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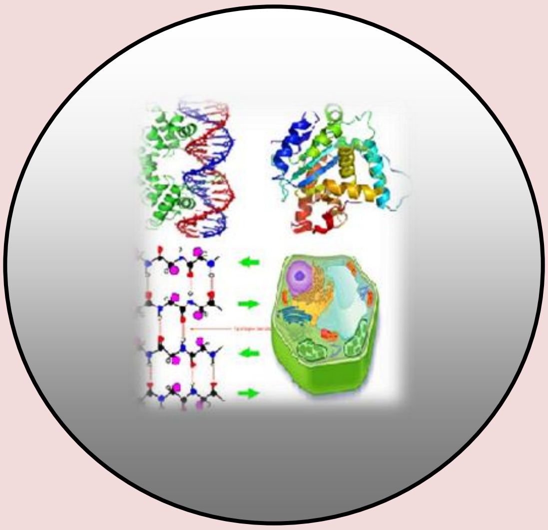
By

Sabiha Khan and Asha Rani Kachhawaha

ISSN 2319-3077 Online/Electronic
ISSN 0970-4973 Print

Index Copernicus International Value
IC Value of Journal 82.43 Poland, Europe (2016)
Journal Impact Factor: 4.275
Global Impact factor of Journal: 0.876
Scientific Journals Impact Factor: 3.285
InfoBase Impact Factor: 3.66

J. Biol. Chem. Research
Volume 40 (1), 2023 Pages No. 60-79



Journal of Biological and Chemical Research

An International Peer Reviewed / Referred Journal of Life Sciences and Chemistry

Indexed, Abstracted and Cited: Index Copernicus International (Europe), World Science Index, Polish Ministry of Science and Higher Education (Poland, Europe) Research Bible (Japan), Scientific Journals Impact Factor Master List, Directory of Research Journals Indexing (DRJI), Indian Science. In, Database Electronic Journals Library (Germany), Open J-Gate, J Gate e-Journal Portal, Info Base Index, International Impact Factor Services (IIFS) (Singapore), Scientific Indexing Services (USA), International Institute of Organized Research (I2OR), Cosmos Science Foundation (Germany), Science Library Index (UAE), Eye Source, Swedish Scientific Publication, World Cat, International Innovative Journal Impact Factor, Einstein Institute for Scientific Information {EISI} and Impact Factor.pl - Kompendiumwiedzy o czasopismachnaukowych, Philadelphia citefactor.org journalsindexing Directory Indexing of International Research Journals

Published by Society for Advancement of Sciences®

J. Biol. Chem. Research. Vol. 40, No. 1, 60-79, 2023
(An International Peer Reviewed / Refereed Journal of Life Sciences and Chemistry)
Ms 40/01/25/2023

ISSN 2319-3077 (Online/Electronic)
ISSN 0970-4973 (Print)


Prof. S. Khan A.R. Kachhawaha
http:// www.sasjournals.com
http:// www.jbcr.co.in
jbiolchemres@gmail.com

RESEARCH PAPER

Received: 04/05/2023 Revised: 28/06/2023 Accepted: 29/06/2023

Control of Water Pollution in Makreda Pond by Bioremediation

Sabiha Khan and Asha Rani Kachhawaha
S.P.C. Government College, Ajmer, Rajasthan, India

ABSTRACT

Water pollution is a major issue in Makreda pond Beawar Industrial waste and sewage wastes have affected the fish fanning very badly. Various species of fish have perished due to water pollution. For maintenance of a healthy aquatic environment and production of sufficient fish food organism in pond, the investigation focused on the physicochemical characteristics of industrial effluent that point to a specific area of water contamination was done. The concentration of physicochemical parameters was determined while the water quality in the area was compared to the international standard indicating local water pollution the level of BOD, COD, TDS, TSS, and cationic or anionic concentration were greater than the WHO-recommendation standards. The bioremediation through probiotics was used for cleaning contamination in water.
Keywords: Water pollution, Physicochemical, parameters, sewage, bioremediation, probiotics, BOD and COD.

INTRODUCTION

All life on Earth depends on water, which is an essential resource. A decline in the amount and quality of freshwater resources that are accessible to people and ecosystems throughout the world is what leads to the problem of water scarcity. Approximately 4.5 billion people worldwide lack access to proper sanitation, and 2.1 billion do not have access to safe drinking water (Growing industrialisation and globalisation have raised awareness of how operations pollute the environment and create trash (Tamrakaret al. 2022). The majority of pollution is produced by a limited number of businesses that lack the necessary infrastructure for waste treatment and pollution control (Purohit et al., 2020). The majority of businesses in underdeveloped nations like India dump their effluents in an untreated manner.

These industrial wastes affect the ecology and water quality and have complicated consequences on flowing streams (Studies by and others have shown that the vast majority of toxic and hazardous substances found in industrial waste and emissions are harmful to human health (Rajaram and Das, 2008).
According to reports, irrigation with freshwater contaminated by industrial and municipal effluents reduces the quality of agricultural output because the watershed's physicochemical characteristics alter (Agoroet al., 2018). The aquatic environment and food chain may be disrupted by the harmful chemicals' potential to kill aquatic creatures (Mbalassaet al., 2012). The levels of pollution in the water as well as its physicochemical properties are two important determinants of surface water quality. The physicochemical properties of water can disclose specific circumstances for the ecology of aquatic creatures and provide effective conservation and management techniques (Abdel-Raoufet al., 2012).
Bioremediation broadly refers to any process wherein a biological system (typically bacteria, microalgae, fungi, and plants), living or dead, is employed for removing environmental pollutants from air, water, soil, flue gasses, industrial effluents etc., in natural or artificial settings [Abdel-Raouf et al., 2012]. The natural ability of organisms to adsorb, accumulate, and degrade common and emerging pollutants has attracted the use of biological resources in treatment of contaminated environment [Abdel-Raouf et al., 2012]. In comparison to conventional physicochemical treatment methods bioremediation may offer considerable advantages as it aims to be sustainable, eco-friendly, cheap, and scalable [Abdel-Raouf et al., 2012]. Most bioremediation is inadvertent, involving native organisms. Research on bioremediation is heavily focused on stimulating the process by inoculation of a polluted site with organisms or supplying nutrients to promote the growth. In principle, bioremediation could be used to reduce the impact of byproducts created from anthropogenic activities, such as industrialization and agricultural processes [Agoro et al., 2018] [Anderson and Grether, 2010]. Bioremediation could prove less expensive and more sustainable than other remediation alternatives [Aniyikaiye et al., 2019].

MATERIALS AND METHODS

Study Area Description

In the Aravali slopes, 70 kilometres from the district capital of Ajmer, located the city of Beawar. Major industries at the moment include those that rely on minerals, machines, machine tools and accessories, plastic goods, textiles, wooden furniture, and cement pipes. The largest cement factory in northern India is located at Beawar. The Makereda Pond is 5 kilometres away. Rajasthan's Ajmer district is located north of Beawar city. It used to be a crucial supply for the nearby farmers' irrigation, agriculture, and fish farming needs. However, when companies grew close by, the water became contaminated by hazardous pollutants and chemical waste. The Beawar city's sewage has made matters worse for irrigation and fish aquaculture.Consequently the water of this pond is not drinkable nor is it safe for farming and fish production.

Sample Collection

About 400 cc of water samples from the two pond locations were taken using the American Public Health Association, 23rd Edition and the Indian Standard Methods IS 3025. The samples were taken in sterile 500 mL vials that measured 43 mm, 69 mm, and 208 mm in size.

Using a bucket sampler and the grab sampling technique, water samples were collected from each location at a depth of around 1 m below the water's surface. Within eight hours of being collected, the bottles were brought to the research facility after being sealed and fastened to keep air out. Before further processing, the materials were kept for four hours in a dark room. Standard methods for laboratory analysis of samples were used (APHA, 1998).

