WATER QUALITY IN POKHARA: A STUDY WITH MICROBIOLOGICAL ASPECTS

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Abstract

Obviously, water management is challenging issue in developing world. Dwellers of Pokhara use water from government supply along with deep borings and other sources as well. Nowadays, people are also showing tendency towards more use of processed water. In spite of its importance, quality analysis of water has been less emphasized by concerned sectors in our cities including Pokhara. The study aimed for qualitative analysis of water in the city with focus on microbiological aspects. For this purpose, results of laboratory examination of water samples from major sources of government supply, deep borings, hospitals, academic institutions as well as key water bodies situated in Pokhara were analyzed. Since water borne diseases are considered quite common in the area, presence of coliform bacteria was considered for the study to assess the question on availability of safe water. The result showed that all the samples during wet seasons of major water sources of water in Pokhara were contaminated by coliform bacteria. Likewise, in all 20 locations of Seti River, the coliform bacteria were recorded. Similar results with biological contamination in all samples were observed after laboratory examination of more than 60 locations of all three lakes: Phewa Lake, Begnas Lake and Rupa Lake in Pokhara. The presence of such bacteria in most of the water samples of main sources during wet seasons revealed the possibilities of spreading water related diseases. Again, microbiological contamination observed from significant number of bottled water samples as well as boring sources clearly alarmed the preoccupied belief in such supply of water. On the other hand, fluctuating water quality of academic institutions and hospitals questioned on the priority of the management and seriousness against possible spreading of water borne diseases. For obtaining the safe water, various treatment options have been recommended from World Health Organization (WHO) with chlorination in top priority due to affordability and simplicity. Urgent execution of such option could be important with due consideration of negative aspects from the possible byproducts. However, proper implementation of filtration technique and planning of further advanced technology could be valuable for fulfilling the need of metropolitan dwellers to get wholesome water for their daily consumption.

Keywords

Water quality, coliform bacteria, WHO, chlorination, sand filtration

1. Introduction

Pokhara is the capital city of Gandaki Province in Nepal. The city was established as municipality in 1960 A.D. (2016 B.S.) meeting the immediate criteria of 5,000 population/inhabitants for announcement of municipality (Pokhara Metropolitan City, 2020).

Table 1: Population of Pokhara (Nepal) in Different Years

S. No.	Year (A.D.)	Population	Data Source
1.	1952	3,755	PSMC (1999) and Adhikari (2000)
2.	1961	5,413	
3.	1971	20,611	
4.	1981	46,642	
5.	1991	95,268	
6.	1998	157,000	
7.	2008	2,26,000	(https://www.macrotrends.net/cities/23352/pokhara/population)
8.	2018	3,84,000	
9.	2020	4,21,000	

Similarly, population expansion rate in Pokhara is also following sharp trend with at least twice of national population growth rate while considering data since 1961 A.D. with some exception (Adhikari, 2000).
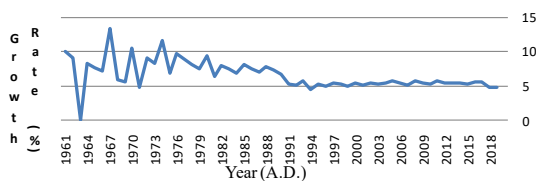

Figure 1: Population Growth Rate (%) of Pokhara in Different Years

(Source: https://www.macrotrends.net/cities)

On the other hand, there was excessively increasing tendency of built up area in Pokhara with continuous and significant reduction of cultivated land for the purpose of residential areas.

Table 2: Variation in Land Use Pattern of Pokhara

Year (A.D.)	Built Up Area (%)	Cultivated Land (%)	Water Body (%)	Forest Cover (%)
1977	6.33	60.73	13.97	1.52
1990	20.08	52.76	12.38	1.36
1999	33.66	38.70	12.84	1.57
2010	51.42	20.27	12.69	2.21

(Source: Rimal, 2013)

Such extremely increasing built up area has been leading towards demand of additional infrastructure facilities to cater the need of inhabitants in Pokhara and can be expected or even accelerating the same with its progress for international air connectivity. The situation is challenging the infrastructure needs of Pokhara including aspects of transportation, residence, health and education facilities including water and waste water management. Out of these, management of water with quality as per standard could be a major aspect of study.

