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Comparative Study of Water Quality Index of Phewa, Rupa and Begnas Lakes

Biwas Babu Sadadev [a], Keshav Basnet [b], Kishor Kumar Shrestha [c]

[a, b, c] *Infrastructure Engineering and Management Program, Department of Civil and Geomatics Engineering, Pashchimanchal Campus, IOE, TU, Nepal*

Corresponding Email: [a] biwasbasnet458@gmail.com, [b] basnet.keshav@gmail.com, [c] kishor103@gmail.com

Abstract

Phewa, Begnas and Rupa are the three major lakes of Pokhara valley. Phewa Lake which is a major tourist destination of Nepal is at present facing high human pressure at both its urban and rural watershed areas in the absence of proper sewage system in Pokhara city. Also, the sedimentation and eutrophication problem has been a threat. Similarly Begnas and Rupa lakes are situated side to each other not being an exception to the possible threats of pollution. So, the assessment of water quality and identification of the variation of water quality parameters could be important. The samples were collected from the representative points within the lake with standard sampling procedure and tested in laboratory following their own standard testing procedure. Most of the water quality parameters of these lakes were observed to be within the desired limit of Nepal Drinking Water Quality Standard, except for E coli in all cases. Along with that, pH values of samples in Begnas Lake and Turbidity value of samples in Rupa Lake were recorded to be significantly high. Thus, there could be the chance of harm to human health if directly consumed or used. With the results obtained Water Quality Index was determined. By Canadian method, the water quality of Phewa Lake was obtained as Fair, Begnas as Marginal and Rupa of Poor quality. As per the Water Quality Index by Arithmetic method, Begnas Lake and Phewa Lake had a good water quality whereas it was poor in case of Rupa Lake. Rupa Lake had the poorest water quality out of three lakes and the rest two however did not have an excellent quality. Effective purification process has been recommended prior to the distribution and consumption of water. Improving the water quality in these three lakes by appropriate measures could be of high concern. Water Quality Index has ensured the water quality condition in three lakes. Based on this, an appropriate measure regarding the parameters that exceeded beyond the desired limit were recommended. This can support for the conservation activities of lake, maintaining water quality, controlling pollution through identification of probable locations of pollution and maintaining ecosystem.

Keywords

Water Quality Index; Sedimentation; Turbidity; Eutrophication; Pollution

1. Introduction

Our water resources are of major environmental, social and economic value. Four broad categories of water use are domestic purposes, industrial purposes, agricultural purposes and recreational purposes. If water quality becomes degraded, it is not just the environment that will suffer but the commercial and recreational value of our water resources will also diminish. Surface water quality deterioration has become a serious concern worldwide due to increased pollution and climate change. Therefore, many countries have implemented water quality protection measures and monitoring regimens.

The principle recent change in rural land use in the Pokhara valley of Nepal is that rural area are being absorbed into growing town and cities. This conversion of rural in to urban land could have several impacts on lake water quality because of development such as industrial installations and so many hotel and restaurants which are located along the bank of environmentally vulnerable lake[1]. Phewa Lake, which is a major tourist destination of Nepal, is at present facing high human pressure at both its urban and rural watershed areas in the absence of proper

sewage system in Pokhara city.

Similarly, Begnas and Rupa Lake situated side to each other not being an exception to the possible threats of pollution. The assessment and management of water resources are vitally important, since it is essential for every form of life. Poorly managed resources can cause water scarcity or pollution, which may lead to social, economic and health crisis. The watershed-based managements should include planning and conserving the available water resources. So the more we monitor the quality of water the better we will be able to recognize and prevent contamination problems.

2. Study Area

The study was related to the comparative analysis of water qualities of the major three lakes situated in Pokhara MetropolitanCity which are Phewa Lake, Begnas Lake and Rupa Lake. The Phewa Lake lies in the core city area. It is located at an altitude of 742 m and covers an area of about 4.43 sq.km (1.7 sq mi). Begnas Lake and Rupa Lake lie in Lekhnath area located in the south-east of the Valley. The former is located at an altitude of 650 m and covers an area of about 3.28 sq.km (1.3 sq mi) whereas the latter is located at an altitude of 600 m and covers an area of about 1.3 5sq.km (0.5 sq mi).