Physiochemical Characterization

Analytical method used for determination of different physicochemical parameters for waters is listed in Table-1.To prevent unforeseen changes in various physicochemical characteristics, water samples were collected from several locations in plastic bottles and transferred to the laboratory in icebox jars. At regular intervals, the chosen parameters—Water pH, Turbidity, Total Alkalinity (TA), Total Dissolved Solids (TDS), Total Hardness (TH), NO3, SO4-2 were examined. The World Health Organization's standard values for a number of physicochemical properties of water samples were compared to the observed values. (WHO, 1993) for drinking purposes. Apart from these parameters Winkler's method (Zhang et al., 2019) was employed to evaluate the Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) for 5 days (APHA, 1999). COD is also a measure of pollution in aquatic ecosystems. It estimates carbonaceous factor of the organic matter.

RESULTS AND DISCUSSION

The results of the physicochemical qualities of the wastewater samples are presented in Table 1.

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Para- -meters	PH	Total Dissolved Solids	Total Suspended Solid	Total Hardness (as$CaCO_3$)	Total Solids	Alkalinity	Sodium (asNa)	Calcium (asCa)	Magnesium(asMg)	Sulphate(SO_4)	Chloride (asCl)	Nitrate (NO_3)	Fluoride (asF)	Dissolve Oxygen (DO)	COD	BOD
Sample		PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	Mg/l	Mg/l	Mg/l
1	8.95	3185	166	1426	3019	182	109.35	644.96	148.65	116	398	12.5	0.78	6.8	35.9	5
2	7.85	2846	165	1516	3206	300	111.2	652.54	145.5	109.27	381.7	10.25	0.82	6.7	35.78	4.8
3	7.56	2648	148	1524	3198	254	108.28	685.42	152.66	108.82	382.08	11.54	0.52	6.9	36.03	4.9
4	8.56	2678	143	1448	3001	223	112.1	648.52	156.48	111.65	383.85	12.48	0.59	6.12	34	5.1
5	8.61	2482	154	1498	3207	248	110.2	642.22	152.85	109.24	383.98	12.65	0.85	6	32	5
6	7.94	2984	168	1682	3103	312	109.27	625.65	148.92	110.69	368.65	10.58	0.58	6.7	33	5.8
7	8.54	2831	154	1688	3004	281	108.82	680.48	142.25	110.28	381.5	10.82	0.95	6.8	34	6.1
8	7.5	3058	158	1598	3103	298	111.65	672.58	149.65	110.12	382.36	11.34	0.85	6.5	32	5.6
9	8.52	2894	146	1648	3206	315	109.24	682.32	149.95	115.34	384.12	11.8	0.88	6.6	34.1	5.4
10	8.16	3156	165	1545	3012	298	110.69	658.59	150.92	104.12	379.9	12.82	0.72	5.8	35.68	5.6
11	7.81	3089	148	1689	3196	248	110.28	685.16	152.42	105.13	380.55	12.92	0.82	7	35	6
12	7.92	3098	158	1452	3298	195	110.12	664.46	148.56	108.9	381.89	11.58	0.8	6.5	35	5.5
13	8.56	2892	142	1526	3194	192	115.34	612.28	146.08	106.8	377.68	11.2	0.84	6.5	32.7	5.6
14	8.94	2796	155	1524	3294	256	104.12	689.68	146.52	111.53	383.9	10.46	0.76	6.4	34.95	5
15	8.64	2489	158	1458	3008	246	105.13	691.85	158.55	109.08	381.34	10.52	0.72	6.3	33.8	4.9
16	8.56	2465	142	1654	3106	285	108.9	621.48	152.52	105.08	377.9	10.12	0.74	6.8	34.52	5.4
17	7.54	3084	165	1489	3092	234	106.8	645.42	150.85	109.55	366.68	11.88	0.78	6.4	33.1	5.6
18	7.85	3179	168	1485	3008	215	111.53	689.22	151.58	112.78	384.66	11.92	0.84	5.3	32.5	5.2
19	8.85	2689	162	1654	2958	196	109.08	626.92	148.52	110.87	380.38	10.65	0.85	6.6	33.4	5.6
20	7.58	2488	158	1452	3085	204	105.08	645.2	142.48	112.76	383.56	10.35	0.92	6.7	34.84	5.8
Average Value	8.222	2851.55	156.15	1547.8	3114.9	249.1	109.359	658.2475	149.7955	109.901	381.234	11.419	0.7805	6.471	34.115	5.395
Std Deviation	0.5003	250.995	8.8274393	90.740579	103.8049	43.33335	2.640755	25.40332	4.08749244	3.10816	6.188611	0.926441	0.11166	0.409594	1.2875	0.38726
Std error	0.11192	56.151	1.9748186	20.299906	23.22258	9.694261	0.590773	5.683069	0.91442784	0.69534	1.384477	0.207258	0.02498	0.091632	0.28803	0.08664

A.) Hydrogen Ion Concentration (pH)
The availability of trace and heavy metals, as well as micronutrients, is known to be influenced by the pH of the water. Water's suitability for a certain function is determined by its pH level. The importance of pH in determining the acid-base balance of water has been established. Surface water's pH level, whether low or high, affects the solubility of certain essential elements as well as the toxicity of other chemical contaminants. The ecology as well as those who rely on it for different purposes might suffer as a result. Water's pH is crucial since many biological processes can only take place within a specific range. Therefore, any deviation outside of a certain range might be deadly to a specific organism. Present study also shows pH is alkaline in most of samples and it ranges from 7.5-8.95. The pH value of different studied in different samples is within highest desirable limit (HDL) prescribed by WHO which is 6.5 to 8.0.
B.) Total Dissolved Solids
Aquatic species may die from high TDS concentrations because they experience osmotic shock, which weakens their ability to regulate their own internal osmotic environment. TDS levels in irrigation water reduce agricultural output, product quality, and plant development (Odjadjare and Okoh, 2010). TDS serve as a measure of the overall inorganic chemical content of a solution. The majority of the inorganic and organic materials in the water body that are typically present in the suspended state are included in total dissolved solids. In our study, the TDS concentrations in the Makereda pond water ranged from 2465 to 3185 mg/l, with an average of 2851.55 mg/l.
C.) Total Suspended Solid
TSS comprises sewage, industrial waste, silt, and animal, plant, and other detritus that has rotted. High levels of suspended particles can have a variety of negative effects on the health of streams and aquatic life. The quantity of home waste water released into the pond affects the amount of total solids, suspended solids, and dissolved solids that are present in the water (Deyet al., 2021). In our study, the TSS concentrations in the Makereda pond water ranged from 142-168 mg/l, with an average of 156.15 mg/l.
D.) Total Hardness
In order to lessen the deleterious effects of dangerous elements, hardness is a crucial factor. The range of Makereda pond water's hardness value in our experiment was 1426–1689 mg/l, with an average hardness value of 1547.8 mg/l. These high values can be a result of the calcium and magnesium bicarbonate and carbonate salt concentrations.
E.) Total Solids
Total dissolved solids and total suspended solids make up the total solids in river water. Floating matter, settleable matter, colloidal matter, and matter in solution make up the majority of it. According to our research, the total solids concentration of Makereda pond water ranges from 2958 to 3298 mg/l, with an average of 3114.9 mg/l.
F.) Total Alkalinity
In a fresh water system, alkalinity of the water is crucial for aquatic life because it balances pH fluctuations brought on by photosynthesis. According to our research, the alkalinity range for the water at Makereda Pond is between 182 and 315 mg/l, with a mean value of 249.1 mg/l. The change in TA corresponds to the change in pollutant load (Parasharet al., 2006). The combined alkalinity of treated water and GW is always within the 200 mg/l WHO permitted range.