Globally, maintaining water quality is quite big issue. As per World Health Organization (WHO), only 71% people are considered to have access to safely managed drinking water system. On the other hand, more than 2 billion people are considered to use drinking water sources contaminated with human waste (including feces). Moreover, about 297,000 children/infants are losing their life every year from diarrhea caused by improper water quality with lack of hygiene and sanitation (https://www.who.int/news-room/fact-sheets/detail/drinking-water). Again, 1.8 Million people died from water related diseases in 2015 according to

The Global Burden of Disease Study (Biswas and Tortajada, 2019). Again, a study of government schools in India revealed that 39.8% of water samples were observed unfit for drinking with coliform bacteria (Sidhu et. al.; 2016).

It is precious to state that, the United Nations General Assembly (UNGA) recognized access to safe and clean drinking water and sanitation as a human right in 2010 in spite of enough challenges for attaining quality water in least developed countries (https://en.unesco.org/waterquality-iiwq/wq-challenge). Though United Nations' Sustainable Development Goal (SDG) No. 6 has set target to provide access to safe drinking water for 100% of the population in each country, socio-economic constraints, lack of monitoring and reporting water quality data and reduction of water pollution are major barriers (Metcalf et. al; 2017) to achieve the same within mentioned time frame.

Table 3: Water Quality of Various Rivers in Nepal

Location /River	pH	Total Dissolved Solids (mg/l)	Dissolved Oxygen (mg/l)	Biochemical Oxygen Demand (BOD) (mg/l)
Mechi	8.3	30	8.9	1.8
Kankai	7.7	60	8.7	2.0
Arun	6.2	222	9.1	2.1
Seti (at Ramghat Pokhara)	8.2	208	9.3	2.0
Bheri (at Chatgaon)	7.8	208	9.3	1.1
Karnali (at Chisapani)	7.8	264	10.5	1.5
Mahakali (at Panchesor)	8.8	110	5	2.0
WHO Guideline Value	6.5 - 8.5	100	>5	3

(Source: CBS, 2019)

Though Environmental Statistics of Nepal (CBS, 2019) showed the physical, chemical and biological aspects of water quality in major rivers of Nepal were observed within the standard range of World Health Organization (WHO), water from only 29% of deep wells in context of Kathmandu Valley was observed drinkable while considering the presence of Escherichia coli (Sakamoto, 2012). Similarly, analysis of water samples collected from Dug wells (37 samples), Shallow Tube Wells (38 samples), Stone Spouts/Dhunge Dhara (16 samples), Deep Tube Wells (5 samples) and Municipal Sources (19 samples) in Kathmandu revealed that samples from all the sources had E. Coli as well as Total Coliform bacteria showing contamination in major sources of water supply to the consumers in the capital. In this case, 86% samples from Dug Wells were detected with microbiological pollution (Warner et.al.; 2008) followed by Municipal Sources with 73%. Moreover, the two third of samples with presence of total coliform bacteria while analyzing water quality of the metropolitan also insisted to be serious about water quality issue in Kathmandu (Tamrakar et.al.; 2017).

On the other hand, all water samples from Mardi River (Major water source of Pokhara) were observed with coliform bacteria (Shah, 2012). Similar result was achieved with presence of the same bacteria while analyzing water quality of Seti River (https://opendatanepal.com). Moreover, only about 55% coverage in

Pokhara was observed to meet the water quality standard with national average value of 43% in overall water systems of Nepal (NWSC, WSMB and KUKL, 2016).