Figure 1: Study Area showing Phewa Lake, Begnas Lake and Rupa Lake

3. Data Used

Qualitative and quantitative measurements are needed from time to time to constantly monitor the quality of water from the various sources of supply[2]. The WHO has issued guidelines for drinking water quality. Most nations have their own guidelines or standards. Water quality monitoring includes water sampling, testing and investigative analysis incorporated by essential treatment methods. The water quality testing in this study included the following parameters. The samples were collected, tested, investigated and analysed for physical examination (Electrical Conductivity, Turbidity and Total Dissolved Solids), Chemical examination (pH, Hardness, Ammonia, Calcium and Chlorides) and Bacteriological examination (E Coli)[3] . The Water Quality Index used is the Weighted Arithmetic Method and Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI).

Table 1: Water Quality Index by Canadian Method and Weighted Arithmetic Method

CCME WQI		Weighted Arithmetic WQI		
WQI Value	**Water Quality**	**WQI Value**	**Water Quality**	**Grading**
95-100	Excellent	0-25	Excellent Water	A
80-94	Good	26-50	Good Water	B
60-79	Fair	51-75	Poor Water	C
45-59	Marginal	76-100	Very Poor Water	D
0-44	Poor Water	Above 100	Unsuitable for Drinking Purpose	E

4. Prevoius Studies

Ministry of Population and Environment has done the assessment of water quality of Phewa and Begnas lakes in 2062. It was observed that the water parameters such as pH, electrical conductivity, dissolved oxygen, biological oxygen demand, total dissolved solid, iron, nitrate, total hardness, magnesium in all four study sites of Phewa Lake were within the desired limit given by national drinking water quality standard, 2062. In case of total coliform and E coli, all the sites were beyond the desired limit. The lake water might have been polluted by not maintaining the cleanliness of lake as number of tourists visit the lake frequently.

In Begnas lake, it was observed that the water parameters such as pH, electrical conductivity, dissolved oxygen, biological oxygen demand, total dissolved solid, nitrate, ammonia, total hardness, magnesium in all four study sites of Begnas Lake were within the desired limit given by national drinking water quality standard, 2062. In case of iron content, it was slightly higher in the centre of Begnas lake.

5. Methodology

5.1 Obtaining Samples from Lakes

The study of the largest three lakes of the famous tourist destination of Nepal was carried out first by sampling phase. The water samples from all the lakes

were collected as per standard procedure. For each lake the samples were collected from various parts of the lake. The samples so collected were examined for various physical, chemical and biological parameters. Total 10 such parameters were tested for which include pH, Turbidity (T), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygne (DO), Total Hardness (TH), Ammonia (NH3), Calcium (Ca), Chlorides (Cl2) and E coli. At first, the quality of water of Phewa Lake was studied. The sources of water to Phewa Lake and the areas concerning the maximum pollutants were discovered. For Phewa Lake, 20 different locations were identified for collecting samples that could represent different conditions of water sample during that time and be the representative samples of the entire lake which has been shown in the figure below. The similar approach was applied in the case of data collection from Begnas Lake and Rupa Lake. In case of Begnas Lake, 23 sampling points were taken and 21 in case of Rupa Lake. The sampling bottles were fully sterilized so as to get the perfect samples. It was performed using a vertical autoclave instrument. The samples were taken from around the banks where the maximum chances of pollution can be predicted such as Hallan Chowk, Barahi Chowk, Dam Side and Pame areas in. The samples at the mid of lakes, around Barahi Temple and near the hill sides were taken. In case of Begnas Lake, the samples were taken in the similar fashion to Phewa Lake. The samples at Rupa Lake were taken mostly around its periphery, upstream, mid and downstream part. The samples were taken from the depth of around 20-40 cm from 2-3 locations just near to it so that it would represent the zone fully under study. The coordinates and the points were noted in bottles. The samples were then carried to laboratory where those were carefully stored with labels.

5.2 Laboratory Examination for Water Quality

The various water parameters were then tested.The parameters used for the indices of water quality in this study are those used for the Global Drinking Water Index Development and Sensitivity Analysis[4]. These parameters have been carefully selected to accurately reflect the major acceptability and health issues relating to water quality. In addition, factors including detection level and general ability for researchers and stakeholders to accurately measure the parameters in most parts of the world have been considered.

pH, Turbidity, Total dissolved solids and Electrical conductivity were measured using digital instruments while the parameters like Total hardness, Ammonia, Calcium and Chlorides were tested using the method of titration applying the standard procedure of measurement. The titrated samples were mathematically treated to get the actual concentration of parameters. The presence of E coli too was determined in the presence of culture media and incubation. The pH value was obtained with the help of pH meter, EC/TDS through EC/TDS meter and turbidity with turbiditimeter.

