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Water quality assessment in the lakes of Pokhara Valley, Nepal

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Abstract

The bacteriological quality of the Lakes water in Nepal is a limited issue. In the lakes of Pokhara Valley, the water quality reaching to the natural sources are highly contaminated. Water may contain many pathogenic micro-organisms from different sources and some of them may be multiple drugs resistant. The sampling method was purposive sampling method. For the quality assessment, a total of 8 Lakes (Fewa, Begnas, Rupa, Khaste, Depang, Maidi, Neureni and Gunde) were selected within the Pokhara. The study period was from January to February 2017. Water quality was assessed by different physico-chemical parameters like, temperature, pH, TDS, total hardness, alkalinity, BOD. The microbiological analysis was enumerated by membrane filtration technique. Antibiotic senesitivity test of the different isolates towards various antimicrobial discs was done by disk diffusion method. Among the total 136 Samples collected, for the study, all the parameters were on the desirable limits except that of the BOD of Fewa, Begnas, Deepang, Rupa Lakes. The total of 202 isolates of the colony shows the large number of coli form bacteria in all the lakes which suggest fecal contamination. Also most of the bacteria were found to be multiple drugs resistant. Most of the lakes were found to be seriously contaminated with marker organisms suggesting the disquieting situation of water contamination. Rapid action is desired to be taken to get better the bacteriological excellence of the lakes of Pokhara valley.

Keywords: Pokhara, BOD, membrane filtration, coli form, multiple drugs resistant.

Introduction

Escalating rate of urbanization, industrialization, unsystematic agricultural and climate change constantly accelerate the risk of water pollution. The extensive range of water borne pollutants such as nutrients, sediments, acidic compounds, toxic metals, metalloid and biocides are of significant in terms of their easy accessibility to aquatic lives where they accumulate and persist in the body organs causing detrimental effects. Due to extreme water pollution caused by unhealthy human practices such as discharge of untreated sewage and solid waste near or into the Lake, laundering activities, agricultural runoff and sediments[1].

The diarrheal diseases are so widespread in developing countries due to inadequate of water supply and sanitation[2,3]. Each year 1.5 million children die due to the cause of diarrhea diseases may be due to 2.5 billion people have no proper sanitation[4]. In developing countries accounts for 10% diarrheal disease burden[3]. The mortality of water associated diseases exceeds 5 million people per year. Among which, more than 50% are microbial intestinal infections[5]. The presence of Coliform group bacteria is the microbiological indicators for water quality. Free from fecal matter in water is generally considered as important parameter of water quality as its contamination results in greater risk to human health which contains human enteric pathogen, and those are the agent of diarrhea[6].

The first study done in 24 lakes of Nepal located at high level altitude around the Mount Everest region[7], where the Rara is the biggest natural lake of Nepal. That lake area of 9.8 km^2 and has only one channel that joins the river Karnali (river Ghaghra in India), a offshoot of the Ganga[8]. Thermocline in this lake was variable with the 14 to 50 m depth and was recorded as 7.5 to 7.6°C in different areas[9,10].

Fewa, Rupa, Begnas and Khaste lakes in Pokhara Valley, which finally deplete their water into the Saptagandaki river system, are well studied compared to other regions. Temperature, transparency, electrical conductivity, pH and alkalinity of the lakes were investigated followed by species composition, vertical distribution and seasonal variations of phytoplankton [11]. Three major lakes (Fewa Tal, Begnas Tal, and Rupa Tal) were investigated in two seasons to examine the influence of monsoon on their limnological conditions. Calcium concentration in Fewa Tal accounted for 66.3% of the cation and 43% in Begnas Tal and Rupa Tal; anions were predominantly bicarbonate in all three lakes. The survey conducted in Nepal (1989) of lakes including lakes of Pokhara valley[12].

Coli form bacteria have been recognized as a suitable microbial indicator of drinking water quality. The term coli form organism refers to gram negative, oxidase negative, non sporing rods capable of growing aerobically on agar medium containing bile

salts and able to ferment lactose within 48 hours at 35-37^{0}C with the production of both acid and gas. Typical examples of the coliform group are *Escheriachia coli*, *Enterobacter aerogenes, Klebsiella pneumonia* and *Citrobacter* spp.[13,14]. Fecal coliform is thought to be a better indicator of fecal contamination because faecal bacteria tolerate higher environmental temperatures; hence, they are more similar to the fecal-oral pathogens[15].