Such situations clearly indicated that microbiological aspects of water quality is quite essential part to be analyzed since people are getting troubled water related diseases with lack of safe water. Following excessive growing trend of urbanization in Pokhara with more than 50% land area covering by the built up area (Rimal, 2013) along with lack of standard water treatment process, it could be valuable to analyze about quality of supplied water. Of course, focus on microbiological pollution is precious for prevention of water related diseases mostly occurring in cities of Least Developing Countries (LDCs) including Pokhara. Till now, quality of water from individual source of was analyzed by many researchers but there was lack of overall approach to discuss about the water quality in Pokhara including water sources as well as water bodies. Such study gap impelled to assess overall water quality in context of Pokhara considering microbiological aspects.

2. Objectives of Study

The key objective of this study was to analyze water quality of various sources and locations of Pokhara considering microbiological aspects. The study aimed to cover major water sources including surface water and ground water, lakes and river including important institutions along with processed water in Pokhara, Nepal as well. Moreover, recommendation of appropriate measures for water quality improvement was also intended by this study.

3. Study Area

The study area; Pokhara is a well-known metro city in Nepal for natural beauty with area of 464.24 Sq. Km. The city was formally announced as metropolitan city on 10th March 2017 A.D.

Figure 2: Pokhara Metropolitan City with Its Coverage Area

(Source: Pokhara Metropolitan City, 2020)

containing 33 divisions (wards) which enclosed former Pokhara Sub-metropolitan City, Lekhnath Municipality and various villages namely; Mauja, Chapakot, Bhadaure Tamagi, Kaski Kot Majhthana, Kalika and Puranchaur (http://pokharamun.gov.np/content). In this article, major sources of water in Pokhara along with key water bodies were covered for this analysis as following.

Sources of Water: Mardi River, Bhoti Khola, Majhkuna Spring, Baldhara Spring, Ghattekhola

Spring, Kalimudha Spring.

Water Bodies: Seti River, Phewa Lake, Rupa Lake, Begnas Lake.

Deep Borings: Phulbari, Lamachaur, Bagar, Rastrabank Chowk, Shreekrishna Chowk, Rambazaar

Hospitals: 14 Hospitals in Pokhara.

Academic Institutions: 4 Government Campuses (Higher Educational Institutions) in Pokhara.

4. Study Methodology

Available resources including research articles on different aspects of Pokhara as well as publication from Pokhara Metropolitan City Office were consulted in this study. Similarly, various statistical data concerned with infrastructures and population trend in Pokhara were also considered. Likewise, References related to the water quality in the study area along with concerned data from environmental statistics of Nepal were followed during this review.
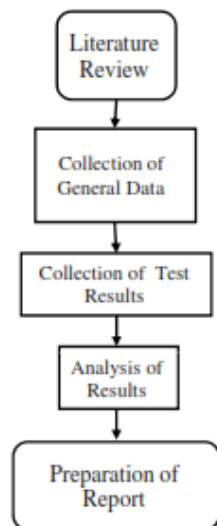
Figure 3: Flow Diagram of Study Methodology

For data analysis with focus on microbiological aspects, water quality results obtained from project works as well as outputs of academic research works focusing key water sources/ water bodies of Pokhara area were considered for this article.

Figure 4: Water Sample Collection and Laboratory Examination

These results of quality examination of water samples from hospitals, academic institutions, sources, processed water bottles, deep borings as well as lakes (Phewa Lake, Begnas Lake, Rupa Lake) and river (Seti River) were mainly considered for analysis in this study. Such examination of water quality of collected water samples were conducted in water laboratories following standard procedures including tube test kits and membrane filtration for microbiological quality assessment for academic purpose by corresponding individual or group after collection of water samples accordingly.

5. Results and Discussion

5.1 Water Quality of Sources

Study of water quality at major sources of Pokhara revealed the microbiological water pollution.

