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Jacobs Journal of Hydrology

Research Article

Water Quality of Wetlands in Nepal: a Case Study of Jagadispur Reservoir Ramsar Site

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Received: 07-17-2015

Accepted: 09-03-2015

Published: 09-29-2015

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Abstract

Wetlands are considered as one of the most diverse ecosystems of the world, providing irreplaceable ecological functions and economic values. However, wetland ecosystem has been increasingly affected by water quality. In order to address this issue, various physico-chemical, microbial parameters, and nutrient content of the water from Jagadispur reservoir Ramsar site (Nepal) were analyzed. The results showed that the values of pH, electrical conductivity, total dissolved solids, nitrate, phosphate, bicarbonate, and chemical oxygen demand were in the permissible range for surface water. However, E. coli was detected and the count ranged from two to >8000 CFU per 100 mL of water. In general, results of this study demonstrate that the water quality is acceptable and the threat of E. coli is not very serious as the water is not generally used for drinking purpose. In addition, preliminary study on biodiversity shows that there are diverse types of aquatic and terrestrial biodiversity surrounding the reservoir.

Keywords: E. coli; Jagadispur Reservoir Ramsar Site; Physico-chemical Parameters; Water Quality; Wetland

Introduction

Wetlands are most diverse ecosystems in the world providing irreplaceable ecological functions and economic values [1]. They support in various ecological functions such as water purification, nutrient retention, ground water recharge, bio-diversity conservation and so on. In addition, they provide a unique habitat for a wide variety of flora and fauna. They also perform as a biological safety net serving as environmental insurance against the impacts of climate change and ecosystem degradation.

There are already many reports published covering various aspects of wetlands, including, but not limited to hydrology [2,3], water quality [4-7], heavy metal analysis [8], vegetation composition [9], environmental impact assessment [10], nutrient removal from waste [11], and environmental purification system [12]. Among these aspects, the water quality monitoring which can also be predicted using the support vector machine [13] has gained increasing attention lately due to the importance of water primarily in biological growth and reproduction. In addition, water quality directly affects on for e.g. land use [14,15] as well as soil and vegetation characteristics [16,17]. Therefore, study of water quality aids in designing long term management policy and decision making. Various anthropogenic activities can be directly related to particular water quality parameters. For instance, nitrate phosphate study would reveal agricultural run-off, electrical conductivity hints anthropogenic discharge, chemical oxygen demand depict organic pollutants and so on.

Nepal possesses wetlands diversity covering a total of 0.42 million hectare, which represents 5% of the total landmass of the country [18]. There are nine wetland sites identified as Ramsar sites of international importance in Nepal. Assuming that many wetlands of Nepal are situated in a similar geographical location and are affected by comparable anthropogenic activities, Jagdispur reservoir Ramsar site has been taken for a case study in this project to demonstrate analogous water quality. The site is covered in 225 hectare and was declared to be a Ramsar site in 2003. The site located in the lowland Terai in west Nepal is rich in biodiversity. Importantly, the reservoir is also being used for irrigation, fishing, grazing, plant collection etc. Unfortunately, the level and extent of dependency on this wetland resource of local communities is not fully documented.

The reservoir is surrounded by the fertile agricultural land. The use of inorganic fertilizers around the site is increasing in prevalence lately which unfortunately results in high nutrient run-off that causes eutrophication, oxygen depletion and accelerates succession towards dry lands. There is a rapid expansion of water hyacinth and macro-phytes. Extensive proliferation of macro-phytes causes a shift in the balance of bird species and promotes towards the growth of alien and invasive species, especially *Ipomea fistula.* Water from the reservoir is being used for various purposes. However, the physico-chemical parameters of the water have not been fully investigated and the quality of water cannot be judged. Our group is interested in the study of water quality [19] and now regarding aforementioned issues, the aim of this study is to monitor the water quality of the reservoir and thereby devise appropriate interventions to improve the quality. More specifically, we wanted to assess the physico-chemical parameters (temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), bicarbonate and chemical oxygen demand), microbial parameter (E. coli), and nutrients (nitrate and phosphate) content of the water. Furthermore, investigating the potential impacts of water quality on the wetland's biodiversity also fall within the scope of this study.