This research, the quality of lakes water will be determined as it is in standard or deviation from them. Knowing the quality of water can act as a major attribute in formulation of necessary and suitable preventive and conservative measures for the concerned water sources. Water may contain many pathogenic micro-organisms from different sources and some of them may be multiple drugs resistant and may act as the source for spread of antibiotic resistance. Thus, a research based model plan has been proposed to assess the quality and risk of water pollution of lakes.

Methodology

This study was conducted in Pokhara and Lekhnath Municipality. It is located in the Gandaki zone, Nepal. Among the many lakes in Pokhara Valley, Fewa Lake is the largest; Begnas Lake is second largest lake and Rupa Tal the third in the Valley and the rest are Khaste, Depang, Maidi, Neureni and Gunde. An experimental study was conducted from February to June 2017. The sampling method was purposive sampling method. All the 8 lakes were taken on the basis of survey among local peoples and the sampling also most represents wise distribution of the lakes.

Water samples were taken for quality assessment. Standard method for analysis of water and wastewater were followed for sample collection, preservation as well as physical (temperature, pH, color, TDS), chemical (alkalinity, hardness, DO, BOD) and microbiological (isolation of bacteria, identification of bacteria, antibiotic sensitivity testing of isolates) assessment[16]. Samples were collected at the morning time. The physic-chemical parameters were measured or fixed at the sampling sites by water quality test kit. All the data will be managed in MS excel spreadsheet and SPSS software will be used for data analysis.

Results and discussion

Study of pH among the different sample from different sides: The study was done in the different lakes of Pokhara valley and adjoining area of the duping side of Pokhara valley. A total 136 Samples were collected for the study. The examined physicochemical and microbiological parameters showed considerable variations in different samples. The analysis and interpretation are shown in the tables.

Status of temperature with the different sample sides: Among the total 136 sample, the pH ranging from 6 to 7. Most of the samples were on pH 6.5-7.0 (64.7%) and only two samples were pH more then 7. The pH value of the lake water was within the range for aquaculture, irrigation and recreational use. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity. This might be due to the variation in physio-chemical condition[17].

The study shown the slightly varies water temperature was ranging from around 22-24^{0}C. In an established system the affect of fish growth, reproduction and immunity are due to management of water temperature and the speed of all chemical reactions. Drastic temperature changes can be fatal to fish. The variation in the water temperature may be due to different timing of collection and influence of season[18,19].

Assessment of alkalinity level (per 100 ml) in different lakes and others: Alkalinity protects or buffers against rapid pH changes which are important for fish and aquatic life because living organisms, especially aquatic life best function in a pH of 6.0 to 9.0. How much acid can be added to a liquid without causing a large change in pH is a measure of alkalinity. Acid rains are buffered by surface water which are highly alkaline, this prevent the alteration of pH otherwise which may be harmful to aquatic life like fish.

Table-1: Status of pH in different sample from different sides.

	Name of sampling sites									Total
pH	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤6.5	0 (.0%)	10 (7.4%)	0 (.0%)	0 (.0%)	10 (7.4%)	10 (7.4%)	6 (4.4%)	10 (7.4%)	0 (.0%)	46 (33.8%)
6.5-7.0	24 (17.6%)	0 (.0%)	8 (5.9%)	28 (20.6%)	0 (.0%)	0 (.0%)	4 (2.9%)	0 (.0%)	24 (17.6%)	88 (64.7%)
≥7.0	0 (.0%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	2 (1.5%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Study of TDS of different water samples: Inorganic salts and small amounts of organic matter present in water can be used to describe total dissolved solids (TDS). The primary constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions.

