Rapid microbiological examination of water quality in ponds of Vadodara city, Gujarat, India

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Rapid microbiological examination of water quality in ponds of Vadodara city, Gujarat, India

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Abstract

Fresh water is one of the most important resources without which life would not exist on planet Earth. The exponential growth of human population has caused deterioration of global resources with conditions most severe in under developed and developing countries. Physical and chemical contaminants entering in ponds, lakes and other freshwater reservoir have caused devastating effects on floral and faunal diversity of the system. In addition to this, the biological contaminants in general and pathogens in particular are also of prime importance for qualitative analysis of the water quality. Presence of pathogens may cause severe health issues such as infection, diarrhoea, vomiting etc. The issue is very serious specifically in the case of developing countries due to lack of sanitation and prevalence of unhygienic conditions. The current study was aimed to assess biological contamination with special emphasis on coliform E. coli and MPN (per 100 ml). The water samples were drawn from 6 ponds of Vadodara city, Gujarat, India. Out of the 6 ponds studied, 4 showed MPN (per 100 ml) to be 1100 and above showing heavy microbial contamination. Moreover, all of the ponds under investigation showed presence of E. coli which is indicative of faecal contamination. The results of the rapid study provides basis for further expansion of the study with more emphasis on public health risk.

Keywords: Exponential growth, Biological contaminants, Diarrhoea, *E. coli,* Health risk.

Introduction

The contamination of freshwater resources of potable as well as non-potable quality is a major issue as far as public health is concerned. A greater fraction of the diarrhoeal diseases are caused due to unsafe water sources, and lack in sanitation and hygiene[1]. In developing countries the diseases of biological origin which are spread by water is a great health burden and is considered to be one of the leading factors associated with deteriorated health of the society[1]. It is also evident that despite of having municipal water supply systems in India, some regions have lopsided supply and are forced to rely on microbiologically unsafe water[2]. Such situations prevailing in the developing countries cost nearly 17% of deaths of children under the age of 5 years[3]. Though the water bodies selected for the study are not directly used for water supply to urban regions[4], they may pose threat to the reliant population as previous review of literature indicate that diarrhoeal disease can spread by multiple pathways and not only by microbiologically contaminated drinking water supply[3]. Microbiological assessment having direct or indirect influence on surrounding population is thus warranted to identify their potential threat to the surrounding population. The current study encompasses examination of six surface water bodies under various degree of anthropogenic pressure with respect to microbial quality.

The vulnerability of surrounding population is dependent upon the severity of contamination as well as the time of exposure. The severity of contamination in turn is dependent upon the type of pathogenic organism involved[5]. The presence of coliform bacteria in water bodies may be attributed to faecal contamination by discharge of faeces by humans and other animals in water either directly or indirectly by surface runoff from surrounding areas. The members of family *Enterobacteriaceae* are included in the coliform group of organisms some of which are *Escherichiacoli* (*E. Coli*), *Enterobacter aerogenes*, *Salmonella* and *Klebsiella*[5]. These bacteria from 10% of the intestinal microbes of humans and other animals. *E. coli* lose its viability at slower rate in freshwater and thus can be used as an indicator organism to detect faecal contamination[6]. The major pathway of infection is by direct consumption. However, when contaminated water comes in contact with hands, the disease may spread as the pathogens may enter via oral route and cause disease.

The study, due to the above stated issues, was important with reference to public health risk. The aim of the study was rapid examination faecal contamination in water bodies of Vadodara city, Gujarat. The results of the study may provide basis for corrective actions to safeguard community wellbeing from waterborne pathogenic diseases.

The present study was carried out in Vadodara city, Gujarat which is located between 22° to 22°30' N latitude and 73° to 73°15' E longitude (Figure-1) covering an area of 158 Sq. km. with elevation ranging from 20 m to 40 m[7]. And the population of the city in the year 2011 was approximately 41.5 Lakh individuals[8]. For the rapid microbial analysis of water quality a total of six fresh water ponds of Vadodara City, Gujarat were selected which were Bapod Pond, Sama Pond, Harni Pond, Gotri Pond, Danteshwar Pond and Sarasiya Pond (Figure-2). The basis of selection of was the frequency and degree of anthropogenic activities on the periphery as well as use of pond water by the adjoining community. The ponds under microbiological investigation were similar in the properties. However, two of them namely Harni pond and Gotri Pond visually appeared to be heavily contaminated which was marked by the presence of floating solid waste and excessive growth of aquatic weeds. The major anthropogenic activities observed at these ponds were bathing, washing of cloths, dumping of solid waste, immersion of religious items etc.

Methodology

The rapid microbiological study was carried out from January, 2016 to April, 2016. Water samples were collected during the morning hours from the ponds under investigation. A total of 6 water samples were randomly collected from each pond and a composite was prepared. The samples were sooner brought to the laboratory after collection. Out of the composite sample 100 ml of the homogenised sample was used for subsequent microbiological analysis.

Microbiological analysis: The Most Probable Number (MPN) method was used to detect the presence of lactose fermenting and gas producing microorganisms and the coliform MPN in 100 ml of water samples. 3 DSLB (Double Strength LST Lactose Broth) and 6 SSLB (Single Strength LST Lactose Broth) tubes containing Durham tubes were used for assessing gas production and calculation of MPN. Samples were vigorously shaken before inoculation into the test tubes to maintain homogeneity of the sample. All the tubes (3 DSLB tubes containing 10 ml sample each; 3 SSLB tubes containing 1.0 ml sample each and 3 SSLB tubes containing 0.1 ml sample each) were incubated at 35°C temperature for 48 hours[9]. The tubes showing presence of trapped gas in the Durham tubes are to be considered as positive tubes. For confirmation of *E. coli*, one positive tube (one with gas trapped in the Durham tube) was selected and streaking of content was carried out on Eosin Methylene Blue (EMB) agar plate[10,11]. These plates were incubated for 24 hours at 35° C temperature and checked for the *E. coli* colonies having green metallic sheen. MPN was determined using MPN Table[9]**.**

Results and Discussion

All the positive test tubes of water samples from the ponds under rapid microbiological investigation showed green metallic colonies on the EMB agar plates (Figure-3). The green metallic colonies were of E. coli. Presence of E. coli other coliforms in surface water bodies is indicative of faecal contamination of the waterbody[5]. Pathogenic organisms from surrounding area may reach to the surface waters by surface runoff, sewage disposal or even by open defecation near the water body.

Figure-1: Ponds of Vadodara City (Gujarat) under microbiological examination. A. Bapod pond, B. Sama pond, C. Harni pond, D. Gotri pond, E. Danteshwar pond, F. Sarasiya pond.

Urban ponds which are the shallow water bodies may serve for recreation and aquaculture as well as they influences the health status of the surrounding population. Microbiological examination of such water bodies, thus, is of prime concern with respect to public health primarily governed by presence or absence of pathogenic organisms[12]. Rapid urbanization and growth of urban population leads to pressure on the natural resources and may lead to deterioration in the quality and/or quantity of the same[13]. The same is applicable to the urban water resources of Vadodara city as well. Rapid population growth has led to encroachment of open fields as well as shallow water bodies with faster disappearance of shallow ponds. In line with encroachment for space, uncontrolled and illegal dumping of solid waste (as in the case of Harni pond, Sarasiya pond and Bapod pond in this study) has led to accelerated eutrophication which makes the ponds shallower and limits their ability to hold larger volumes of water. Presence of faecal coliforms in urban ponds may be attributed to untreated sewage discharge contaminated with pathogens[14]. The ponds studied showed the gas production as the gas was trapped in the inverted Durham tubes (Figure-3). Based on the number of positive tubes the MPN values were identified from the MPN table[9]. The values ranged from 43/100 ml to 1100+ /100 ml of sample. Bapod pond, Sarasiya pond, Harni pond and Gotri pond showed very high MPN index (Table-1). In a study carried out in rural areas of Northern Rajasthan all the water bodies the MPN (per 100 ml) ranged between 25 to 41[5]. Higher MPN count in monsoon season is generally attributed to the surface runoff from surrounding area which may bring the pathogens to the surface water bodies[15]. However, the current study was carried out during January – April where no substantial rains recorded in the study area which would lead to entry of pathogens in the water body from surrounding area. This indicates the existence of other point and non-point source of faecal coli forms leading to contamination of ponds which is a matter of concern with respect to public health. The presence of pathogens in water bodies is a major source of threat to those who are directly or indirectly exposed to such water[16]. Though the ponds under investigation do not serve as a source of fresh drinking water, accidental contact or consumption of this water may lead to infection, diarrhoea, vomiting etc.[5]. Urban runoffs, illegal discharge of sewage, improper sanitation practices as well as high intensity of anthropogenic activities are the major factors contribution to deterioration of water quality[17]. Similar may be the case with the ponds under current investigation. Serious interventions are to take actions to bring the water quality of urban ponds to a safe level so that public health is not compromised.