G.) Sodium (as Na)

In our finding, range of sodiumconcentration of Makereda pond water is 104.12-115.34 mg/l, whereas average alkalinity value ofMakereda pond water is 109.36mg/l.

H.) Calcium (as Ca)

In our investigation, range of calcium contents of Makereda pond water is 612.28-691.85 mg/l, whereas average calcium contents of Makereda pond water is 658.25mg/l.

I.) Magnesium (as Mg)

In our investigation, range of magnesium contents of Makereda pond water is 142.25-158.55 mg/l, whereas average magnesium contents of Makereda pond water is 149.80mg/l.

J.) Sulphate

According to Njoku et al. 2015, the use of detergents and soaps by inhabitants may be the cause of a high sulphate value. Additionally, ground water and pond water have values of SO4-2 levels that are far lower than the 250 mg/l maximum permissible concentration of sulphate ions in drinking water recommended by the WHO. The range of SO4-2 concentrations in the Makereda pond water studied in this study is 104.12–116.0 mg/l, with an average SO4-2 concentration of 109.90 mg/l.

K.) Chloride ion

In our investigation, range of Chloride ion value of Makereda pond water is 366.68-398.0 mg/l, whereas average Chloride ion of Makereda pond water is 381.23 mg/l., which was found within the permissible limit for drinking water (250 mg/L) prescribed byIS: 10500 and BIS, FAO.

L.) Nitrate

Even at low quantities (1 mg/L), nitrate has been shown to promote eutrophication, which affects aquatic species, reduces biodiversity, and produces unpleasant odours, making the water unsuited for recreational activities (Mooket al., 2012). According to the current study, NO3 levels are below 45 mg/l. The NO3 value of the Makereda pond water ranges from 10.12 to 12.92 mg/l, with an average NO3 value of 11.42 mg/l. With regard to pH, alkalinity, total hardness, chloride, and phosphate, nitrate exhibited positive correlation, whereas dissolved oxygen, TDS, and conductivity showed negative correlation (Sharma et al., 2011).

M.) Fluoride (as F^-)

It was within the permitted limit for fluoride, a trace element that is commonly present in water at values of 0.1 to 1.5 mg/L (Mukherjee et al. 2022). Human tooth decay can be avoided by putting it in water (0.7 to 1.2 mg/L). Depending on the complicated water conditions, levels at or over 3 mg/L are found to result in losses of several fish species (Kumari and Maiti, 2021). According to our research, the average fluoride ion concentration in Makereda pond water is 0.78 mg/l, with the range of fluoride ion values being 0.52-0.95 mg/l.

N.) Dissolve Oxygen (DO)

The degree of organic matter pollution, the destruction of organic material, and the capacity of water bodies to purify themselves are all assessed using DO. Low DO in the water disrupts fish life by making them more susceptible to illness, migrating, and reproducing, reducing their swimming ability, causing feed to fluctuate, and causing the loss of aquatic species (Rahman et al. 2021). Due to the high levels of BOD and COD, the amount of dissolved oxygen in the waste water sample is extremely low. In our study, the DO value of Makereda pond water ranges from 5.3 to 7.0 mg/l, with an average DO value of 6.47 mg/l.

The amount of organic material in a sample that is sensitive to being oxidised by a powerful chemical oxidant is measured in terms of oxygen equivalent as further chemical oxygen demand. Rapidly measured metrics are crucial for the management of waste treatment and industrial wastewater. Measurements of the load of organic contaminants in industrial waste water are made using the COD test. High COD levels in water may indicate poor water quality from urban or agricultural wastewater discharges, which might then lead to increased oxygen depletion that harms aquatic life (Anderson and Grether, 2010). It was shown that the highest allowed value, 30.0 mg/l, is significantly higher in all of the effluents than what is considered safe.According to our investigation, the COD value of the water at Makereda Pond ranges from 32.0 to 36.03 mg/l, with an average COD value of 34.12 mg/l (Fig 2).

P.) BOD

BOD is the rate at which dissolved organic matter in water is being aerobically degraded by microorganisms during a 5-day period. High amounts of organic matter, including leaves and dead plants, dead animals, industrial effluents, wastewater treatment facilities, food processing plants, woody debris, animal manure, and urban storm water runoff, are the main contributors to BOD in aquatic systems (Joshi et al. 2022). The BOD range for the water in the Makereda pond, according to our research, is 4.8-6.1 mg/l, with an average BOD value of 5.39 mg/l (Fig 3).

Implications

Water sample-before-treatment

Although water naturally works to filter out and dissolve potentially harmful contaminants, as humans and large animals pump greater amounts of synthetic and natural waste into the environment, it becomes increasingly difficult for water to filter these out. As a result, water resources could become toxic and require remediation or become non-consumable for human and animal use. Water is essential to our communities and, like you, we care about the health and beauty of our lakes and ponds. Partnering with freshwater management experts can help stakeholders understand the unique characteristics of their waterbodies and arm them with essential tools to protect their precious aquatic resources as pollution becomes an increasingly concerning issue.

Fish Production before using probiotics EMO-301	
Time Duration	Fish Production in Kg
April to November 2017	81359 Kg
December 2017	0 Kg
April to December 2017	81359 Kg
Fish Production after using probiotics EMO-301	
April to November 2018	178815 Kg
December 2018	142533 Kg
April to December 2018	321348 Kg

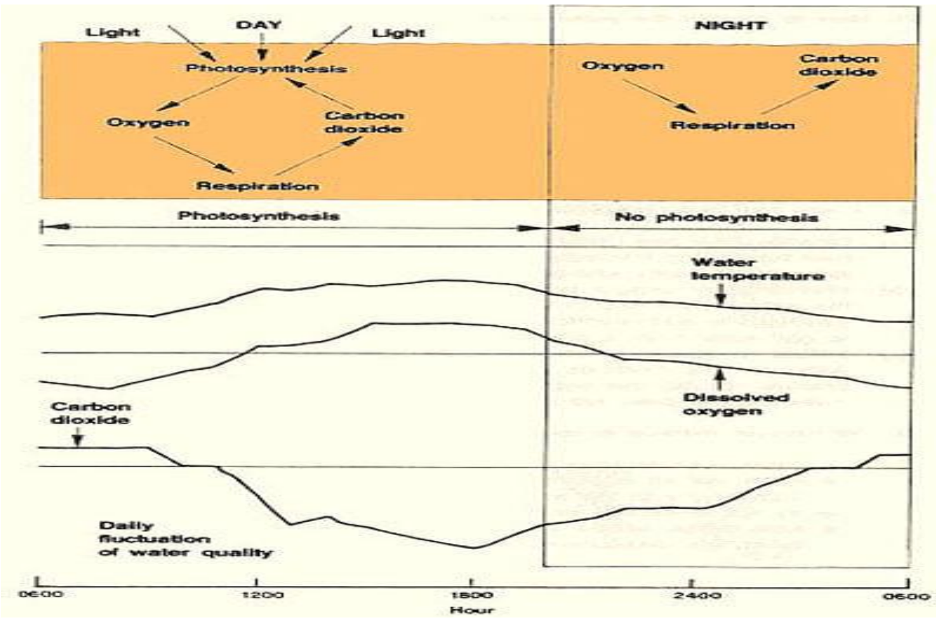
Thermal ranges of common fish species

Fish species	Dangerous pond-water temperature		Optimum thermal range for adults (opt. temper)	Thermal range for spawning
	Lower	Upper		
WARMWATER FISH				
Micropterus salmoides *Largemouth bass*	2	35	23-30	17-20
Ictalurus punctatus *Channel catfish*	5	35	25-30	16-28
Cyprinus carpio *Common carp*	2	36	23-26 (25)	Above 18
Ctenopharyngodon idella *Grass carp*	-	32	23-28	15-30
Hypophthalmichthys molitrix *Silver carp*	-	32	23-28	15-30
Aristichthys nobilis *Bighead carp*	5	37	23-31	17-30
Carassius auratus *Goldfish*	5	37	25-30 (25)	Around 25
Clarias gariepinus *African catfish*	-	-	25-27	20-30
Tilapia aurea *Blue tilapia*	9	38	27-30	20-30
Tilapia nilotica *Nile tilapia*	12	38	27-30	22-32