Materials and Methods

Study area

Jagadispur reservoir (centered at 27°37'N 83°06'E) is located in Niglihawa Village Development Committee of Kapilvastu District, Lumbini Zone of Nepal and lies in the lowland western Terai region of southern Nepal (Figure 1). The detailed geographical locations of the sampling sites are shown in Table 1.

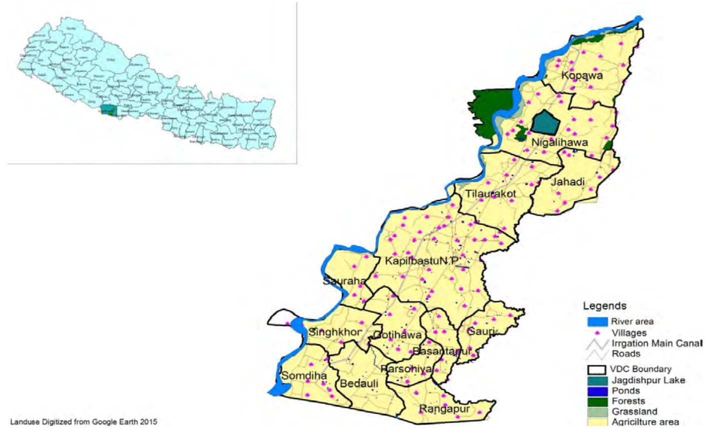

Figure 1. Location of the site. Inserted is the map of Nepal showing study site.

Table 1. Notation/label and location of the sampling sites.

Notation/Label	Latitude/Longitude	Altitude (m)
1 Inlet (S1)	N 27° 40.007' E 83° 06.885'	108
2 SW (S2)	N 27° 37.054' E 83° 05.636'	97
3 NW (S3)	N 27° 37.724' E 83° 06.153'	100
4 NE (S4)	N 27° 37.344' E 83° 06.153'	102
5 SE (S5)	N 27° 36.869' E 83° 06.368'	105
6 Jahadi, water canal (S6)	N 27° 36.869' E 83° 06.368'	98

Sample collection

Water samples were collected from six sampling stations, the four corners of the lake as well as inlet and outlet locations. Samples were taken in June 2015. Sampling was done according to United States Environmental Protection Agency (USEPA) sample preservation guidelines. Samples were collected in different plastic bottles and/or glass bottles using specific preservatives depending upon the parameters intended to be tested.

Analysis

Temperature, pH, dissolved oxygen, electrical conductivity, and total dissolved solids were analyzed at the chemistry laboratory of Kathmandu University using the instrument 'Consort bvba' (Parklaan 36, B-2300 Turnhout, Belgium). Specific electrodes were chosen for various parameters intended to be investigated. The electrodes were calibrated following standard protocol before the start of the measurement. Bicarbonate, chemical oxygen demand, nitrate and phosphate were analyzed in ENPHO Lab at Kathmandu. Moreover, microbial parameter E. coli was also checked at the ENPHO Lab. The concentrations of bicarbonate, chemical oxygen demand, nitrate, phosphate and the presence of E. coli were investigated following the protocol reported elsewhere [20]. From the six sites, three replicates of each parameters (temperature, pH, DO, EC, TDS, bicarbonate, phosphate, nitrate) were tested to make the results statistically relevant. Descriptive statistics was used for data analysis. E. coli from five sites was tested and the COD of one sample was analyzed.

Results and Discussion

Physico-chemical and microbial parameters

The study was designed to conduct water quality assessment of the Jagadispur reservoir, focusing on different physico-chemical, microbial parameters, and nutrients contents of the water. The investigated parameters and the results are depicted in Table 2. In addition, Table 3 gives information of analyzed parameters expressed as mean results, permissible range, WHO and nepal standards. This study also examined possible effects of the water quality on wetlands' biodiversity at the Ramsar site.

pH. It is a measure of the acidic or basic (alkaline) nature of a solution. A pH range of 6.0 to 9.0 is considered suitable for the life of fresh water fish and bottom dwelling invertebrates. In our current study, pH varied from 7.13 to 8.07 with mean value of 7.58 ± 0.26, recording highest value at S2 (mean at S2, 8.0 ± 0.050) which is still below the limit of WHO and Nepal standard of 8.5 [21,22]. This shows that all the sites have pH values within the desirable and suitable range.