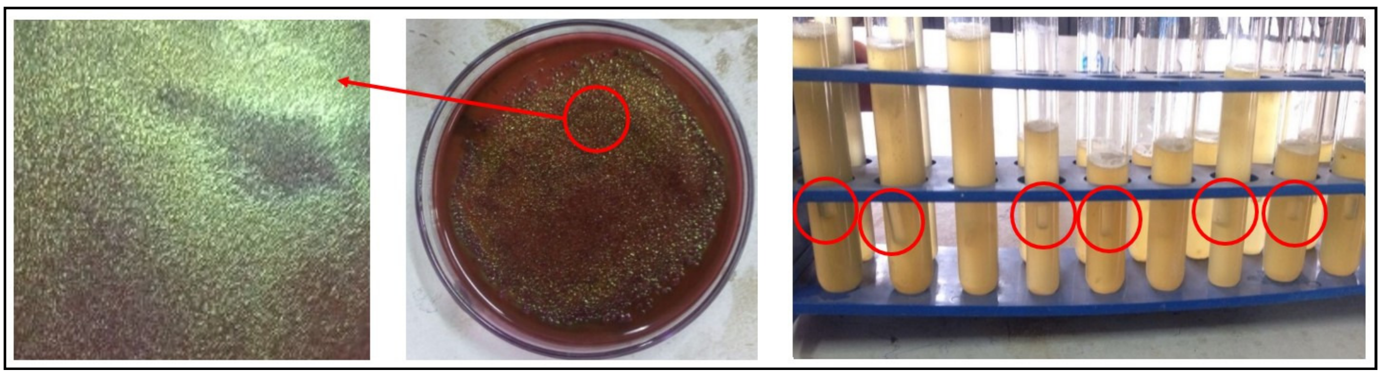

Figure-3: (A) Green Metallic sheen of E. coli colonies on EMB Agar plates and (B) Gas Production in Durham tubes immersed in DSLB and SSLB

Table-1: MPN and examination of *E. coli*

Sr. No.	Pond	Number of Positive Tubes out of three tubes in Dilutions			MPN per 100 ml	*E. coli*
		10 ml (DSLB)	1.0 ml (SSLB)	0.1 ml (SSLB)		
1	Bapod pond	3	3	3	1100 +	+
2	Danteshwar pond	3	1	1	75	+
3	Sarasiya pond	3	3	3	1100 +	+
4	Harni pond	3	3	2	1100	+
5	Sama pond	3	3	2	1100	+
6	Gotri pond	3	1	0	43	+

Conclusion

All the six water bodies under examination showed the presence of faecal contamination during the study period. This indicates untreated and illegal sewage discharge into water bodies. Open defecation at the periphery is one of the major influencing factors causing faecal contamination. Proper hygiene and sanitation practices are immediately required to mitigate potential health risk in the surrounding population. Urban ponds must be given an due consideration as a part of "Swacchha Bharat Abhiyan" with emphasise on biological contamination to avoid potential threat to community health.

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Comparative study of two Urban Ponds of Vadodara city with special reference to their chemical parameters

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Comparative study of two Urban Ponds of Vadodara city with special reference to their chemical parameters

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Abstract

In the present study two ponds of Vadodara City, Gujarat were selected for analysis of the chemical properties of their water. Both the ponds were almost equally surrounded by human settlements. Mahadev Pond was having a constructed boundary where as Bapod Pond had a natural boundary with inward slope. The chemical parameters selected for analysis were Dissolved Oxygen, pH, Chloride, Total Hardness, Phosphate and Nitrate. Dissolved Oxygen of the waters in both the Ponds was found to be as good as to support healthy aquatic life forms. The results showed that the pH of water of both the ponds was found to be alkaline throughout the study period and was similar in both the ponds. Dissolved Oxygen, pH and Total Hardness were almost similar in both the ponds. In the case of Chloride, Nitrate and Phosphate the Bapod Pond which is having a natural boundary showed very high concentration in comparison to Mahadev Pond. The analysis also showed that the constructed boundary of Mahadev Pond was helpful in restricting the entry of water soluble ions which would make their way by the runoff from adjoining areas. The higher concentrations of Chloride, Phosphate and Nitrate can be attributed to the natural boundary which leads to unrestricted inflow of sewage from adjoining human settlements.

Keywords:

Introduction

Water is associated with almost every aspect of life on our planet. It governs many of the environmental processes and plays a central role in deciding the fate of life on Earth. Almost 3/4th of the Earth's surface is covered with water in the form of oceans. If the water resources of Earth are classified on the basis of its utility, then nearly 97% of the water resources are in the form of Salt water having very limited utilities such as transportation, release of heat, fishery etc. However, these waters are not suitable for consumption due to very high salt content. Out of the remaining 3% freshwater, most of the volumes are either locked in polar ice caps or present as ground water having conditional accessibility. Finally, the surface fresh water that is directly accessible for human utilization is only a small fraction of water resources that is approximately 0.33% which fulfills most of the human requirements of freshwater. However, haphazard utilization without sustainable development of these resources (viz., lakes, ponds, rivers and streams) causes their degradation at a very faster rate. There is not any mechanism which strongly and effectively restricts the contamination of these water resources caused by human activities which ultimately limits the utility of these resources for further consumption. Many of the ponds and lakes of the developing countries are polluted to a level from where their redevelopment is not possible and ultimately these water bodies are lost forever.

To analyse the contamination status and the effect of contaminants coming from the human settlements, two ponds of Vadodara city, Gujarat were selected out of which one was having a constructed boundary and the other was having a natural boundary with inward slope. It was presumed that the pond with a constructed boundary limits the inflow of waters to some extent which drain into the pond from adjoining human population. The parameters selected for the study were Dissolved Oxygen, pH, Chloride, Total Hardness, Phosphate and Nitrate. The subsequent analysis of the result would enable to decide if the constructed boundary affects the level of contamination.

Materials and Methods

Mahadev Pond: Mahadev Pond is located at latitude 22˚17' N and longitude 73˚13' E in Vadodara city (Figure- 01). The water body has constructed boundary of cement and bricks. At the centre of the pond there is a community hall where various celebrations take place. So there are frequent chances of organic waste disposal in the pond. Apart from this the most common activities seen are fishing and washing of cloths which in turn add nutrients to the waters. The dimensions of the pond are as follows: i. Perimeter: 1138.08 m, ii. Area: 36,448.86 m^2

Bapod Pond: Bapod Pond has natural boundary and is located at latitude 22˚18' N and 73˚14' E longitude (Figure- 02). Due to the natural boundary human activities and surface runoff of sewage water might be affecting the water quality. Activities at the temple situated at the boundary of the pond also affect the water quality as disposal of waste takes in the pond. These materials include flowers, coconut shells, polythene bags etc.

Other than this, the common activities are bathing, washing of cloths and washing of animals. All these activities alter the natural quality of water. The dimensions of the pond are as follows: i. Perimeter: 712.43 m, ii. Area: 21,933.95 m^2

Figure–01
Sampling sites of Mahadev Pond (Constructed Boundary)

Figure–02
Sampling sites of Bapod Pond (Natural Boundary)

For the purpose of analysis, water samples from both the ponds were collected between 7:00 am to 8:00 am from the pre decided sampling points (Figure-01 and 02). The selected parameters were analysed using available standard methods[1]. The Dissolved Oxygen of the samples was fixed on the site before further analysis to reduce error. For rest of the water parameters, the samples were collected in one liter air tight plastic bottles and analysed within 4 hours of sample collection (Table-01).