Clarias batrachus *Walking catfish (Asian)*	15	-	29-32	22-32
Catla catla *Catla (Indian carp)*	15	34	26-29	22-28
Cirrhinus mrigala *Mrigal*	12	38	22-32	24-31
Labeo rohita *Rohu*	3	36	(28)	24-31
COLDWATER FISH				
Salvelinus fontinalis *Brook trout*	Close to 0	18	10-14 (13)	0-14
Salmo trutta *Brown trout*	Close to 0	20	12-15 (14)	0-15
Oncorhynchus mykiss *Rainbow trout* *(syn. Salmo gairdneri)*	Close to 0	22	15-17 (16)	4-18

Because the fish require sufficient dissolved oxygen in the pond water, the water temperature also affects the breathing, or respiration, of the fish. The maximum quantity of dissolved oxygen present in water depends on its temperature: the warmer the water, the less dissolved oxygen it can contain. For this reason, if the pond becomes too warm, the fish can run out of oxygen (Khan 2017).

HOAs, golf courses, municipalities, and other stakeholders with waterbodies should have management plans in place that incorporate water quality monitoring to help mitigate the effects of pollutants (as well as many other facets that affect water) on their waterbodies.



Monitoring is a valuable tool, but it cannot be used alone. The introduction of a natural vegetative buffer around the water's perimeter may help filter pollutants before they flow into the water. Aging shorelines should also be restored to prevent nutrient-rich sediment from eroding into the water. In more extreme cases, nutrient remediation products such as Phoslock, Alum, and Eutro SORB, can be applied by licensed professionals to capture and "deactivate" pollutants in the water column.

These and other solutions are part of a sustainable management program designed to reverse and prevent water quality problems well into the future. Partnering with an experienced aquatic expert can help decision-makers successfully protect and preserve their water resources for all to use and enjoy for years to come.

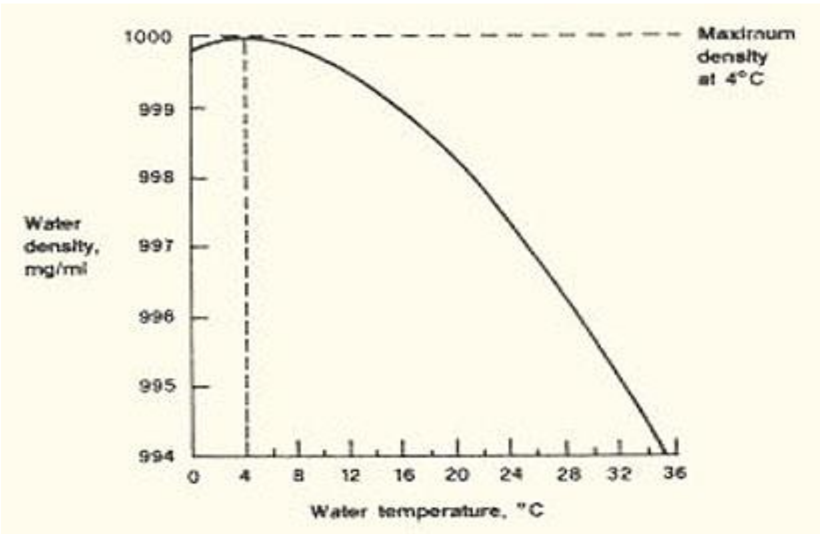
Water Parameters after Treatment

pH	Total Dissolved Solids	Total Suspended Solid	Total Hardness (as $CaCO_3$)	Total Solids	Alkalinity
	PPM	PPM	PPM	PPM	PPM
7.74	1580	126.53	994.28	2586.00	176.23
7.72	1588	125.94	995.11	2585.00	178.65
7.75	1588	126.97	992.87	2586.00	164.9
7.72	1590	127.29	978.89	2586.00	160.78
7.7	1592	127.61	975.07	2585.00	167.8
7.78	1584	126.43	982.99	2584.00	170.03
7.74	1586	126.51	958.92	2583.00	172.87
7.75	1574	126.83	952.2	2949.45	176.78
7.77	1572	127.15	970.87	2950.58	172.3
7.79	1580	127.47	902.15	2949.93	175.22
7.71	1580	127.51	900.1	2950.69	171.98
7.76	1582	127.55	904.2	2952.45	160.00
7.72	1578	126.45	998.04	2458.00	160.50
7.7	1588	125.35	970.88	2457.00	160.10
7.77	1590	124.25	970.34	2457.00	172.95
7.76	1580	123.15	994.09	2582.00	173.27
7.67	1588	123.19	999.9	2582.00	173.59
7.74	1588	125.98	990.12	2582.00	174.29
7.75	1590	126.32	958.12	2583.00	173.70
7.73	1592	129	987	2582.00	174.73
7.7385	1584.5	126.374	968.807	2656.56	170.534
0.03014	5.90718	1.46526	31.9079	179.903	6.02397
0.00674	1.32152	0.3278	7.13823	40.2468	1.34765

Analysis for Management
Other parameters after treatment

Alkalinity	Sodium (as Na)	Calcium (as Ca)	Magnesium (as Mg)	Sulphate (SO_4)	Chloride (as Cl)	Nitrate (NO_3)	Fluoride (as F)	Dissolve Oxygen (DO)	COD	BOD
PPM	PPM	PPM	PPM	PPM	PPM	PPM	PPM	Mg/l	Mg/l	Mg/l
176.23	109.4	543	157	116	293.6	45.69	0.07	6.6	25.6	4.9
178.65	111.35	544	156.93	108.8	293.59	35.84	0.08	6.1	28.08	4.3
164.9	110.83	542	156.64	106.8	292.42	44.29	0.07	6.3	28.15	4.3
160.78	110.9	543	157.82	106.8	292.39	44.28	0.08	6.2	27.10	4.3
167.8	112.85	539	156.22	107.8	293.9	36.52	0.07	5.8	26.58	4
170.03	112.33	539	156.25	107.8	293.89	42.88	0.06	5.9	26.65	3
172.87	112.4	539	156.44	108.8	295.4	41.49	0.07	5.6	26.70	4.1
176.78	111.35	540	157.04	108.8	295.39	42.5	0.1	7.1	26.18	4.4
172.3	110.83	539	157.02	106.8	296.9	42.5	0.08	7.4	26.25	4.5
175.22	110.9	540	157.05	106.8	296.89	42.6	0.1	6.9	35.68	4.6
171.98	109.85	539	157.24	106.8	296.2	43.5	0.08	8.8	32.44	3.5
160.00	109.33	537	157.84	106.8	292.38	43	0.1	8.3	34.04	2
160.50	109.4	540	128.47	106.1	292.42	43.1	0.1	8.4	36.4	5.20
160.10	108.35	540	128.46	106.1	291.9	42	0.1	7.3	27.75	5.30
172.95	107.8	540	127.07	107.1	291.89	40.5	0.06	6.8	28.7	4.20
173.27	109.2	540	127.06	107.1	293.4	42.5	0.1	6.9	35.64	3.70
173.59	108.9	542	125.67	108.1	286.56	42.5	0.09	5.8	29.78	3.80
174.29	109.2	541	125.66	108.1	286.6	42.6	0.12	5.3	31.99	3.10
173.70	107.85	542	124.27	112.1	286.59	43.5	0.18	5.9	24.35	2.60
174.73	106.33	567	138.8	110.1	290.9	32.45	0.16	7.025	21.68	2.70
170.534	109.968	541.8	145.448	108.18	292.661	41.712	0.0935	6.72125	28.987	3.925
6.02397	1.70554	6.17806	14.727	2.3404	3.11213	3.18956	0.03083	0.9708	4.07839	0.88131
1.34765	0.38155	1.38212	3.29463	0.52358	0.69623	0.71355	0.0069	0.21718	0.91239	0.19716

Effect of temperature on pure water density



(a) Water becomes lighter as it cools down **below 4 C**, therefore ice which forms at 0 C will float on the surface of the pond, and water below it will be warmer.
(b) Water also becomes lighter as it warms up **above 4 C**, therefore the warmest water is always at the top of a pond and the coolest water at the bottom.
(c) Over longer periods of warm weather, the warmer and lighter surface waters tend to form a separate layer from the colder and heavier bottom waters: **the pond water stratifies into distinct layers**.
(d) **In deeper pond**, such as barrage ponds, such stratification may establish itself for a long period.