High level of total dissolved solids (TDS) was a remarkable observation in the investigation which was alarming. The TDS of all the samples were in range of 100-800 ppt (parts per thousand) while the maximum permissible limiting value of TDS for potable water is 0.5 ppt according to WHO [19]. Presence of high level of TDS in water for drinking purposes results to many diseases which are not water-borne but due to presence of excess salts. For endemic acute gastrointestinal illness (AGI) the US Environmental Protection Agency (EPA) presents a conceptual approach for developing a national estimate which is due to portable water and through a nobel application developed a national estimate analysis[5,16].

Table-2: Analysis of Temperature with the different sample sides.

	Name of lake									Total
Temp	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤23	0 (.0%)	0 (.0%)	0 (.0%)	28 20.6%)	0 (.0%)	0 (.0%)	10 (7.4%)	0 (.0%)	24 (17.6%)	62 (45.6%)
23-24	0 (.0%)	10 (7.4%)	8 (5.9%)	0 (.0%)	10 (7.4%)	10 (7.4%)	0 (.0%)	10 (7.4%)	0 (.0%)	48 (35.3%)
≥24	24 (17.6%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	26 (19.1%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Table-3: Level of alkalinity (per 100 ml) in different lakes and others.

	Name of lake									Total
Total alkalinity	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤50	24 (17.6%)	4 (2.9%)	0 (.0%)	16 (11.8%)	4 (2.9%)	10 (7.4%)	0 (.0%)	0 (.0%)	22 (16.2%)	80 (58.8%)
50-100	0 (.0%)	6 (4.4%)	0 (.0%)	12 (8.8%)	6 (4.4%)	0 (.0%)	6 (4.4%)	6 (4.4%)	2 (1.5%)	38 (27.9%)
100-150	0 (.0%)	0 (.0%)	8 (5.9%)	0 (.0%)	0 (.0%)	0 (.0%)	4 (2.9%)	4 (2.9%)	0 (.0%)	16 (11.8%)
≥200	0 (.0%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	2 (1.5%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Table-3: Total dissolve solids of different water samples.

	Name of lake									Total
TDS	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤400	12 (8.8%)	10 (7.4%)	7 (5.1%)	26 (19.1%)	10 (7.4%)	8 (5.9%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	103 (75.7%)
400-500	8 (5.9%)	0 (.0%)	0 (.0%)	2 (1.5%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	4 (2.9%)	16 (11.8%)
500-600	4 (2.9%)	0 (.0%)	3 (2.2%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	4 (2.9%)	11 (8.1%)
≥600	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	6 (4.4%)	6 (4.4%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Study of hardness of different water samples: Hardness of water is due to the two most common minerals calcium and magnesium dissolved in water[20,21]. The hardness was found to be in the range of 3.8-11.8mg/lit. It is within desirable limit. In ground water or natural source of water calcium are common in concentrations up to 100mg/l. In natural groundwater Magnesium is usually present at lower concentrations (from negligible to about 50mg/l and rarely above 100mg/l), so presence of calcium hardness usually predominates[16].

Study of BOD of different water samples: Dissolved oxygen are the measure of BOD is which is consumed by microorganisms. Amount of dissolved oxygen in water directly affects BOD. This study shows variation in the BOD of the lakes. The Begnas, Deepang, Fewa and Rupa Lake had the BOD lowest through 3 which suggest the presence of the aquatic habitat in considerable amount than those lakes which have BOD highest through 5. Khaste lake had BOD amount more than 5 (2) and within 3-5 (8) and Gudi (10), Maidi (10), Neurani (10)) had within the remarkable range of BOD. Higher the BOD, more rapidly oxygen is decline which means low O_2 is accessible for higher forms of aquatic existence.

Mean physiochemical Parameters value of different water samples: The study shows that all the lakes have the mean pH value in the range of 6-7 without any variation in the mean pH of the water. Also the temperature was in the range of 23^{o}C which may be due the similar duration of time for the sample collection from the lake. The mean total alkalinity showed the variation from one lake to another. The Khaste Lake showed the minimum value of 36/100ml whereas the Rupa Lake had the total alkalinity in the range of 500/ml. Also the sample collected from the dumping site showed the total alkalinity in the range of mean 166.25/100ml. The mean total dissolved solid (TDS) of all the lakes was in the range of 100-500 ppt. The mean total hardness was found in the normal range except that of the Dumping side which suggests presence of the minerals and any other impurities in the source. The mean Biological Oxygen demand (BOD) is in the limit lowest through 3 except those of the four lakes Gudi, Khastee, Neurani and Maidi. This suggests that the water is not suitable for the aquatic habitat. This may be due to the presence of the dead plants and animals; animal manure and also may be lack of the proper cleanliness of the source of the lakes.