Table-1
Methods used for analysis of water parameters

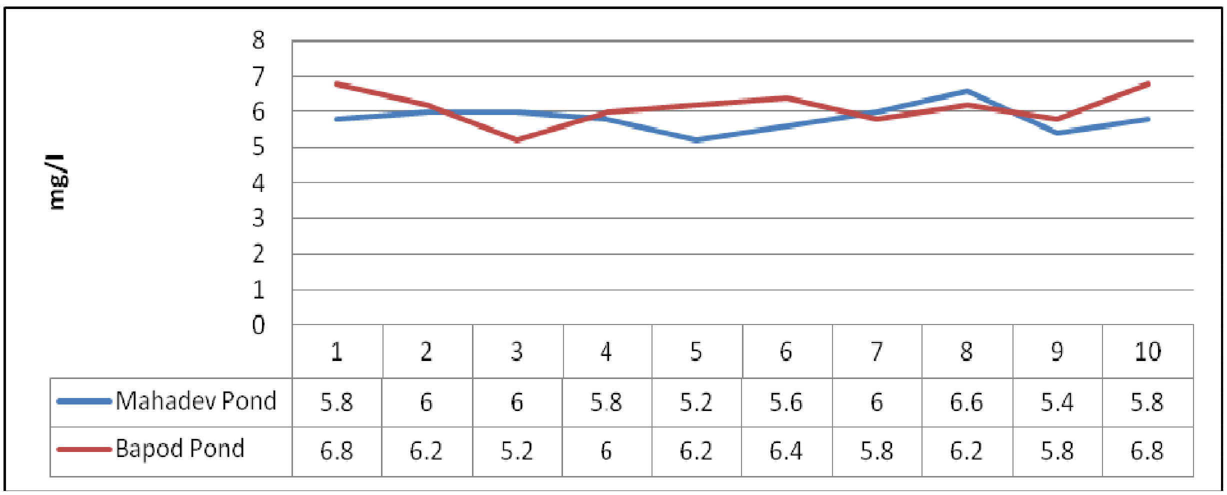
Sr. No.	Parameter studied	Method used
1	Dissolved Oxygen	Alkaline azide - Titrimetric
2	pH	pH probe
3	Chloride	Titrimetric
4	Total Hardness	Titrimetric Method – Erichrome black T indicator
5	Nitrate	Colorimetric
6	Phosphate	Colorimetric

Result and Discussion

Analysis of the water samples drawn from the Mahadev Pond showed the following results. The Dissolved Oxygen (DO) level (Figure-03) of the Bapod Pond was found to be higher than the Mahadev Pond. Surface Diffusion of gases plays a major role in maintaining the levels of Dissolved Gases in a surface water body like Pond[2]. Moreover, comparatively smaller amounts of DO are produced by the photosynthetic organisms residing in the pond as a result of their photosynthetic activities. With a balance in the natural ecosystem, the pond which has aquatic plants will have slightly more DO in comparison to the pond having scarce aquatic flora. Although the aquatic vegetation is important to maintain the productivity of a pond ecosystem; their growth may be accelerated with continuous addition of nutrients. If this growth remains unchecked, it leads to formation of a mat of floating algae which eventually covers the whole surface of the water body. This does not allow the surface diffusion of gases leading to depleted oxygen levels in the water causing death and decay of aquatic organisms in anoxic condition. Some of the aquatic plants, when decomposed in anaerobic conditions are known to be producing toxic chemicals such as “Strychnine” which are not only harmful to the aquatic organisms but also to cattle and other organisms including aquatic birds that rely on the pond[3]. Although it was not part of the study, due to its much importance in a pond ecosystem some of the information was gathered regarding blue green algae. In many of the studies, it is observed that the Secondary Metabolites of Blue Green Algae (Cyanobacteria) are harmful and are known to be having deleterious impact on aquatic plants, aquatic animals as well as cattle and birds dependent on it[4,5].

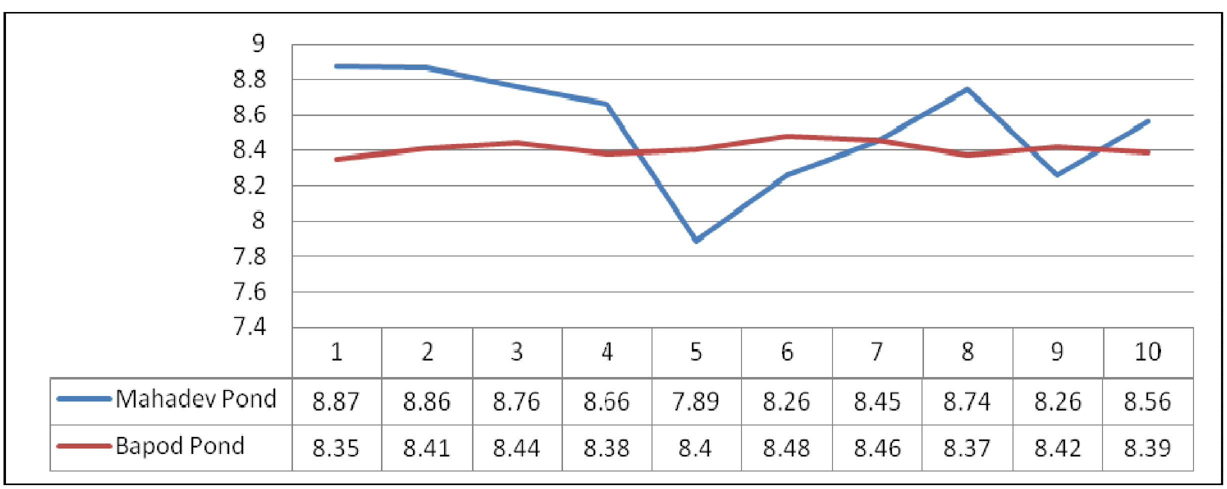
The pH of both the water bodies was found to be on alkaline side of the scale throughout the study period[6]. The average pH of Mahadev Pond was 8.53 and that of Bapod Pond was 8.41. In the case of Mahadev Pond the pH fluctuated between 7.89 and 8.89 (Figure- 04). Out of 10 samples, in 6 of the samples pH value was found to be more than 8.5 which is beyond the desirable limit for drinking purpose[7]. Beyond this value the water affects the mucous membrane of the human digestive system. pH values of Bapod Pond did not show much fluctuations. The pH values ranged from 8.35 to 8.48 only throughout the sampling duration which was well within the permissible limit. The results of pH analysis show that Mahadev Pond which is having the constructed boundary showed comparatively higher pH value in spite of limited entry of the water from the surrounding areas. Many soft bodied aquatic organisms and the Anurans (Toads and Frogs) are very fragile to changes in pH. The optimum pH range for most aquatic organisms is 6.5 – 8.0. Further changes in this range at both the ends may cause harmful effect in the body and raise the question of their survival in the same habitat. The toxic compounds present as deposits at the bottom may be liberated if the pH decreases. Apart from this, much higher or lower ranges of pH may also interact with other Physico-chemical parameters of the pond and may adversely affect the utility value of the water[8]. So, pH is a very important chemical property of water which has greater influence on the health of the Pond Ecosystem.

The average chloride value for Mahadev Pond water sample was found to be 162.35 mg/l where as Bapod Pond water contained chlorides as high as 352.3 mg/l which more than double than that of Mahadev Pond (Figure-05). The higher chloride concentrations in the pond water can be attributed to the sewage disposal, the surface runoff as well as agricultural runoff. The chloride in Mahadev Pond water samples was found to be below desirable limit throughout the study period but in the case of Bapod Pond it showed a very high concentration of Chloride which was exceeding the desirable limits of 250 mg/l[7]. The comparative lower levels of chloride in Mahadev Pond can be due to restricted entry of the sewage runoff from the streets due to the constructed boundary. The inward sloping boundary of Bapod Pond might have failed to restrict the entry of surface runoff which leads to substantially higher levels of chlorides in the waters. Open defecation near the pond boundary may also have lead to increased chloride levels.



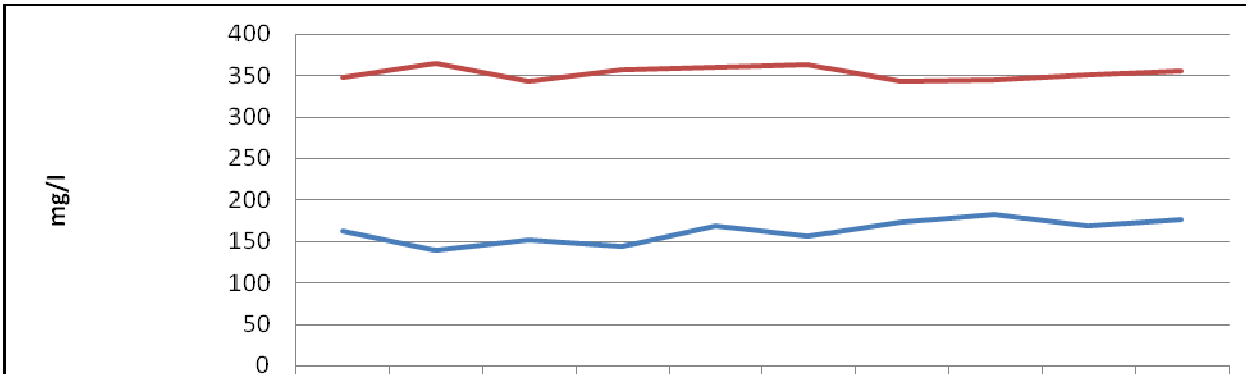
	1	2	3	4	5	6	7	8	9	10
Mahadev Pond	5.8	6	6	5.8	5.2	5.6	6	6.6	5.4	5.8
Bapod Pond	6.8	6.2	5.2	6	6.2	6.4	5.8	6.2	5.8	6.8