The ammonia content was identified by the solution of ammonia tablet in the sample and comparing the color with the color comparator disc. The dissolved oxygen content was observed directly using a DO meter. Total hardness value was obtained by titrating 25 ml samples provided with 2 ml buffer and a drop of indicator (Arichrome Black) against EDTA solution, for which the change in color is noted from pink to bluish one. The calcium content was determined through 25 ml sample in which 2 ml NaOH and 1N of mureoxide indicator was added and titrated against EDTA solution till change in color from pink to violet purple. The chloride content was evaluated by the addition of 1 drop of chromate indicator in 25 ml of sample titrated against silver nitrate (AgNO3) for which color change was from yellow to brick red. The concentration of these hardness, calcium and chlorides were obtained in mg/l with molecular conversions.

For determination of E coli content, membrane filter apparatus was sterilized in which 100 ml sample was filtered through membrane filter of pore size 0.45µm. The absorbent pad was saturated with culture media (M lauryl Sulphate broth) and membrane filter was placed above it for expansion of E coli concentration in the presence of media. Then so produced sample was incubated at 44.5ºC for 24 hrs. The formation of yellow colonies was counted which represented the concentration of E coli.

5.3 Determination of Water Quality Index

The WQI method is a powerful tool that enables easy communication of the quality of water to the public especially the policy makers. It is an unambiguous tool that enables the integration of the water parameters, which are deemed important to the quality of the water accordingly[5] . The water quality index was obtained by two different methods which include

Figure 2: Examination of Water Quality in Laboratory

Canadian WQI method and Weighted Arithmetic Method. For determination of WQI by Canadian method, the three scope variables F1, F2 and F3 were determined which respectively represent number of variables whose objectives are not met, number of times which the objectives are not met and amount by which objectives are not met. By Weighted Arithmetic Method, Relative Weight of each of the parameters was obtained which was multiplied against quality rating scale obtained by comparing individual parameter against standards, which gives the sub indices for each of the parameters. The sub indices finally contribute to the WQI. The quality of water signified by these two indices was compared with one another[6] .

6. Results and Discussion

The test results of water from Phewa Lake, Begnas Lake and Rupa Lake included various physical, chemical and biological parameters. The test results showed that for different twenty points, the value of parameters differs more or less. In case of pH concentration, the water in Phewa Lake was observed somehow close to neutral and within the limit of drinking water. The water away from the main settlement area and close to hill side was observed to have got some little basic properties. The electrical conductivity of lake water sample was less when compared to standard, 1500µS/cm. The maximum electrical conductivity of 104.8µS/cm was obtained in between Pame and Hallan Chowk area. The value of total dissolved solids too was maximum there among entire lake area. This is the region which was very much dominant to eutrophication. The water in Phewa Lake is within the limit of turbidity. The data was collected in a clear sunny days and there had not been rain since long thus, turbidity could have been reduced. The turbidity was maximum 10.3 NTU at the same place where EC and TDS were maximum. Turbidity value might be high there too since there were direct disposal of sewer. Also the road expansion, houses construction and some excavation activities near to it might have reduced clarity of water.