Table-4: Status of hardness among different water samples.

Total hardness	Name of lake									Total
	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤50	24 (17.6%)	10 (7.4%)	0 (.0%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	6 (4.4%)	24 (17.6%)	122 (89.7%)
50-100	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	4 (2.9%)	0 (.0%)	4 (2.9%)
100-150	0 (.0%)	0 (.0%)	8 (5.9%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	8 (5.9%)
≥150	0 (.0%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	2 (1.5%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Table-5: Comparative Study of BOD of different water samples.

	Name of lake									Total
BOD	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
≤3	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	24 (17.6%)	96 (70.6%)
3-5	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	10 (7.4%)	8 (5.9%)	10 (7.4%)	10 (7.4%)	0 (.0%)	38 (27.9%)
≥5	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	2 (1.5%)	0 (.0%)	0 (.0%)	0 (.0%)	2 (1.5%)
Total	24 (17.6%)	10 (7.4%)	10 (7.4%)	28 (20.6%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	10 (7.4%)	24 (17.6%)	136 (100.0%)

Study the bacteriological profile of isolated from different water samples: Among the total of 202 isolates of the colony there shows the large number of coliform bacteria in all the lakes especially in Fewa Lake which suggests facial contamination. *Klebsiella pneumonia* is the common bacterial isolates in both lakes and dumping side which is considered as the coliform bacteria with fecal contamination. *Citrobacter* spp is also the common isolates in the lakes. It is also commonly found to be a member of the soil microbiome. This microbe plays an important role in the nitrogen cycle in the environment. *C. freundii* is responsible for reducing nitrate to nitrite in environment.

The pseudomonas dermatitis outbreaks are associated with hot tubs and are preventable if water is maintained at a pH of 7.2-7.8 with free, residual chlorine levels in the range of 2.0-5.0 mg/L (CDC, 1981).

Citrobacter, *Klebsiella* and *Enterobacter* are present in low numbers in the human intestine and are widespread in environmental waters, and therefore are also not suitable as indicators of fecal pollution[5], Salmonella and shigella spp. are the common pathogen isolated after the fecal coliforms which is common in all the lakes except dumping sites. The principal habitat of salmonella and shigella is the intestinal tract of humans and animals[22].

Table-6: Comparative Mean of physiochemical Parameters value in different water samples.

Name of sampling sites	pH	Temp	T alk/100ml	TDS	Total Hardness / 50ml	BOD
Deepang	6	23.74	56	148	10	1.74
Maidi	6.46	22.5	90	160	18.8	3.86
Neurani	6.4	24	85	200	44.4	3.58
Khastee	6	24	36	252	12	4.48
Gudi	6.22	23.2	53.8	260	19.6	4.36
Rupa	6.74	22.4	40	500	24.5	1.19
Begnas	6.83	24.5	27.25	402.5	16	1.59
Fewa	6.72	22.7	51.4	228.57	35.42	1.82
Dumping	6.93	23.5	166.25	400	150	1.38

Table-7: Bacteriological profile of isolated from different water samples.