Figure–03
Comparison of Dissolved Oxygen between Mahadev Pond and Bapod Pond



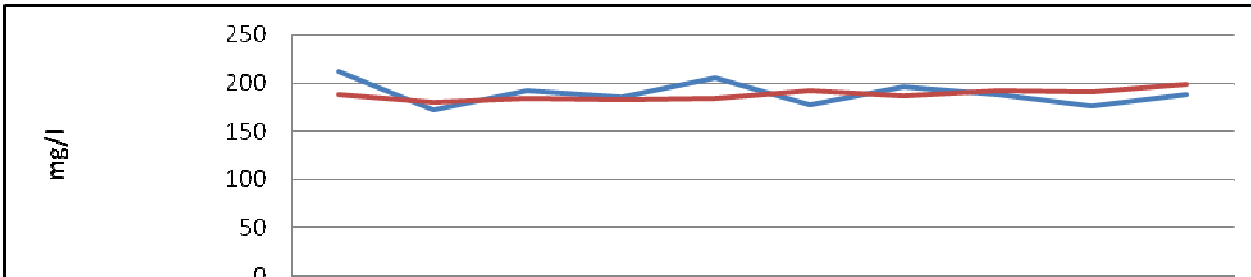
	1	2	3	4	5	6	7	8	9	10
Mahadev Pond	8.87	8.86	8.76	8.66	7.89	8.26	8.45	8.74	8.26	8.56
Bapod Pond	8.35	8.41	8.44	8.38	8.4	8.48	8.46	8.37	8.42	8.39

Figure–04
Comparison of pH between Mahadev Pond and Bapod Pond



	1	2	3	4	5	6	7	8	9	10
Mahadev Pond	162	140	152	145	168	156	173	182	168	176
Bapod Pond	346	364	342	356	360	362	342	344	350	354

Figure–05
Comparison of Chloride between Mahadev Pond and Bapod Pond



	1	2	3	4	5	6	7	8	9	10
Mahadev Pond	212	172	192	186	206	178	196	188	176	188
Bapod Pond	188	180	184	182	184	192	186	192	190	198

Figure–06
Comparison of Total Hardness between Mahadev Pond and Bapod Pond

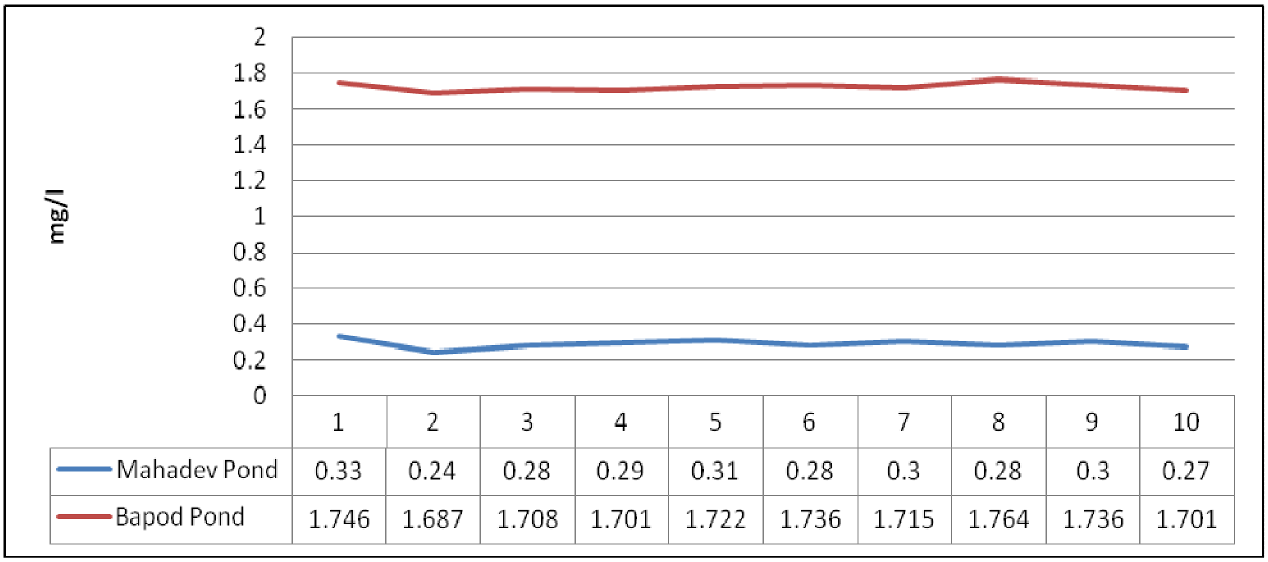
The average Total Hardness values of Mahadev Pond and Bapod Pond was found to be 189.4 mg/l and 187.6 mg/l respectively. The Total Hardness of both the ponds was below the desirable limits for drinking water i.e. 300 mg/l[7]. In the case of Bapod Pond, however, there were consistent higher values Total Hardness in the last three observations where there was initiation of summer months. This indicates that the increased evaporation rate may have lead to higher salt concentration and subsequent higher total hardness of water in summers than in winters[9].

In the case of dissolved nutrients, the average Phosphate levels of Mahadev Pond and Bapod Pond were found to be 0.28 mg/l and 1.72 mg/l respectively and average Nitrate levels were 3.13 mg/l and 5.26 mg/l respectively (Table-02). It was observed that the water of Bapod Pond contained much higher values of dissolved Phosphates and Nitrates in comparison to Mahadev Pond (Figure- 07, Figure- 08). The inward sloping boundary of Bapod Pond allows sewage and surface runoff from adjoining areas which can be held responsible for much higher values of these nutrients in the Pond, similar observation is marked at Danteshwar pond also[10]. The Phosphate and Nitrate can be considered to be major nutrients for aquatic plants. When the levels of these nutrients increase there is an increase in the primary productivity of the pond, provided rest of the environmental conditions are favorable. The natural sources of Phosphate are the geological deposits which contain phosphorous in soluble as well as insoluble form. These phosphate releases due to natural processes of weathering and erosion which ultimately enters into the ecosystem and the aquatic plants utilizes them for growth and development. Urban ponds receive excess of nutrients from house hold sewage, waste water from nearby shops and lorries, street runoff etc[11]. This ultimately results into Eutrophication of the pond and as this is caused by human activities and not by natural processes, it is called “Cultural Eutrophication”[12]. In a study of Lake Washington it was observed that when the Phosphate levels exceeded the value of 57 µg/l, it caused the nuisance of Algal

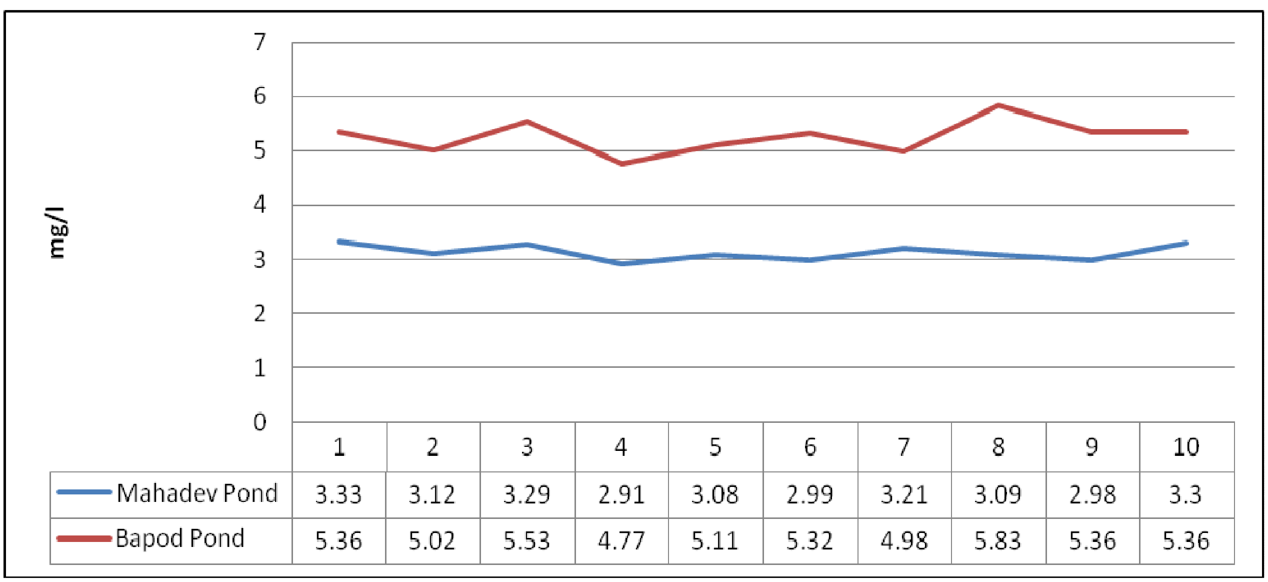
Bloom[13]. If the phosphate concentration in the pond increases beyond the requirement of organisms present in the aquatic environment, they tend to uptake more than their normal requirement. If this happens, the pond will continue to show algal blooming due to presence of already stored nutrient even if the ambient phosphate level drops[14]. If the continuous entry of nutrients cannot be restricted due to the natural boundary such as in the case of Bapod Pond, some methodology has to be developed to combat algal bloom in such ponds[15]. If some biological or chemical agent developed to reduce or restrict the growth of Cyanobacteria, the issue of Eutrophication of Urban Ponds can be checked and ecological balance can be sustained.