The pond water then forms three different layers

- the upper, warmer and lighter **epilimnion**, in which the water temperature is relatively similar across the layer; the water is well mixed by wind, and usually has active photosynthesis and good oxygen levels;
- the thermocline, in which the water temperature drops and the density increases rapidly, thereby forming a sort of barrier which separates the pond water into two distinct parts;
- the lower, cooler and denser **hypolimnion**, in which the water temperature is relatively similar across the layer. The water cannot be mixed by wind any more, and in the absence of light and photosynthesis, dissolved oxygen gradually decreases, being mostly used for decomposition. It may even disappear completely from the bottom water, making life for fish and many other plants and animals impossible in this part of the pond. Because this area is separated from the surface waters, fertilizers or feed materials falling to the pond floor are no longer available for the plankton or the fish.

Table 1. Different physicochemical parameters and their permissible range used for waters samples analysis before probiotics treatment and compare with Makhreda Pond water.

Unit	IS 10500 : 2012 Requirement Acceptable Limit	Water sample from pond Mean ± SEM	Range of Various parameters of water collected from (Min. -Max value)	Protocol
-	6.5-8.5	8.22±0.111	7.5-8.95	IS: 3025 (pt-11)-1983, Reaff.2017
mg/l	500	2851.55±56.15	2465-3185	IS: 3025 (pt-16)-1984, Reaff.2017
mg/l	-	156.15±1.974	142-168	
mg/l	200	1547.8±20.299	1426-1689	IS: 3025 (pt-21) Reaff.2019 (EDTA Titrimetric Method)
mg/l	500	3114.9±23.222	2958-3298	IS-3025(Pt-15)1984,Reaff.2019

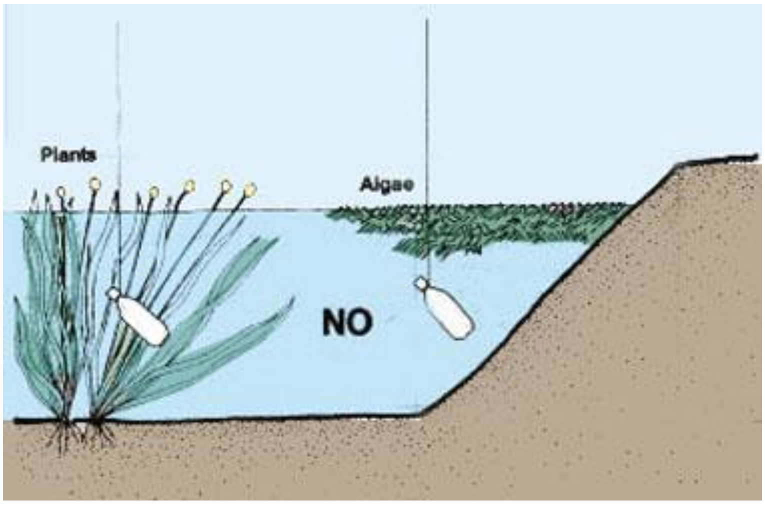
mg/l	200	249.1±9.694	182-315	IS: 3025 (pt-23)-1986, Reaff.2019
mg/l	200	109.36±0.590	104.12-115.34	IS: 3025 (pt-45)-1993, Reaff.2019
mg/l	200	658.25±5.683	612.28-691.85	IS: 3025 (pt-40)-1991, Reaff.2019
mg/l	150	149.80±0.914	142.25-158.55	IS: 3025 (pt-46)-1994, Reaff.2019
mg/l	200	109.90±0.695	104.12-116.0	IS: 3025 (pt-24)-1986, Reaff.2019 Turbidity Method
mg/l	250	348.23±23.778	366.68-398.0	IS: 3025 (pt-32)-1988, Reaff.2019
mg/l	45	11.42±0.207	10.12-12.92	IS: 3025 (pt-34)-1988, Reaff.2019 (Chromotropic Acid Method)
mg/l	1.0	0.78±0.024	0.52-0.95	IS: 3025 (pt-60)-2008, Reaff.2019
mg/l	4.00-6.00	6.47±0.041	5.3-7.0	IS: 3025 (pt-38)-1989, Reaff. 2019 (Titrimetric Method)
mg/l	30	34.12±0.288	32.0-36.03	IS: 3025 (pt-58)-2006, Reaff. 2017
mg/l	5(ICMR)	5.39±0.086	4.8-6.1	IS: 3025 (pt-44)-1993, Reaff.2019

(Mean ± SEM of 20 Samples)

- In biostimulation, the population of these helpful bacteria can be increased by adding nutrients.
- Bacteria can in principle be used to degrade hydrocarbons. Specific to marine oil spills, nitrogen and phosphorus have been key nutrients in biodegradation. The bioremediation of hydrocarbons suffers from low rates.
- Bioremediation can involve the action of microbial consortium. Within the consortium, the product of one species could be the substrate for another species.
- Anaerobic bioremediation can in principle be employed to treat a range of oxidized contaminants including chlorinated ethylenes (PCE, TCE, DCE, VC), chlorinated ethanes (TCA, DCA), chloromethanes (CT, CF), chlorinated cyclic hydrocarbons, various energetics (e.g., perchlorate, RDX, TNT), and nitrate.[7] This process involves the addition of an electron donor to: 1) deplete background electron acceptors including oxygen, nitrate, oxidized iron and manganese and sulfate; and 2) stimulate the biological and/or chemical reduction of the oxidized pollutants. Hexavalent chromium (Cr[VI]) and uranium (U[VI]) can be reduced to less mobile and/or less toxic forms (e.g., Cr[III], U[IV]).

Similarly, reduction of sulfate to sulfide (sulfidogenesis) can be used to precipitate certain metals (e.g., zinc, cadmium). The choice of substrate and the method of injection depend on the contaminant type and distribution in the aquifer, hydrogeology, and remediation objectives. Substrate can be added using conventional well installations, by direct-push technology, or by excavation and backfill such as permeable reactive barriers (PRB) or biowalls. Slow-release products composed of edible oils or solid substrates tend to stay in place for an extended treatment period. Soluble substrates or soluble fermentation products of slow-release substrates can potentially migrate via advection and diffusion, providing broader but shorter-lived treatment zones. The added organic substrates are first fermented to hydrogen (H_2) and volatile fatty acids (VFAs). The VFAs, including acetate, lactate, propionate and butyrate, provide carbon and energy for bacterial metabolism.