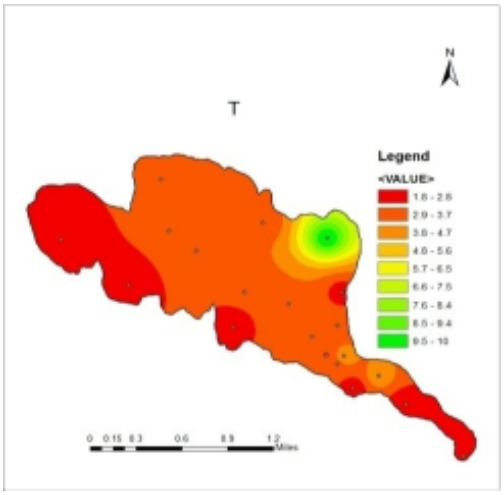

Figure 3: Variation of Turbidity in Phewa Lake

The water in all parts of lake was not subjected to pungent and displeasing color. And after testing water for ammonia, in all parts of lake, the ammonia content was below 0.1 mg/l. The value of dissolved oxygen was found to be more at region between lakeside and Pame area and at some parts of hillside while it was found lower at mid part of lake. The value of total hardness was more at centre and the region between Hallan Chowk and Pame area. The amount of dissolved calcium and magnesium in the water which indicated total hardness was however within the safer limits. The calcium content was comparatively more in Pame area and centre of lake which might have entered lake water systems through the weathering of rocks, especially limestone, and from the leaching and runoff of forest soils nearby. Chlorides are one of the major indicators of water pollution. The chloride values in water of Phewa Lake were below the level of worry. However it was higher in tail part of lake. The formation of E coli colonies indicates faecal presence. In all the samples collected, some colonies of E coli were generated under standard incubation conditions. The tolerance limit of E coli is nil however the colonies were generated in almost all samples collected from lake. E coli are actually indicator organisms that indicate the faecal contamination in lakes which when consumed can cause health

problems.

In Begnas Lake, the value of pH was observed to be considerably higher than Phewa Lake and Rupa Lake. The water was found to be more basic. The downward south east part of lake was found to be more basic than the desired limit of pH value 9. Also at boat parking zone, the value of pH was comparatively observed to be high.Electrical Conductivity and Total dissolved solids were well within the desired limit. These values were comparatively lower at the southern part of lake and more at the centre and northern part of lake.

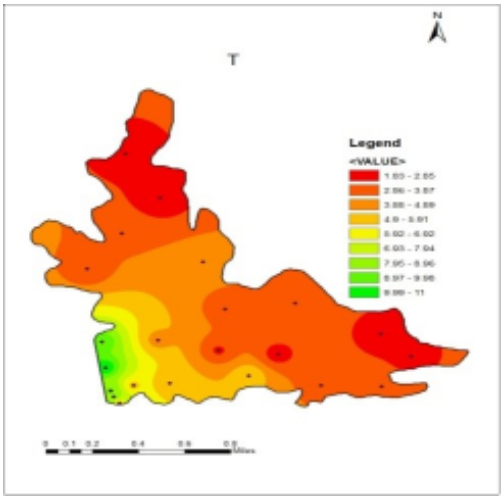

Figure 4: Variation of Turbidity in Begnas Lake

However, Turbidity value was observed to be higher near the dam area and boat parking zones. This could be because of high and direct influence of human activities there. The value of DO was found to be above 6 mg/l, which indicated better DO environment for aquatic life. The DO was examined to be higher in all parts but it was comparatively lower near the dam area. Total hardness too was observed higher there as there were some bathing zones. The calcium and chlorides content were observed higher at the same place but very safe within the limits.

In case of Rupa Lake, the physical parameters regarding water quality were examined to be within desired limit except for Turbidity which was very much high with respect to standards. Average value of Turbidity was about 19 NTU which is approximately 4 times more than safer limit. Turbidity in Rupa Lake was observed to be higher at upstream and mid part of lake and slightly decreased after just reaching the tail part. pH, EC and TDS were found to be following a decreasing trend on reaching downstream. The chemical parameters regarding water quality, DO, TH, Ca and Cl2 were observed to have a satisfactory value well within the standard limits. The presence of E coli was highest in Rupa Lake in comparison to Phewa Lake and Begnas Lake. At upstream left bank it was observed to be highest. The water was examined to be very much unsafe for direct consumption and usage.

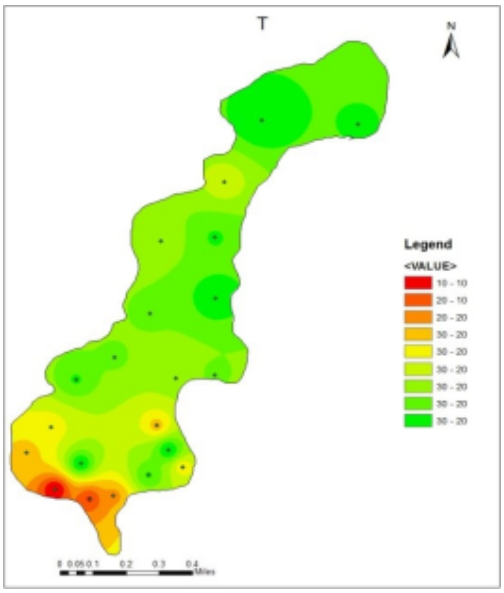

Figure 5: Variation of Turbidity in Rupa Lake

The correlation of data obtained after lab examination were obtained using Python of Pandas Library using a scatter plot function. The correlation of the parameters with one another and own self was observed.