Table-2
Average Values of Parameter studied

	D.O (mg/l)	pH	Chloride (mg/l)	Total Hardness (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
Bapod Pond	6.14	8.41	352.3	187.6	5.26	1.72
Mahadev Pond	5.82	8.53	162.3	189.4	3.13	0.28



Figure–07
Comparison of Phosphate between Mahadev Pond and Bapod Pond



Figure–08
Comparison of Nitrate between Mahadev Pond and Bapod Pond

Conclusion

From the above results it can be concluded that the pond having natural boundary was receiving more contaminants in comparison to the pond with constructed boundary. Mahadev Pond with constructed boundary showed very low levels of Chlorides, Phosphate and Nitrates when compared with Bapod Pond. From the study it can be coined that the constructed boundary has, although to some extent, helped to restrict the entry of contaminants into the Pond. The same type of mitigatory measures should be taken to combat the issue of Health of the Urban Ponds.

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Physico-Chemical status of Danteshwar pond of Vadodara City, Gujarat India and its Environmental Implications

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Physico-Chemical status of Danteshwar pond of Vadodara City, Gujarat India and its Environmental Implications

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Abstract

The present study is the investigation of physico-chemical status of Danteshwar pond of Vadodara city. The water quality parameters selected for the study were dissolved oxygen, pH, chloride, total hardness, nitrates and phosphates. The sampling duration was from February, 2010 to April, 2010. Samples were collected from four pre-decided points from the pond. Standard methods were used to analyze all the water samples collected from the pond. The results of the analysis showed that the parameters were within the permissible limits for drinking water standards as directed by BIS (Bureau of Indian Standards) as well as American Public Health Association. However, concentration of some of the parameters was found to be high which may cause a potential threat and interfere with the normal growth, development and reproduction of aquatic organisms leading to their death and ultimately eradication of life from that pond which in turn may to disappearance of the pond itself.

Keywords: BIS, American Public Health Association, the parameters, aquatic organisms

Introduction

Comprising over 70% of the Earth's surface, water is undoubtedly the most precious natural resource that exists on our planet and which is of fundamental importance. It is utilized for irrigational purposes, industrial as well as domestic consumption[1,2]. Earth's environment is degraded due to man's economic exploitation of natural resources[3]. Even though we recognize importance of water; we disregard it by polluting our rivers, lakes, ponds and oceans. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for various purposes. In the developing world over 1 billion people still lack access to clean drinking water, 2.5 billion do not have access to adequate sanitation services and over 3 million death each year are traced to water borne diseases (mostly in children under 5 years age)[4].

There are number of sources of pollution including sewage and fertilizers containing nutrients such as nitrates and phosphates. In excess levels, nutrients over stimulate the growth of aquatic plants and algae[5]. Excessive growth of these consequently clog our waterways, use up dissolved oxygen as they decompose, and block light penetration to deeper waters. This, in turn, poses a threat to aquatic organisms by depletion of dissolved oxygen levels. When aerobic bacteria and Protozoans in the water break down the deposits of organic material, they begin to use up the oxygen dissolved in the water. Various fishes and bottom-dwelling animals cannot survive when level of dissolved oxygen drops below 2.0 – 5.0 ppm. When this occurs, mass mortality of organisms occurs, these continue to deposited at the bottom and shallower the pond depth; ultimately leading to disappearance of the pond.

To develop a better understanding of the status of the water in such a habitat Danteshwar pond of Vadodara city, Gujarat was selected and analysis of the physico-chemical characteristics of the water was carried out.

Material and Methods

Danteshwar Pond: The Danteshwar Pond is an urban pond located in the Vadodara City with natural boundaries (figure 1). Half of the periphery of the pond has modification in its natural state. For example at South and East of the pond there is a residential cum commercial area as can be seen in the image. These boundaries are assumed to be under constant pressure of the human activities. Some parts of the periphery of the pond is having natural boundary covered with vegetation. The common human activities at the pond were observed to be washing of cloths and bathing of animals, washing of vegetables and disposal of waste from nearby shops and households. The dimensions of the pond were recorded to be as follows:
Perimeter: 749.91 m Area: 29,998 m^2

The samples of water from the pond were collected from pre-decided points at the periphery of the lake to reduce biasness. All the samples were collected in the morning time between 7:00 to 8:00 a.m. The physico-chemical parameters were analyzed using the standard methods[6]. The following table - 1 shows the methods adopted for analysis of water quality parameters for the collected water samples.

Figure-1
Sampling points at Danteshwar pond of Vadodara City (Image source: Google Earth)

Table–1
Represents list of methods and parameters studied

Parameter studied	Method used
Dissolved Oxygen	Alkaline azide - Titrimetric
Ph	pH probe
Chloride Total	Titrimetric
Hardness	Titrimetric Method – Erichrome black T indicator
Nitrate	Colorimetric
Phosphate	Colorimetric

Results and Discussion

The primary results of the analysis showed that the dissolved oxygen levels of the water sample were between 5.2 mg/l to 7.4 mg/l with average value of 6.14 mg/l. Value of pH ranged between 8.20 to 8.88 and average of 8.42. In the case of chloride and total hardness the values ranged between 118.11 mg/l – 142.14 mg/l (average – 131.12 mg/l) and 206 mg/l – 228 mg/l (average – 216 mg/l) respectively. The nutrients analyzed i.e. phosphate and nitrates ranged between the values of 0.714 mg/l to 0.924 mg/l and 1.73 mg/l – 2.15 mg/l with average values of 0.79 mg/l and 1.86 mg/l respectively.

The dissolved oxygen plays an important role in defining the fate of the living organisms (figure 2a). The dissolved oxygen enrichment of a pond may be due to surface diffusion of atmospheric oxygen but the photosynthetic activity also plays a major role in increasing the levels of dissolved oxygen in the pond. In the present study the dissolved oxygen levels were found to be ranging between 5.0 – 7.4 mg/l with an average value of 6.14 mg/l. For continuous optimum levels of Dissolved oxygen equilibrium is required amongst various trophic levels of the system. When this equilibrium is broken, it may cause disruption in the natural stability of the system. Though the photosynthetic plants are important for the higher levels of dissolved oxygen in the water, their (especially algae) excessive growth may cover the surface of the pond leading to decreased surface diffusion of gases ultimately causing depletion in the oxygen levels resulting into the death of organisms which cannot sustain lowered levels of oxygen. Bacteria that decompose dead aquatic organisms consume oxygen indirectly decreasing the levels of dissolved oxygen in water[7]. Total phosphate content in water should not exceed a range of 0.05 mg/l to 0.1 mg/l, depending upon whether the water sources discharge directly into a lake or reservoir[7,8].

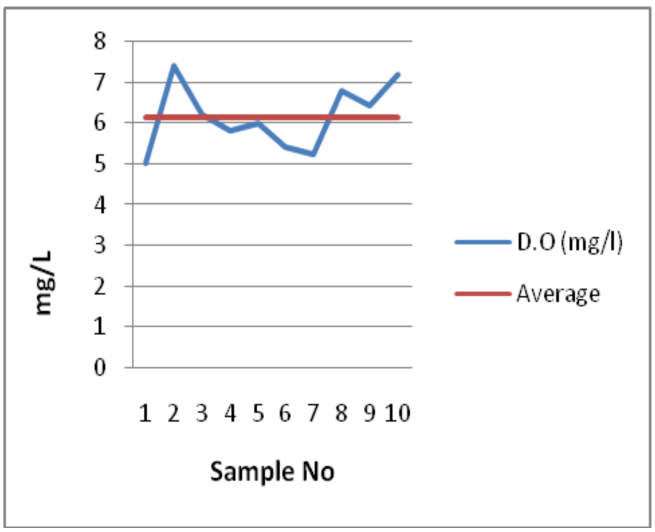

Figure-2(a)
Dissolved Oxygen

The pH of the water ranged from 8.20 – 8.88 (figure 2b) with an average value of 8.42 which says that during the whole sampling period the pH was found to be more than 7.0 which means the water was alkaline throughout the study duration. Though the average pH was within the permissible standards, at four instances it was above the permissible limits having the values of 8.51, 8.74, 8.61 and 8.88. The last three values of the pH were found by the end of the April Month of the study duration where the average ambient air temperature was 30°C[9]. Apart from the drinking purposes, the pH also plays an important role in defining the fate of the aquatic organism. Most of the aquatic life requires a pH range of 6.5 – 8.0. If the pH increases or decreases far from these values it may affect metabolism, growth and reproduction of the organisms and even death in extreme cases. Moreover, at lower pH, the toxic compounds and other materials present in the sediments at the bottom of the pond may be liberated and ultimately make their path to the food web of the pond ecosystem causing deterioration of the quality of biotic environment of the pond as well. The chloride levels of the water sample were observed to be ranging within 118.11 mg/l – 142.14 mg/l (average – 131.12 mg/l) (figure 2c). Chlorides are associated with many physiological functions of aquatic plants and animals, however if the levels of chloride becomes increased it might be having negative impact on growth, development and reproduction of aquatic organisms on a long term exposure. The values of Total Hardness kept on fluctuating during the whole study period with minimum value of 205 mg/l and 227 mg/l respectively (figure 2d). The permissible level for drinking water is 300 mg/l so in this case the total hardness so further increase in the hardness may lead to unwanted impact on human health as well the health of other aquatic organisms. Moreover, increased level of Hardness may also lead to corrosion of metals used in private water supply systems.