Do not sample water near aquatic plants or beneath heavy algae



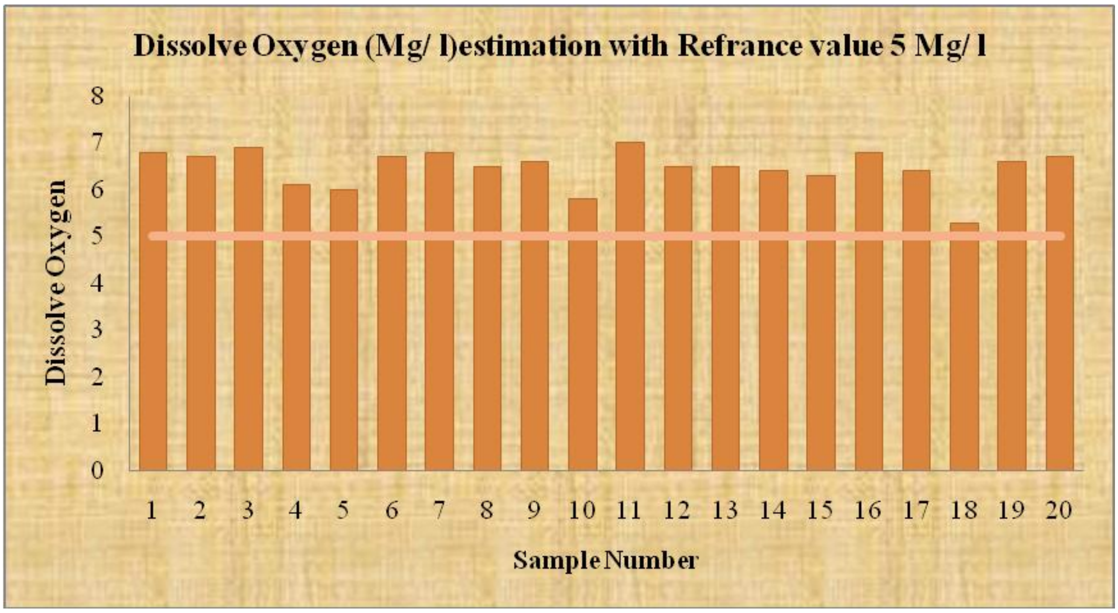


Figure 1.

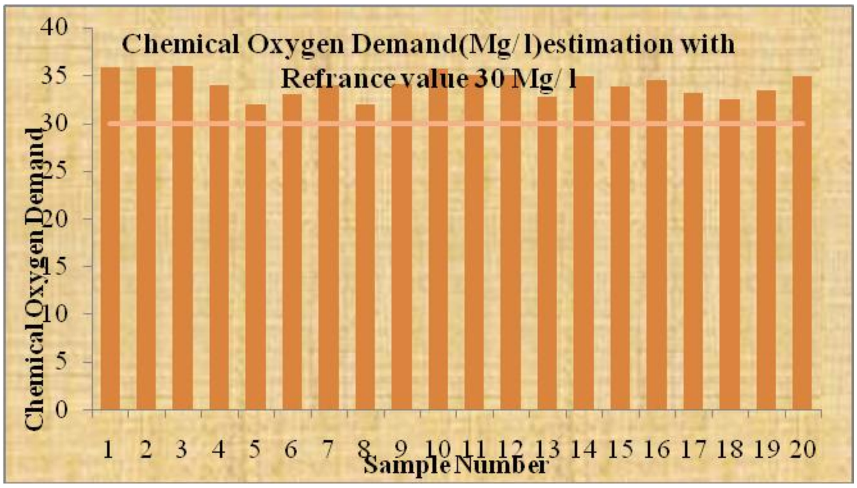


Figure 2.

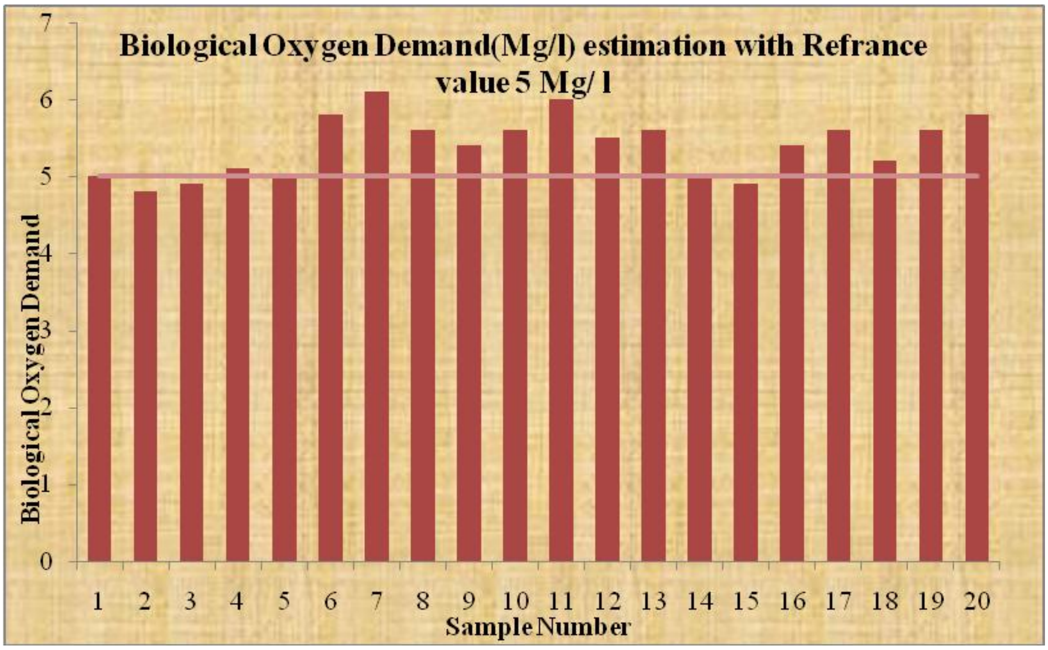


Figure 3.

Expressing the DO content of the water

The concentration of DO in water may be expressed in several ways:

(a) As **the weight of oxygen** per volume of water, for example:

- in milligrams per litre (mg/l);
- in grams per cubic metre (g/m^3);
- in parts per million (ppm), where **1 ppm = about 1 mg/l**.

(b) As **the volume of oxygen** per volume of water, most generally in millilitres per litre (ml/l), where **1 ml/l = 0.7 mg/l**.

(c) As **the oxygen saturation value**, the percentage of the maximum amount of oxygen that the water can hold at that particular temperature

Table 2. Different physicochemical parameters and their permissible range used for waters samples analysis after probiotics treatment and compare with Makhreda Pond water in season 2018, in mg/l.

S. No.	Parameters	IS 10500 : 2012 Requirement Acceptable Limit	Water sample from pond Mean ± SEM	Protocol
1	**pH**	6.5-8.5	7.738±0.0067	IS: 3025 (pt-11)-1983, Reaff.2017
2	**Total Dissolved Solids**	500	1584.5±1.321	IS: 3025 (pt-16)-1984, Reaff.2017
3	**Total Suspended Solid**	-	126.374±0.327	
4	**Total Hardness (as $CaCO_3$)**	200	968.807±7.138	IS: 3025 (pt-21) Reaff.2019 (EDTA Titrimetric Method)
5	**Total Solids**	500	2656.555±40.246	IS-3025(Pt-15)1984,Reaff.2019
6	**Alkalinity**	200	170.533±1.347	IS: 3025 (pt-23)-1986, Reaff.2019
7	**Sodium (as Na)**	200	109.967±0.381	IS: 3025 (pt-45)-1993, Reaff.2019
8	**Calcium (as Ca)**	200	541.8±1.382	IS: 3025 (pt-40)-1991, Reaff.2019
9	**Magnesium (as Mg)**	150	145.447±3.294	IS: 3025 (pt-46)-1994, Reaff.2019
10	**Sulphate (as SO_4)**	200	108.18±0.523	IS: 3025 (pt-24)-1986, Reaff.2019 Turbidity Method
11	**Chloride (as Cl)**	250	292.660±0.696	IS: 3025 (pt-32)-1988, Reaff.2019
12	**Nitrate (NO_3)**	45	41.712±0.713	IS: 3025 (pt-34)-1988, Reaff.2019 (Chromotropic Acid Method)
13	**Fluoride (as F)**	1.0	0.094±0.006	IS: 3025 (pt-60)-2008, Reaff.2019
14	**Dissolve Oxygen (DO)**	4.00-6.00	6.721±0.217	IS: 3025 (pt-38)-1989, Reaff. 2019 (Titrimetric Method)
15	**COD**	30	28.987±0.912	IS: 3025 (pt-58)-2006, Reaff. 2017
16	**BOD**	5(ICMR)	3.925±0.197	IS: 3025 (pt-44)-1993, Reaff.2019