Temperature. Temperature is obviously one of the most important factors in an aquatic environment [23]. Water temperature helps in controlling the metabolism of the aquatic ecosystem. When the water temperature is high, the concentration of dissolved gases like oxygen in the water is low which ultimately results in inhospitable living conditions, leading to eventual death of aquatic life. In the present study, the average temperature of water samples was 23.99 ± 0.30°C ranging between 23.5-24.5°C. It should be noted that the temperature was recorded at Kathmandu and there might be slight difference compared to the site.

Dissolved oxygen. Analysis of dissolved oxygen indicates the amount of gaseous oxygen dissolved in an aqueous solution. Oxygen can penetrate into water through a number of ways including the surrounding air via diffusion, aeration, and as a waste product of photosynthesis. Reduced DO levels in water imply (i) the water is relatively warm; (ii) too many bacteria present; (iii) fertilizer run-off present from farm fields. The generally accepted amount of DO that will support a large aquatic population is from 5.8 to 6.8 mg/L [24]. In the present study the mean value of DO was observed at 6.09 ± 0.43 mg/L varying from 5.25 to 6.94 mg/L in all sites indicating acceptable range.

Electrical conductivity. Conductivity is a measure of the ability of water to pass an electrical current and it is mainly affected in water by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, sodium, magnesium and so on. It helps to figure out the quality of water on the basis of dissolved salts and also helps to determine amounts of chemical reagents or treatment methods needed to purify the water. In the present study, the measured electrical conductivity is 288.11 ± 41.86 µS/cm (mean value) which ranges from 219 to 340 µS/cm and is well within the standard range of electrical conductivity of Nepal standard (< 1500 µS/cm) and WHO standard (< 600 µS/cm).

Total dissolved solids. It is the sum of all ion particles that are smaller than 2 microns. Excess dissolved solids lead to the elimination of plant species but dissolved solids are also important to aquatic life as they keep cell density balanced. In this study, TDS was recorded 156.39 ± 15.89 mg/L (mean value) varying from 130 to 179 mg/L which falls well within the Nepal standard (<750 mg/L).

Nitrate. Nitrate and Nitrite are naturally occurring ions that are part of nitrogen cycle. Generally vegetables are the main source of nitrate intake. However, a high level of nitrate in water indicates excessive use of agricultural fertilizers, decayed vegetable water and sewage disposal and ultimately causes disease. In this study nitrate was detected only in S1 site (mean value 0.23 ± 0.058) which is far below Nepal and WHO standard (< 50 mg/L). Nitrate concentration in all other sites was below the detection limit (<0.2 mg/L).

Phosphate. Phosphorus is one of the key elements necessary for growth and development of plants and animals and phosphate PO_4^{3-} is formed from this element. Phosphate stimulates the growth of plankton and aquatic plants which provide food for fish. However, if an excess of phosphate is present in the water, algal and aquatic plants will grow wildly and consume large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. The total phosphate should be less than ≤ 0.025 mg/L for reservoirs while the level at which plant growth is stimulated is 0.1 mg/L. In this study, phosphate was not detected in any sites indicating the concentration below the detection limit of the instrument (<0.05 mg/L).

Table 2. Sampling sites and results of parameters.