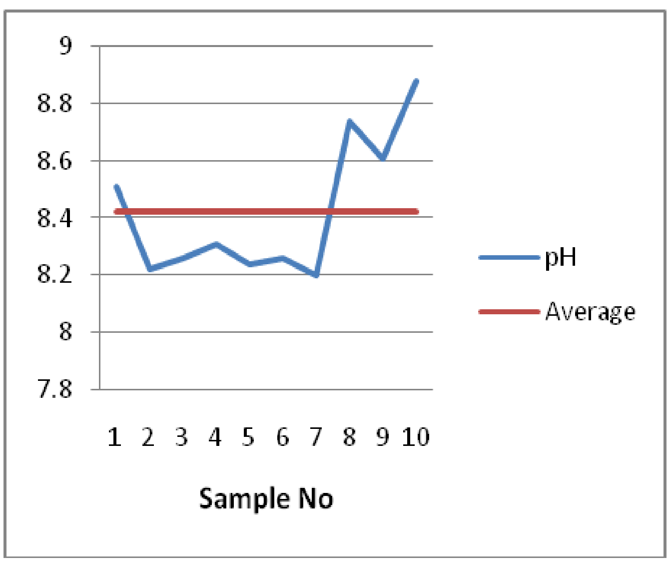

Figure-2(b)
pH

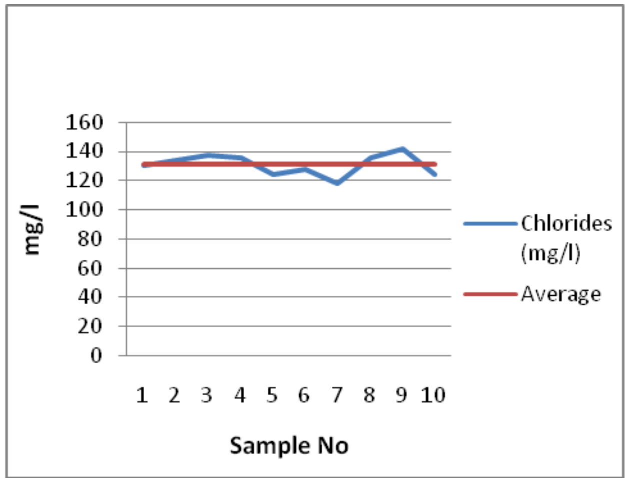

Figure-2(c)
Chlorides

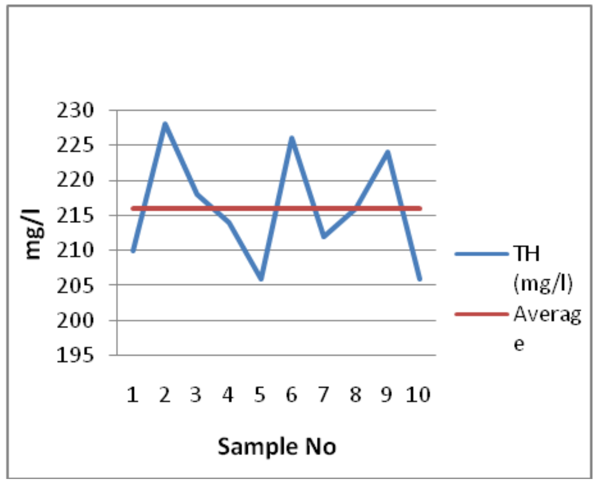

Figure-2(d)
Total Hardness

In the present study, values of nitrates were found to be ranging between 1.73 mg/l - 2.15 mg/l (figure 2e). Many of the freshwater animals such as invertebrates[10] (*E. toletanus, E. echinosetosus, Cheumatopsyche pettiti, Hydropsyche occidentalis*), fishes (*Oncorhynchus mykiss, Oncorhynchus tshawytscha, Salmo clarki*), and amphibians (*Pseudacris triseriata, Rana pipiens, Rana temporaria, Bufo bufo*) etc. showed a higher sensitivity towards elevated concentration of nitrates in the freshwater environment[11]. A maximum level of 2 mg NO_3-N/l would be appropriate for protecting the most sensitive freshwater species. It is suggested that, though the permissible nitrate concentration in the drinking water is 10 mg/l[6], some fish and invertebrate larvae may be affected after a long exposure of these high concentrations of nitrates[11]. This could be the probable impact of continuously increasing concentration of nitrates in the Danteshwar Pond[11].

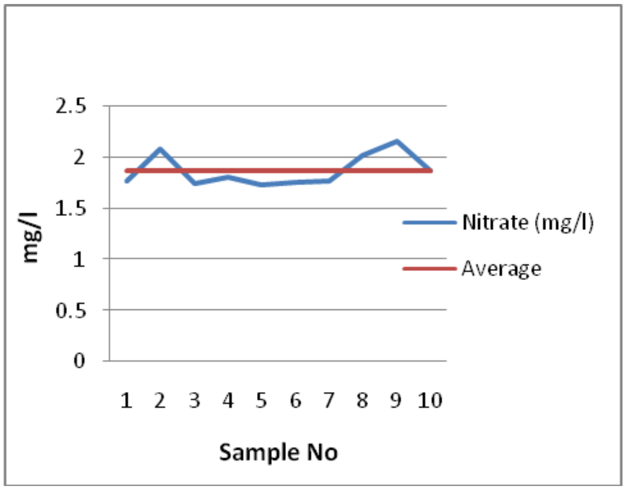

Figure-2(e)
Nitrate

Some scientists have categorized trophic status of a wetland according to phosphorus concentration[8]. Lakes with phosphorus concentrations below 0.010 mg/l are classified as oligotrophic, phosphorus concentrations between 0.010 and 0.020 mg/l are indicative of meso trophic wetland, and eutrophic wetland have phosphorus concentrations exceeding 0.020 mg/l[9]. In the present study the concentration of the phosphate – phosphorous in the water was found to be 0.79 mg/l on an average (figure 2f). This value is sufficiently high to convert the pond into a eutrophicated pond. The problem with excessive growth of aquatic plant is a major issue with respect to maintenance of the water quality for drinking purposes[12]. With such high concentration of phosphates in the surface water there is faster growth of aquatic plants.

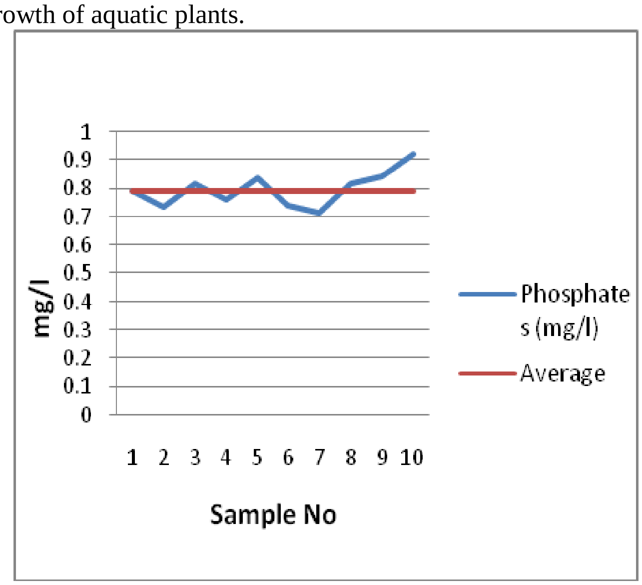

Figure-2(f)
Phosphate

Figure-2(a-f)
Graphical representation of water quality parameters

Conclusion

The above results and discussion suggest that besides smaller fluctuations from the standard values, the water quality of the Danteshwar pond has not completely deteriorated. If mitigatory steps are taken to control the inflow of pollutants and nutrients then the possibilities of the pond being eutrophicated can be reduced or minimized. Proper waste management practices at the boundaries of the pond can help the pond to regain the status of a healthy water body which can be utilized as a freshwater source by the surrounding community for various purposes.