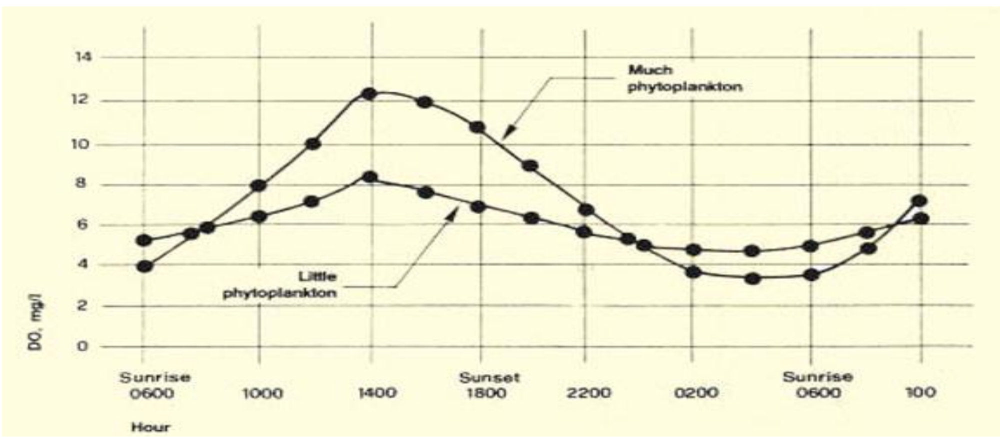
(Mean ± SEM of 20 Samples)

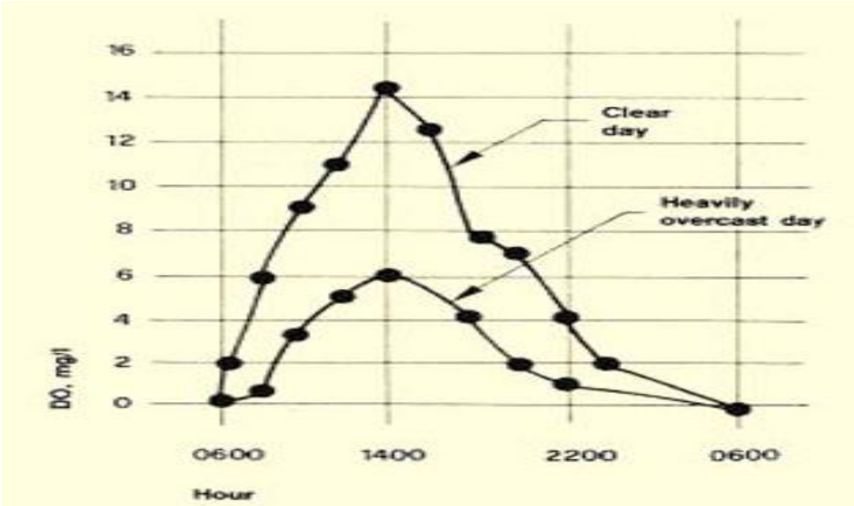
(a) **From sunrise to sunset**, photosynthesis increases the DO level. On clear days, DO production is higher than on cloudy days. The higher the phytoplankton population, the higher the DO production.
(b) **At night**, photosynthesis does not take place, and therefore respiration reduces the DO content until sunrise. The higher the plankton population, the faster the DO will fall.

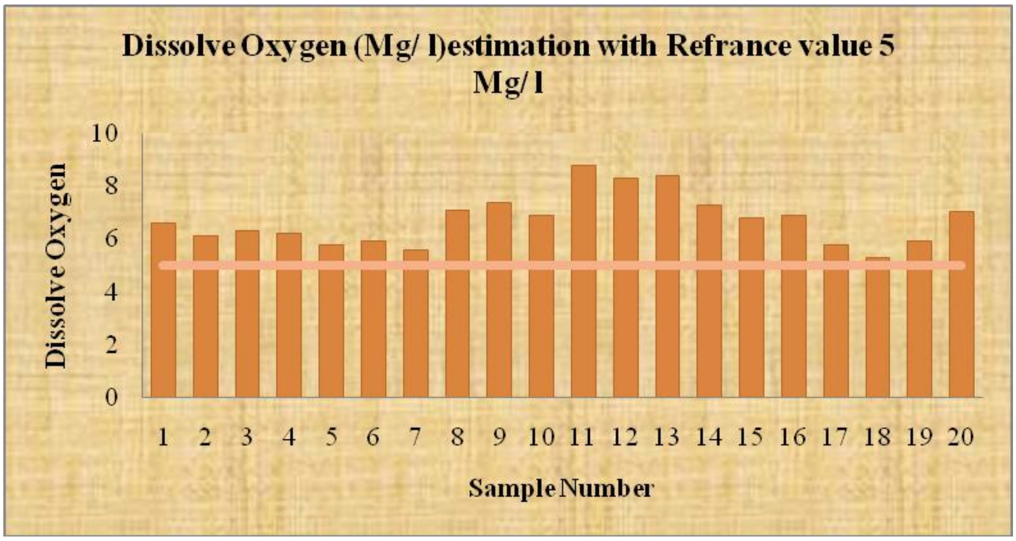
DO content in the surface water of a shallow pond during a 24-hour cycle (water temperatures from 28 to 33C)

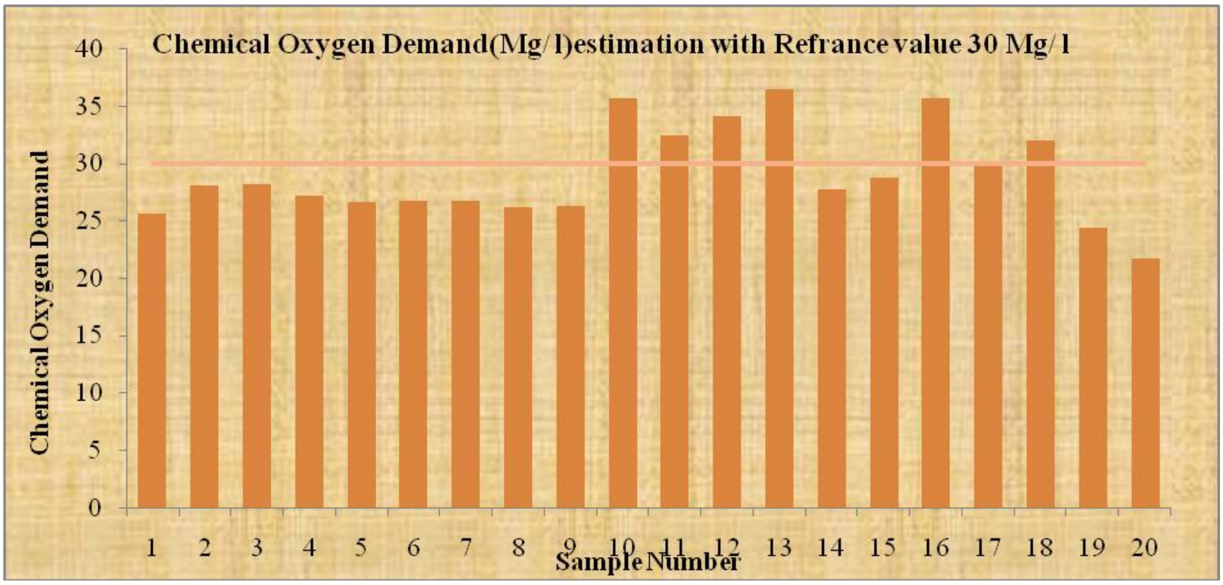
Bioventing is a process that increases the oxygen or air flow into the unsaturated zone of the soil, this in turn increases the rate of natural *in situ* degradation of the targeted hydrocarbon contaminant (Mook et al., 2012).

