, A.K., (2003). Physico-chemical properties of soil and water and their role in the production process of wetlands. *Training manual* of *Cetral Inand Fisheries Research Institute* (ICAR) Kolkata. 18-24.
6. Dixon, M. J. R., Loh, J., Davidson, N. C., Beltrame, C., Freeman, R., & Walpole, M., (2016). Tracking global change in ecosystem area: The Wetland Extent Trends index. *Biological Conservation*. 193: 27-35.
7. Gupta, S., & Palit, D., (2013). Inventory and Charecterization of wetlands in Birbhum district, West Bengal, India: implications for conservation. *Ecology, Environment and Conservation.* 19(4): 995-1000.
8. Gupta, S., & Palit, D., (2014a). A study on wetlands in Birbhum district, West Bengal, India. *Journal of Applied Sciences in Environmental Sanitation.* 9(2): 79-84.
9. Gupta, S., & Palit, D., (2014b). Biosurvilance of Wetlands in Eastern India (Birbhum, West Bengal) for wise use. *International Journal of Science, Environment and Technology*. 3(6) :2136-2144
10. Haydar, S., Haider, H., Nadeem, O., Hussain, G., & Zahra, S., (2015). Proposed model for wastewater treatment in Lahore using constructed wetlands. *Journal of Faculty of Engineering & Technology.* 22(1): xx-xx.
11. Kanakiya, R. S., Singh, S. K. and Sharma, J. N., (2014). Determining the water quality index of an urban water body, Dal Lake, Kashmir, India. *IOSR. Journal of Env. Sci. Toxico.and Food Techno.* 8(12): 64-71.
12. Kepuska, X., Daija, L. and Kristo, I., (2014). Determination of physic-chemical parameters of water in Biological minimum in the Lake 'Radoniq' . *European Scientific Journal.* 3: 63-70.
13. Kumar, R. and Jha, A. K., (2015). Physico-chemical studies on Kamla River water .*IJARCSSE.* 5(5) : 1141-1115.
14. Mackintosh, T. J., Davis, J. A., & Thompson, R. M. (2015). The influence of urbanisation on macro invertebrate biodiversity in constructed storm water wetlands. Science of The Total Environment. 536: 527-537.
15. Mahananda, M. R., Mohanty, B. P. and Behera, N. R., (2010). Physico-chemical analysis of surface and ground water of Bargarh District , Orissa, India. *IJRRAS.* 2(3): 284-295.
16. Mandal, S. K. and Mukherjee, A., (2012). Study of wetlands in Puruliya District, West Bengal, with special emphasis on their macrophytes (Ph. D. Thesis).
17. Mukherjee, A., Palit, D., & Gupta, S., (2015). Rare record on Plaintive Cuckoo (Cacomantis merulinus) from a fresh water wetland of Bankura district, West Bengal, India. Zoosprint. 30 (3):19-21.
18. Olawale, S. A., (2016). Physico-chemical analysis of water from Asha River, Horin, Nigeria. *IJIR.* 2(3):122-129.
19. Onwughara, N. I., Ajiwe, V. I. E. and Nnabuenyi, H. O., (2013). Physico-chemical studies of water from selected Boreholes in Umuahia North local Government area , in Abia State, Nigeria. *Int. J. Pure. App. Biosci.* 1(3):34-44.
20. Ouyang, W., Song, K., Wang, X., & Hao, F., (2014). Non-point source pollution dynamics under long-term agricultural development and relationship with landscape dynamics. *Ecological Indicators.* 45: 579-589.
21. Palit, D. and Mukherjee, A., (2012). Studies on water quality and macrophyte composition in wetlands of Bankura district, West Bengal, India. *Indian Journ. Plant Science.* 1(2-3):97-115.
22. Paka, S. and Narsing Rao, A. (1997). Interrelationships of physico-chemical factors of a pond. *J. Env. Biol*. 18 (1):67-72.
23. Patil, P. N., Sawant, D. V. and Deshmukh, R. N., (2012). Physico-chemical parameters for testing of water- a review. *Intern. Journ. Of Environmental Science* 3(3):1194-1207.
24. Raja, R.E., I. Sharmila, J. Princey Merline and G. Christopher., (2002). Evalution of ground water quality in residential areas of Tiruchirapalli. *India J. Env. Prot.* 22(2):137-140.
25. Sharma, J. N., Kanakiya, R. S. and Singh, S. K., (2015). Limnological study of water quality parameters of Dal lake, India. *Inter. Jour. Innov. Resear. in Sci. Enginee. and Techno.* 4(2): 380-386.
26. Shukla, D., Bhadresha, K., Jain, N. K. and Modi, H. A., (2013). Physico-chemical analysis of water from various sources and their comparative studies. *IOSR Journal of Environ. Science. Toxico. and Food Techno.* 5(3): 89-92.
27. Scholz, M., (2015). Wetlands for Water Pollution Control. Elsevier.
28. Singanan, M. and Somasekhara Rao, K., (1996). Chemical characteristics of Rameswaram Temple Town drinking water. *Indian J. Env. Port*. 15(6):458-462.
29. Swaminathan, K. and Manonmani, K., (1997). Studies on toxicity of viscose rayon factory effluents. I. effect on water. *J. Env. Biol*., 18 (1):73-78.

30. Vymazal, J., (2013). The use of hybrid constructed wetlands for wastewater treatment with special attention to nitrogen removal: a review of a recent development. *Water research.* 47(14): 4795-4811.
31. Zhao, J., Zhao, Y., Zhao, X., & Jiang, C., (2016). Agricultural runoff pollution control by a grassed swales coupled with wetland detention ponds system: a case study in Taihu Basin, China. Environmental Science and Pollution Research, 1-12.