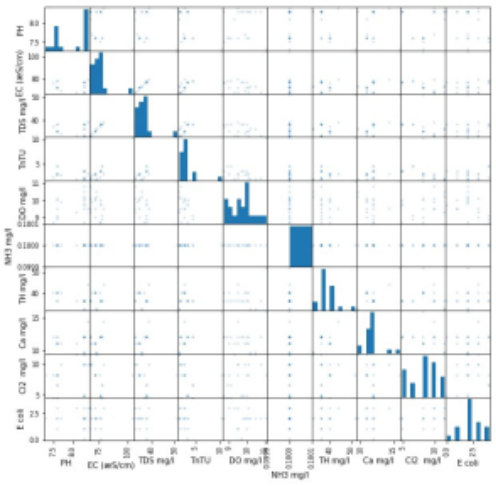

Figure 6: Correlation of Water Quality Parameters

In case of all three lakes, except for Ammonia, all the variables as has been represented by histogram didn't follow normal distribution. There were variations in the values of variables obtained for different points in lakes. Regarding the correlation among the variables,

only the Electrical Conductivity and Total Dissolved Solids seemed to have possessed a perfect correlation. It has been observed that these two shared a linear interrelationship which indicated increment in one with another in all lakes. Besides these, all other variables with one another except with ammonia, rest of other parameters were, found to be poorly correlated as presented in scatter plot diagram where the plots are observed to be highly scattered.

By Canadian Method of Water Quality Index, the value of WQI obtained was 50.36, 65.35 and 44.94 for Phewa, Begnas and Rupa Lake respectively. The water quality of Begnas Lake was obtained to be better among three and Rupa Lake had the poorest of all.

Table 2: Water Quality Index by Canadian Council of Ministers Method

Items	Lake		
	Phewa	Begnas	Rupa
Scope (F1) for number of variables whose objectives are not met	10.00	20.00	20.00
Scope (F2) by number of times which the objectives are not met	10.00	17.83	19.05
Excursion i	1.3+4.3	0.06+1.1	2.76+5.7
Normalised sum of Excursions (nse)	5.60	1.16	10.46
Scope (F3) for amount by which objectives are not met	84.85	53.70	91.27
Water Quality Index	50.36	65.35	44.94

By Weighted arithmetic method, the WQI for Phewa Lake was obtained as 37.7 which indicated water of Grade B and of good quality. For drinking purpose, still purification is needed.

The WQI for Begnas Lake was obtained as 41.9 which indicated water of Grade B and of good quality. The quality has been declined form excellent to good. However the quality is poorer compare to that of Phewa Lake. For drinking still purification is needed.

The WQI for Rupa Lake was obtained as 56.9 which indicate water of Grade C and of poor quality. The water quality of Rupa Lake was obtained to be poorest of three.

The water quality parameters of three lakes so obtained after tests were compared with each other and against Nepal Drinking Water Quality Standards, 2062. Except for Ecoli in all three lakes and Turbidity too in Rupa Lake all the water quality parameters were within the desired limit. The results obtained were too compared with the report regarding water quality of Phewa Lake prepared by Ministry of Population and Environment, 2073. The values when compared with the one obtained by Ministry of Population and Environment, the results seem to be similar but the measurement of total hardness (TH) and ammonia content varies rapidly. This might be because the water parameters vary rapidly during different parts of year and seasons.

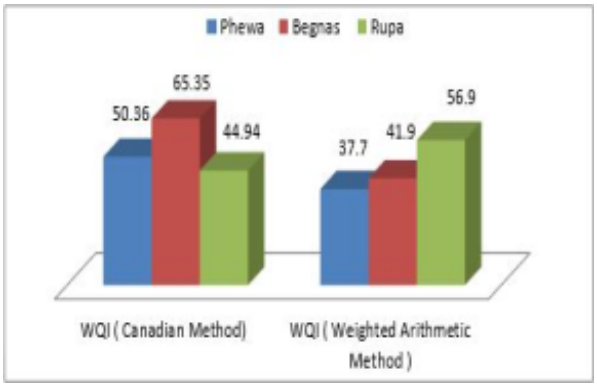

Figure 7: Comparitive Graph of Water Quality Index for Phewa, Begnas and Rupa Lakes