Bioventing, an aerobic bioremediation, is the most common form of oxidative bioremediation process where oxygen is provided as the electron acceptor for oxidation of petroleum, polyaromatic hydrocarbons (PAHs), phenols, and other reduced pollutants. Oxygen is generally the preferred electron acceptor because of the higher energy yield and because oxygen is required for some enzyme systems to initiate the degradation process (Joshi et al., 2022). Microorganisms can degrade a wide variety of hydrocarbons, including components of gasoline, kerosene, diesel, and jet fuel. Under ideal aerobic conditions, the biodegradation rates of the low- to moderate-weight aliphatic, alicyclic, and aromatic compounds can be very high. As molecular weight of the compound increases, the resistance to biodegradation increases simultaneously (Joshi et al., 2022). This results in higher contaminated volatile compounds due to their high molecular weight and an increased difficulty to remove from the environment. Most bioremediation processes involve oxidation-reduction reactions where either an electron acceptor (commonly oxygen) is added to stimulate oxidation of a reduced pollutant (e.g. hydrocarbons) or an electron donor (commonly an organic substrate) is added to reduce oxidized pollutants (nitrate, perchlorate, oxidized metals, chlorinated solvents, explosives and propellants) (APHA, 1998). In both these approaches, additional nutrients, vitamins, minerals, and pH buffers may be added to optimize conditions for the microorganisms. In some cases, specialized microbial cultures are added (bioaugmentation) to further enhance biodegradation. Approaches for oxygen addition below the water table include recirculating aerated water through the treatment zone, addition of pure oxygen or peroxides, and air sparging (Mukherjee et al., 2022). Recirculation systems typically consist of a combination of injection wells or galleries and one or more recovery wells where the extracted groundwater is treated, oxygenated, amended with nutrients and re-injected (Njoku et al., 2015). However, the amount of oxygen that can be provided by this method is limited by the low solubility of oxygen in water (8 to 10 mg/L for water in equilibrium with air at typical temperatures). Greater amounts of oxygen can be provided by contacting the water with pure oxygen or addition of hydrogen peroxide (H_2O_2) to the water. In some cases, slurries of solid calcium or magnesium peroxide are injected under pressure through soil borings. These solid peroxides react with water releasing H_2O_2 which then decomposes releasing oxygen. Air sparging involves the injection of air under pressure below the water table. The air injection pressure must be great enough to overcome the hydrostatic pressure of the water and resistance to air flow through the soil (Mukherjee et al., 2022, Njoku et al., 2015).




16
14
12
10
8
6
4
2
0
DO, mg/l
0600
1400
2200
0600
Hour
Clear day
Heavily overcast day


Dissolve Oxygen (Mg/ l)estimation with Refrance value 5 Mg/ l
Dissolve Oxygen
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Sample Number


Chemical Oxygen Demand(Mg/ l)estimation with Refrance value 30 Mg/ l
Chemical Oxygen Demand
40
35
30
25
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15
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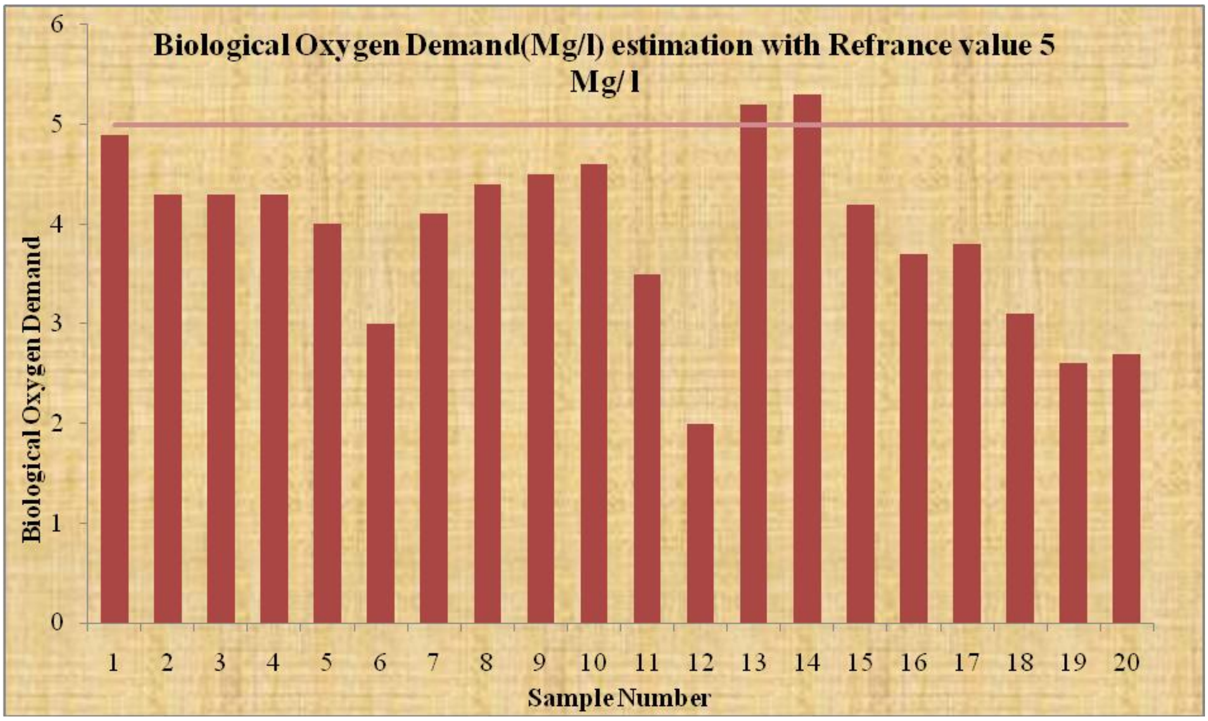
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Sample Number



CONCLUSION

During bioattenuation, biodegradation occurs naturally with the addition of nutrients or bacteria. The indigenous microbes present will determine the metabolic activity and act as a natural attenuation (Zhang et al., 2019). While there is no anthropogenic involvement in bioattenuation, the contaminated site must still be monitored (Zhang et al., 2019). Biosparging is the process of groundwater remediation as oxygen, and possible nutrients, is injected. When oxygen is injected, indigenous bacteria are stimulated to increase rate of degradation. However, biosparging focuses on saturated contaminated zones, specifically related to ground water remediation. This investigation focused on the physicochemical characteristics of industrial effluents that point to a specific area of environmental contamination. The concentration of physicochemical qualities was determined while the water quality in the area was compared to the international standard. Indicating local water pollution, the levels of BOD, COD, TDS, TSS, and cationic or anionic concentration were greater than the WHO-recommended standards. According to a recent UN forecast, if prompt action is not done, two-thirds of the world's population would experience water scarcity by 2025 (Aniyikaiyeet al., 2019). Nevertheless, millions of people only have limited access to this vital resource because of its scarcity and pollution. Pesticides employed in agricultural regions find their way to food distribution networks through subterranean channels, much as how oil spills occur. Therefore, it is our responsibility to clean up contaminated water and stop additional contamination. If not, a water deficit will occur. In the end, all life will perish as a result.

ACKNOWLEDGEMENTS

My thanks to my Supervisor Dr. Sabiha Khan for her guidance and motivation due to which I was able to write paper.

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Corresponding author: Dr. Sabiha Khan, S.P.C. Government College, Ajmer, Rajasthan, India
Email: dr.sabihakhan786@gmail.com