Sample ID		pH	Temp (°C)	DO (mg/L)	EC (μS/cm)	TDS (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	HCO_3^- (mg/L)	COD (mg/L)	E. coli (CFU/100mL)
1 Inlet (S1)		7.62	24.1	5.5	314	167	0.3	ND(<0.05)	152		6
		7.50	23.8	6.08	317	165	0.2	ND(<0.05)	152		
		7.55	23.5	5.43	312	162	0.2	ND(<0.05)	152		
	Mean	7.6	23.8	5.67	314.3	164.7	0.23		152		
	S.D.	0.06	0.3	0.357	2.517	2.517	0.058		0		
2 SW(S2)		8.07	23.9	6.39	251	133	ND(<0.2)	ND(<0.05)	120	19.97	35
		7.97	23.9	6.12	249	137	ND(<0.2)	ND(<0.05)	120		
		8.01	24.1	6.15	245	130	ND(<0.2)	ND(<0.05)	120		
	Mean	8	24	6.22	248.3	133.3			120		
	S.D.	0.05	0.115	0.148	3.055	3.512			0		
3 NW(S3)		7.16	23.5	5.25	319	169	ND(<0.2)	ND(<0.05)	160		2
		7.20	23.7	6.08	322	172	ND(<0.2)	ND(<0.05)	160		
		7.13	23.5	5.85	327	175	ND(<0.2)	ND(<0.05)	160		
	Mean	7.20	23.6	5.7	322.7	172			160		
	S.D.	0.035	0.115	0.429	4.041	3			0		
4 NE(S4)		7.53	24.1	5.79	336	179	ND(<0.2)	ND(<0.05)	172		18
		7.5	24.5	6.01	340	171	ND(<0.2)	ND(<0.05)	170		
		7.46	24.1	5.85	335	175	ND(<0.2)	ND(<0.05)	170		
	Mean	7.50	24.2	5.88	337	175.0			170.7		
	S.D.	0.035	0.231	0.114	2.646	4.000			1.155		
5 SE(S5)		7.70	24.1	6.48	227	147	ND(<0.2)	ND(<0.05)	140		TNTC
		7.61	24.1	6.52	219	145	ND(<0.2)	ND(<0.05)	138		
		7.59	24.2	6.18	229	143	ND(<0.2)	ND(<0.05)	138		
	Mean	7.60	24.1	6.4	225	145			138.7		
	S.D.	0.059	0.058	0.186	5.292	2			1.155		
6 Jahadi(S6)		7.66	24.2	6.94	284	150	ND(<0.2)	ND(<0.05)	144		
		7.58	24.2	6.51	280	143	ND(<0.2)	ND(<0.05)	144		
		7.60	24.4	6.45	280	152	ND(<0.2)	ND(<0.05)	144		
	Mean	7.60	24.3	6.6	281.3	148.3			144		
	S.D.	0.042	0.115	0.267	2.309	4.726			0		

Table 3. Investigated parameters, their unit, permissible range and standard values. Results are expressed as mean ± standard deviation (S.D.).

Physicochemical parameters	Unit	Permissible range	WHO standard	Nepal standard	Results Mean ± S.D.
pH	Scale	6 - 9 (surface water)	6.5-8.5	6.5-8.5	7.58± 0.26
Temperature	(°C)				23.99±0.30
Dissolved oxygen	(mg/L)	5.8 - 6.8			6.09±0.43
Electrical conductivity	(µS/cm)		<600	<1500	288.11±41.86
Total dissolved solids	(mg/L)			<750	156.39 ±15.89
Nitrate	(mg/L)		<50	<50	0.23±0.058
Phosphate	(mg/L)	≤ 0.025			not detectable
Bicarbonate	(mg/L)	20-200			147.56 ±16.60
COD	(mg/L)		<250 (surface water)		19.97

Bicarbonate. Bicarbonate, carbonate and hydroxide in water are the primary sources of alkalinity which is used in the interpretations and control of water and waste water processes. Alkalinity helps to determine the buffering capacity of water. Alkalinity values of 20-200 mg/L are common in freshwater ecosystems. Alkalinity levels below 10 mg/L indicate poorly buffered streams meaning that these streams are the least capable of resisting changes in pH and therefore are most susceptible to problems which occur as a result of acidic pollutants. In this study, bicarbonate was recorded 147.56 ± 16.60 mg/L (mean value) varying from120 to172 mg/L which indicates the acceptable quality of water.

Chemical oxygen demand. The COD test is generally used to indirectly measure the concentration of organic compounds in water. The amount of oxygen used to oxidize the organic compounds can be correlated with the amount of organic waste present in the water. High COD levels decrease the amount of dissolved oxygen available for aquatic organisms and also cause adverse impact on human health. WHO standard of COD for surface water is 250 mg /L [25]. In this study, COD of one sample (S2 station) was found to be 19.97 mg/L which also indicates the acceptable quality of water.