Acknowledgement

Mr. Tailor would like to thank the Dean, Forest Research Institute University, Dehradun, Uttarakhand for the permission to carry out his dissertation work in Vadodara City. Authors would also like to acknowledge the Head, Department of Zoology, for allowing the utilization of the laboratory facilities of the department.

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Role of suburban wetland in carbon sequestration and climate change

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Case Study

Role of suburban wetland in carbon sequestration and climate change mitigation - Case study of Timbi Reservoir, Vadodara, Gujarat, India

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Abstract

The wetland systems, characterized by transition between terrestrial and aquatic systems; which also include shallow reservoirs; are important in a number of ways to human and environment. Such systems are known for providing ecological services such as supporting higher biodiversity, nutrient cycling, sediment retention, flood control, combating drought, supply of water, regulating microclimate etc. Nevertheless, there is another dimension for appraisal of such systems i.e. their carbon sequestration potential and their role in mitigation of Climate Change. The study was carried out to assess the spatial distribution of Organic Carbon (OC) stock in the sediments and total carbon stored per unit area of Timbi Reservoir. The study revealed that the OC stored in the sediments was 76.2tons/hectare (sediment depth 15cm) with a total OC stock of $3.33x10^3$ tons equivalent to $12.21x10^3$tons of atmospheric CO_2. The study also indicated that the part of the wetland inundated for longer period of times stored more OC. This, in fact, is an important result as depleting water levels and exposed sediments may release the stored OC back into the atmosphere. The climate change and depleting wetland and other lentic systems may trigger a positive feedback accelerating climate change.

Keywords: Wetlands, ecological services, organic carbon (OC), carbon sequestration, climate change.

Introduction

Wetlands are one of the important ecosystems harbouring a number of diverse flora and fauna. Previous work has identified the wetlands to be supporting various organisms at their critical stages of life as well as help in conservation of endemic species[1]. Apart from harbouring immense diversity, the wetlands also furnish various services and has functions such as nutrient cycling, drought and flood control, supply of irrigation water, aquaculture etc.[2]. Apart from these benefits derived from such transitional systems, there is an additional role being played by them i.e. carbon storage and carbon sequestration[3-5]. The global small water bodies and wetlands (area < 1 km^2) are estimated to be having covered nearly half of the area totally covered by the lakes and have higher capacity of OC burial in comparison to their larger counterparts.

Vadodara District has numerous wetlands and reservoirs of various dimensions and properties. They are used for the purpose of irrigation, aquaculture, recreation etc. Studies have been carried out for many of such systems on different environmental aspects such as water quality, avifaunal diversity, ichthyofaunal diversity, aquatic floral diversity to name a few[6-10]. Inspite of this, there are no studies carried out pertaining to OC storage/stock in the ponds, lakes and such other wetland systems in Vadodara district, Gujarat. However, the study of carbon stock, carbon sequestration potential, carbon pools etc. were the recent research ventures for various ecological components such as forests, scrublands, soils under various land use practices[11-14]. By having an insight of the deficiency on the carbon sequestration aspect, the current research work was taken up.

The study was thus aimed at appraisal of spatial distribution of OC in the sediments of Timbi reservoir and to estimate the total carbon stock per unit area of the reservoir.

Materials and methods

Site description: The study was conducted at Timbi reservoir; an inland wetland; located in the East of Vadodara city between 22°19'19"N to 22°18'28" N latitude and 73°16'42"E to 73°17'46"E longitudes in Gujarat, India (Figure-1). Sir Sayajirao Gaekwad III constructed the reservoir in the year 1947 – 48[15]. Earthen dam with basic masonry work on the Western and Southern boundaries characterizes the reservoir. It has an area and perimeter of approximately 1.6 square km and 5.6km respectively at full water capacity. The reservoir is largely rain-fed and at times quantities of water are discharged by canal from Ajwa Reservoir. By pre-monsoon season (Month of May), the water cover reduces as much as 70%. This occurs when water is not supplied to the reservoir through the canal from Ajwa Reservoir. The primary utility of the reservoir is to provide irrigation water in surrounding fields but also used for aquaculture. The reservoir harbours a number of migratory and native wetland birds as well as diverse floral diversity. Thus, the reservoir under investigation is having reasonably high importance in terms of economy as well as ecology.

Sampling: The sediment samples (n=20) from various locations were collected using hand shovel and ruler (Stainless steel, length =30cm) up to a depth of 15cm[16] in the year 2016. Soil cores were collected for estimation of bulk density (BD). The soil cores were oven dried at 105°C to constant weight to estimate the dry Bulk Density[17,18]. The representative samples were randomly collected[19] in 01 (one) kilogram capacity zip lock air tight polythene bags and labelled appropriately ensuring authenticity to a fair extent for estimation of Organic Carbon (OC) content. The sampling geo-locations were recorded using GPS Navigator (Garmin Oregon 550T). The samples were air-dried followed by oven drying at 65°C[4] and the clods were broken in mortar and pestle and were sieved to collect sediments sizing less than 2mm. The OC content was analysed by digestion with chromic acid followed by titration against FAS using Diphenylamine indicator[20]. Geospatial analysis of the data was carried out using an open source GIS software QGIS (version 2.14.14 with Grass 7.2.0)[21].

Following formula were developed for calculating the OC stock of Timbi Reservoir: i. Volume of Sediments (m^3) = Total Reservoir Area (m^2) x Sampling depth (m), ii. OC(kg/kg of sediments) = OC (%)/100, iii. Total OC sediments (kg) = OC(kg/kg) x BD (kg/m^3) x Sediments Volume (m^3), iv. OC (tons/ha) = Total OC(tons)/Total Reservoir Area (ha).

Results and discussion

OC content in the sediments of Timbi reservoir ranged from 0.13% to 3.56% with an average value of 1.14%. The average concentration of OC content is much higher in comparison to an agricultural field. In a study carried out in western India the researchers estimated an average OC concentration of 0.62 upto a depth of 30cm to agricultural fields[22]. The OC content showed an increasing trend from the North, Northeast and East boundary towards the deeper point in the reservoir viz., the South Western area (Figure-2). The bulk density ranged from 1.21gm/cc to 1.38gm/cc having an average value of 1.28gm/cc. The OC content and the Bulk density indicate a strong negative relationship (r= -0.8) (Figure-3). The negative correlationship between OC and BD are found in previous studies carried out for a Riverine as well as a Wetland system[16]. The total OC Content in the sediments of Timbi reservoir was calculated to be $3.33 x 10^3$ Tons. By subsequent conversions, the carbon storage was calculated per unit area of the Timbi reservoir, which is 76.2 tons/hectare. A study carried out for estimation of OC stock under various land use in Uttarakhand, India, indicate that the forests stored OC ranging from 69.8tons/hectare to 128 tons/hectare[18].

The same study also implied that the agricultural land had approximately 63 tons/hectare OC stored which was the lowest of all. Considering the area under different land use, the reservoirs have a capacity of store more OC per unit area, thus largely contributing to Carbon sequestration. A further role of Timbi reservoir in carbon sequestration can be assessed by converting the OC content and its equivalent removal of Carbon Dioxide (CO_2) from the atmosphere. In previous studies, it is estimated that each ton of OC in soil/sediment is responsible for removal of 3.667ton of CO_2 from the atmosphere[18]. Considering this, the total amount of CO_2 stripped from the atmosphere by Timbi Reservoir can be calculated to be approximately $12.21 x 10^3$ tons.