Hence by these two different methods of determining WQI, the Rupa Lake was of poor quality by both methods and the poorest among three. By arithmetic method, water quality of Phewa Lake showed to have better water quality and by Canadian Method, water of Begnas Lake showed to have the better water quality by Canadian method. Arithmetic method is just a mathematical method, and depends less on variation in amount, frequency of test results. Canadian method incorporates these factors more than Arithmetic method to some extent. The more the value of WQI by Canadian method, the more the water is of better quality. Just contrary to this, the lesser the WQI value by Weighted Arithmetic method, the better is the quality of water. Still the quality of water was observed to be only good. Special concerns to improve water quality shall be the need of time.

7. Conclusion

The water quality assessment of three major lakes of Pokhara valley was done based on different physical,chemical and biologial parameters. The water quality within the same lake at different places may differ because of various natural and

Table 3: Weighted Arithmetic WQI of Phewa, Begnas and Rupa Lakes

Parameters	Lakes	pH	EC (μS/cm)	TDS mg/l	Turbidity NTU	NH3 mg/l	DO mg/l	TH mg/l	Ca mg/l	Cl2 mg/l	E-coli
Average value obtained	Phewa	8	74.7	36.7	3.2	0.1	9.7	38	11.8	8.3	2.3
	Begnas	9	64	733	106.98	0.1	8.3	31.5	10.5	14.2	2.1
	Rupa	8.1	67.6	33.9	18.8	0.1	7.3	34.1	14.4	13.4	6.7
MoPE, 2073	Phewa	7.5	50	50	-	-	9	150	-	-	5
	Begnas	7.6	22	15	-	-	7	160	-	-	5
NDWQS	6.5-8.5	<1500	<1000	<5	>5	<1.5	<500	<200	<250	0	
Assigned weight (AW)	2.54	3.22	2.75	2.4	4.09	2.3	2	2	2	3	
Relative weight (RW)	0.1	0.12	0.1	0.09	0.16	0.09	0.08	0.08	0.08	0.11	
Quality Rating Scale (Qi)	Phewa	100	4.98	3.67	64.27	50.83	6.67	7.6	5.89	3.32	100
	Begnas	100	4.27	3.19	93.03	65.4	0	6.3	5.25	5.7	100
	Rupa	100	4.51	3.39	100	100	100	6.82	7.2	5.36	100
Sub Indices (Si)	Phewa	9.66	0.61	0.38	5.86	7.91	0.58	0.58	0.45	0.25	11.41
	Begnas	9.66	0.52	0.33	8.49	10.17	0	0.48	0.4	0.43	11.41
	Rupa	9.66	0.55	0.35	9.13	8.75	15.55	0.52	0.55	0.41	11.41
Water Quality Index $\sum(Si)$										Phewa	37.7
										Begnas	41.9
										Rupa	56.9

anthropogenic causes. While comparing with the standards and after determining the WQI, the water quality in Phewa lake and Begnas lake was observed to be of good quality and but it was poor in case of Rupa Lake. In case of all lakes, pH content was slightly to be basic but it was more in case of Begnas Lake. The average pH value was observed to be 9.0 which was not relatively high considering the probabilities of harm that could cause to aquatic life. If pH gets more than that, and if the lake water is used for irrigation, it might cause some nutrient disorders. Turbidity was too high in case of Rupa Lake which could have been due to excavation activities being done at the upstream hillside of the lake. The presence of E coli was observed in all lakes. This signified that there were presence of faecal decomposition in all these lakes which in case consumed without purification might pose health threats. Effective purification method needs to be adopted before the consumption and any kind of use of lake water. Sedimentation processes for reducing turbidity could be done. The sediment particles could be wiped off. Filtration/ disinfection methods to eliminate E coli content could be recommended to take appropriate approach to control further deterioration and improve the water quality of these lakes. Eutrophication was observed to pose threats. For controlling this, the nutrient excess in lakes and the degree of pollution should be controlled. This could help enhance aesthetic value of city.

Future Enhancements

The study could be extended by determining the variation in water quality of lakes in different seasons. The change in water quality as per depth of the lake could be the future studies. Similarly, the soil structure of catchment of Phewa Lake, Rupa and Begnas seems to be of very different nature for which the study could be done. Also, parameters of water quality measurement may be different in different stagnation water bodies whichh could be looked after.

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