E. coli. *Escherichia coli is* the most common member of the specific subgroups of fecal coliform bacteria and its presence in aquatic systems implies that the water has been contaminated with the fecal material of man or other animals. The presence of fecal contamination is an indicator that a potential health risk exists for those exposed to this water. In this study, E. coli was observed in all sites (S6 station was excluded) and the value was from 2 CFU (colony-forming units)/100 mL to TNTC (too numerous to count). It indicates that the water is contaminated with the fecal material of human or other animals and high counts of fecal coliform create an elevated risk of waterborne gastroenteritis.

Impact of water quality on wetlands' bio-diversity

The results of pH, dissolved oxygen, conductivity, total dissolved solids, nitrate, phosphate, bicarbonate and chemical oxygen demand are within the permissible range, and indicate that the tested water exhibit acceptable properties. Moreover, nitrate and phosphate are below the detection limit, suggesting that there was no agricultural run-off. However, the presence of microbial parameter E. coli in all sites indicates an elevated risk of waterborne gastroenteritis.

Fecal coliform bacteria can enter into the aquatic environment through direct discharge of waste from mammals and birds, from agricultural run-off, human sewage and from plant materials. Birds especially swans, geese and other migrant species in the area can increase the count of E. coli in that wetland. The presence indicates a higher risk of pathogens in the water and some waterborne diseases to human, e.g. ear infections, dysentery, typhoid fever, bacterial gastroenteritis, and hepatitis [26], while the effect is less severe to other aquatic creatures. Another issue with fecal coliform would be the reduction of oxygen in the water. As the aquatic system contains some organic material, fecal coliform will be active in the aerobic decomposition and thus consume oxygen which will eventually lead to an inhospitable habitat for many aquatic animals.

As a final remark, it can be said that the water exhibit acceptable properties and suitable for wetlands biodiversity. Fecal coliform has been detected but it should be noted that it is almost impossible to get rid of E. coli on surface water because fecal material of birds and other animals cannot be excluded.

However, the count can be reduced if the direct discharge of excreta from various domestic animals and also from humans is discouraged into the reservoir. It is also important that E. coli count is not very severe for physiology and metabolism of other flora and fauna.

Other studies

The preliminary biodiversity assessments and measure of socioeconomic values in and around the site were carried out. The major findings are listed here. The major forest of that area is Sal forest (Shorea robusta). There are some serious threats on forest biodiversity such as logging for timber/firewood, branch cutting for fodder/wood, forests fire, grazing, grass cutting, and river erosion/flooding. The wetland consists of diverse plant species and the wetland vegetation of that area is in a submerged succession stage with patches of floating species. The agricultural ecosystem mostly includes agricultural crops such as paddy, wheat, maize, vegetables and fruits. There are 43 species of fish, 52 species of herpeto fauna, 168 species of bird and 30 species of mammals [27].

Conclusion

The water quality assessment in Jagadispur reservoir Ramsar site was performed focusing on various physico-chemical and microbial parameters of the water. The findings of pH, dissolved oxygen, electrical conductivity, total dissolved solids, nitrate, phosphate, bicarbonate, and chemical oxygen demand are within the permissible range. These results indicate that water quality is satisfactory with respect to various analyzed parameters. However, microbial parameter E. coli was detected ranging the count from 2 CFU/100 mL to TNTC. This indicates that there is fecal contamination present which carries the potential risk of a variety of health hazards. However, the effect is less severe to other aquatic creatures compared to humans. As a concluding remark, it can be said that there is not as such major threat while using this water as it is not directly used for drinking purpose. The dominant forest of that area is Sal forest, and wet land vegetation is seen in a submerged succession stage. Paddy, wheat, fruits are main agricultural source at the site and the area is rich in faunal diversity. In future, we are planning to investigate the water quality in postmonsoon season in which there will be dilution of organic and inorganic pollutants via washing off of solid matter.

Acknowledgement

This outcome is the part of the project "Wetlands for the Future: Improving Livelihoods and Enhancing Biodiversity through Participatory Restoration and Management of Jagadispur Reservoir Ramsar Site in Nepal" implemented in the Jagadispur Reservoir Ramsar Site of Nepal by IUCN Nepal. We would like to extend our thanks to Ramsar Convention Secretariat and Norwegian Agency for Development Cooperation for funding this project.

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