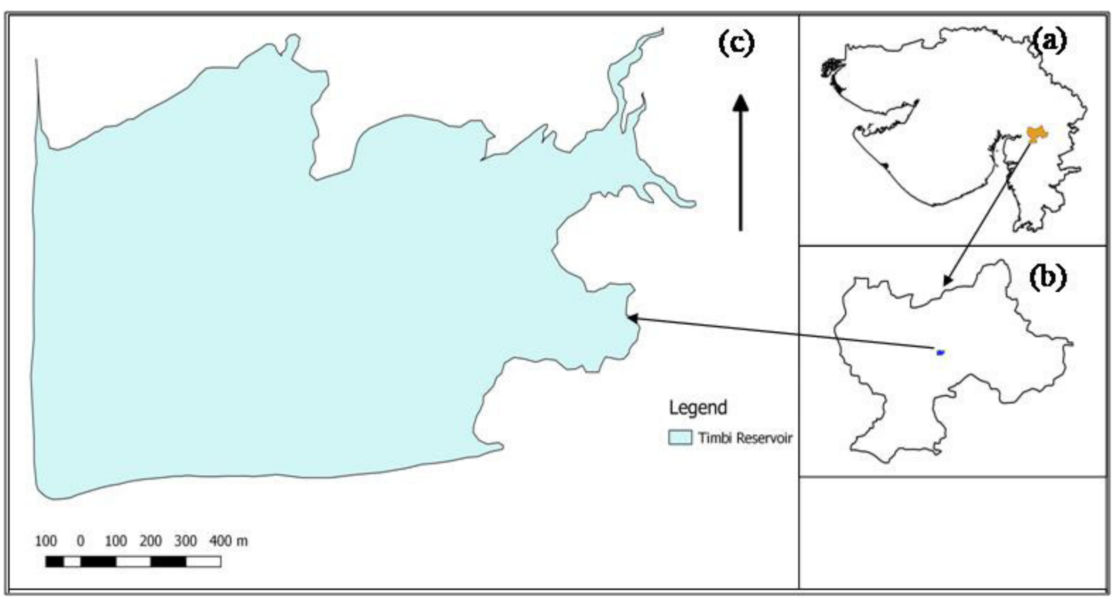

Figure-1: Study area and study site: (a) Map of Gujarat, (b) Map of Vadodara District; (c) Map of Timbi Reservoir.

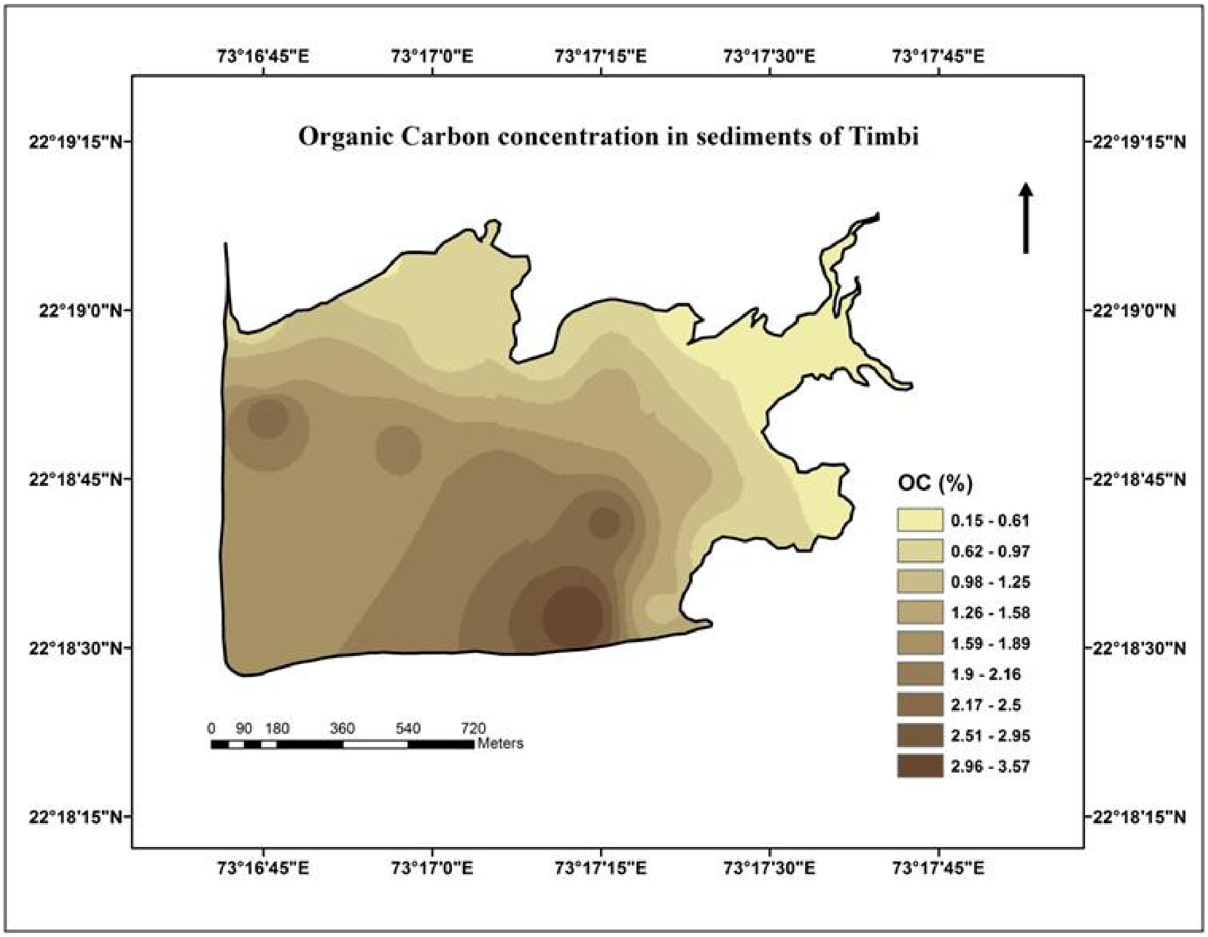

Figure-2: Organic Carbon Concentration in sediments of Timbi Reservoir.

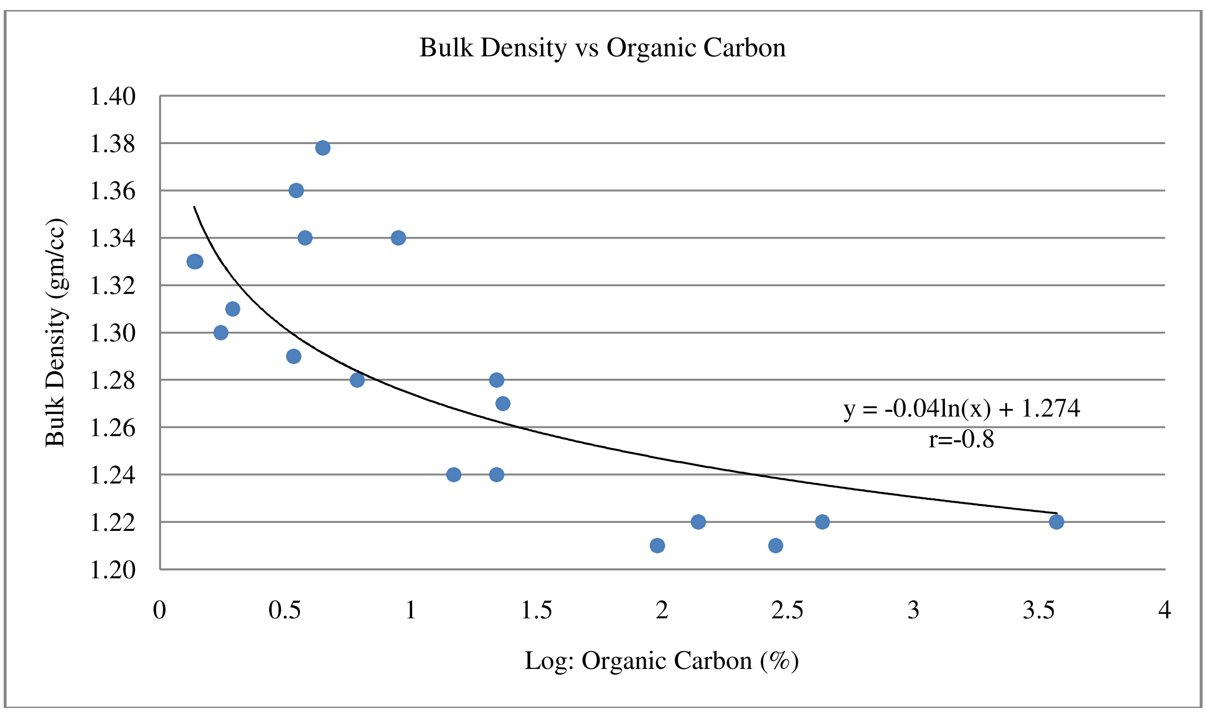

Figure-3: Scatter plot: Bulk Density vs. Log Organic Carbon.

Conclusion

The present research article deals with the estimation of OC content of Timbi reservoir located in Vadodara District, Gujarat, India. It was estimated that the average OC content was 1.14 % and the total OC stored in the sediments be $3.33x10^3$tons, which is higher than major land use practice of the country viz., agriculture. Apart from the functions and services of such marginal reservoirs, they have a great potential for carbon sequestration by acting as a Carbon sink as in the case of Timbi reservoir, which is estimated to be removing $12.21x10^3$tons of atmospheric CO_2. Furthermore, a detailed investigation is advised for clearer understanding of the independent variables affecting carbon sequestration potential of such reservoirs. In addition to the above facts, considering the rate of wetland disappearance due to climate change, stress should be put on the role of such wetlands in carbon sequestration and mitigating climate variability.

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