	Name of lake and dumping side									Total
Bacteria	Begnas	Deepang	Dumping	Fewa	Gudi	Khastee	Maidi	Neurani	Rupa	
Acinetobacter spp	2	0	0	0	0	0	0	0	2	4
Citrobacter spp	2	0	0	2	2	10	4	4	4	28
E. coli	2	6	0	14	4	0	6	10	4	50
Enterobacter spp	8	0	0	6	0	0	0	0	2	16
K. oxytoca	2	0	2	4	0	0	0	0	8	16
K. pneumonia	4	6	9	12	4	0	6	4	6	51
P. mirabillus	2	0	4	2	0	0	0	0	0	8
P. vulgaris	2	0	2	6	0	0	0	0	0	10
Salmonella spp	2	1	0	4	2	2	1	1	0	13
Shigella spp	1	1	0	2	0	1	0	0	1	6
Total	27	8	17	52	12	13	17	19	27	202

Study the Antibiotics sensitivity pattern of isolated from different water samples: Different studies have mention the antibiotic resistance pattern of feacal indicator bacteria to examine the source of feacal pollution in the aquatic environment[23,24]. The highlight reasons causing the marine environmental contamination were improper and unnecessary use of antimicrobial drugs by human and animals[25]. The study reveals the microbial population for antibiotic resistance profile to different classes of antibiotics showed a high ratio of strains resistance to β-lactam antibiotics, followed by resistant to macrolides[26,27].

From this study we can suggest that the aquatic habitats of the Lakes are deteriorating whether due to the lack of the proper planning of sanitation towards the lake or proper management of it source. Extreme water pollution are caused by unhealthy human practices such as discharge of untreated sewage and solid waste near or into the Lakes, laundering activities, agricultural run-off and sediments are also increasing the pollution of Lakes.

Table 8: Antibiotics sensitivity pattern of isolated from different water samples.

Antibiotics		Acinetobacter N=4	Citrobacter N=28	E. coli N=50	Enterobacter N=16	K. oxytoca N=16	K. pneumonia N=51	P. mirabillus N=8	P. vulgaris N=10	Salmonella spp N=13	Shigella spp N=6
Amikacin (30 mcg)	S	0	4	4	0	16	44	0	0	0	0
	I	0	2	0	0	0	7	0	0	0	0
	R	4	22	46	16	0	0	8	10	13	6
Ciprofloxacin (5 mcg)	S	4	28	46	16	16	51	8	10	12	
	I	0	0	4	0	0	0	0	0	0	6
	R	0	0	0	0	0	0	0	0	1	0
Gentamicin (30 mcg)	S	4	28	40	16	16	48	6	10	13	6
	I	0	0	4	0	0	0	1	0	0	0
	R	0	0	6	0	0	3	1	0	0	0
Norfloxacin (10 mcg)	S	4	28	48	16	16	51	7	10	13	3
	I	0	0	2	0	0	0	1	0	0	3
	R	0	0	0	0	0	0	0	0	0	0
Nitrofurantoin (300 mcg)	S	0	2	4	6	9	48	2	10	4	4
	I	0	0	44	0	0	3	1	0	1	1
	R	4	26	2	10	7	0	5	0	8	1
Nalidixic acid (30mcg)	S	0	28	34	16	12	51	7	10	13	0
	I	0	0	4	0	4	0	1	0	0	0
	R	4	0	12	0	0	0	0	0	0	6
Cotrimoxazole (25 mcg)	S	2	4	46	16	13	44	2	0	13	2
	I	2	2	2	0	3	0	0	0	0	3
	R	0	22	2	0	0	7	6	10	0	1

Conclusion

All the parameters were more or less on desirable limits except that of the BOD of fewa, Begnas, Deepang, Rupa Lakes according to WHO guideline which suggests the presence of the aquatic habitat in considerable amount than those lake which have BOD highest through 5. It is found that the water of most of the lakes and Seti river were used for different activities like bathing, swimming and washing as well for irrigation and for waste dumping this can be the major reason for deteriorating the conditions of these areas. The person may get infected through these routes indirectly by the coliform and other bacteria as well. The result shows multiple pathogenic bacteria also multidrug resistant pattern were found in the isolated colony too which may show adverse effect on its exposure directly or indirectly through any source.

Recommendation: The study suggests that Chemical and microbiological parameters should be monitored for identifying source of possible contamination and proper bioremediation techniques should be carried out to improve the water quality. Oxygen depletion can cause fish kills and lack of fish increases malaria-hosting mosquitoes as mosquitoes are normal food for fish. Absence of oxygen at the bottom, useful bacteria and insects cannot biodegrade the organic sediment. Before introducing any foreign material into the water body, purification methods should be carried out.

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