Table 4: Status of Coliform Bacteria at Water Sources of Pokhara

Description	Status of Coliform Bacteria		Remarks
	Dry Season	**Wet Season**	
Source 1	-	Present	Mardi Intake 1
Source 2	-	Present	Mardi Intake 2
Source 3	-	Present	Bhotikhola Intake 1
Source 4	-	Present	Bhotikhola Intake 2
Source 5	-	Present	Majhkuna Spring
Source 6	-	Present	Ghattekhola Spring
Source 7	-	Present	Kalimudha Spring
Source 8	-	Present	Baldhara Spring

(Source: Bhatta et. al. 2014)

during wet season in most of the cases. On the contrary, it clearly indicated absences of coliform bacteria in all water samples of the water sources (Bhatta et. al.; 2014). Similar result was obtained by Shah (2012) while determining water quality index of Mardi River (major source of water supply in Pokhara) with all water samples at all five locations having presence of coliform bacteria. Presence of fecal coliform could be due to disposal of household waste including night soil being carried by storm water.

5.2 Water Quality of Hospitals

Since the healthcare facilities are places to improve health condition, it could be worth to assess whether people are susceptible to water related diseases by consuming water in such institutions or not. Following water quality examination in these locations, water samples from 5 out of total 14 hospitals in Pokhara were having coliform bacteria during dry season. On the other hand, 85.7% water samples were observed with the same bacteria from the results of water quality examination of wet

season samples (Thakali et. al.; 2015). Of course, municipal supply of water with microbiological contamination and lack of institutional treatment works could be major reason for such poor water quality in both seasons.
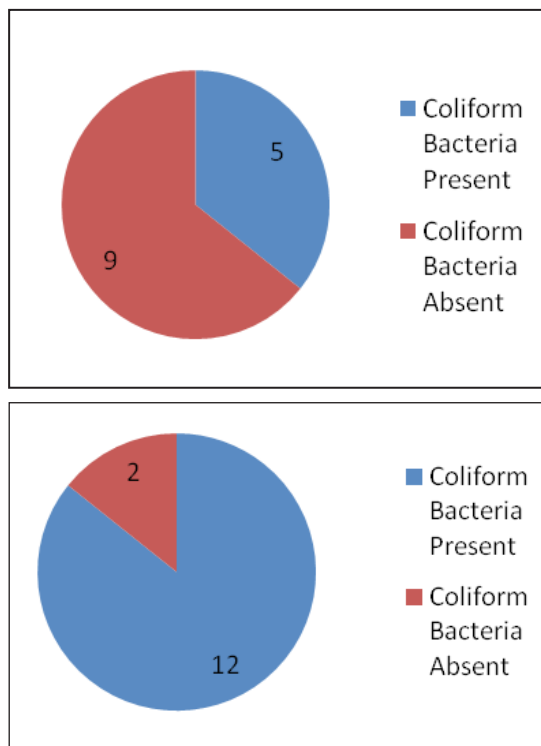

Figure 3: Number of Hospitals in Pokhara with Status of Coliform Bacteria in Water Samples of Dry Season and Wet Season (Thakali et. al; 2015)

The scenario revealed the poor water quality condition of hospitals in Pokhara with need of further improvement before consumption or even critical use including medical/surgical purposes.

5.3 Water Quality of Bottled Water

A microbiological study of bottled/processed drinking water in Pokhara indicated the presence of total coliform in 38% monsoon water samples out of 21 brands though there was absence of the same in pre-monsoon water

samples (Maskey et. al.; 2020). Significant presence of coliform bacteria in water samples at monsoon season indicated the lack of proper quality management of water processing plants questioning the consistency of the treatment processes. This scenario also expressed the poor quality of bottled water during rainy season against the general public consideration of proper water quality and belief as well.

Table 5: Total Coliform Risk of Bottled Drinking Water

Range of Total Coliform (CFU/100 ml)	Number of Pre-monsoon Samples	Number of Monsoon Samples
0	-	13
1-10	-	4
11-100	-	1
101- >1000	-	3

(Source: Maskey et. al.; 2020)

5.4 Water Quality at Deep Borings

While analyzing water quality of deep borings at government and other sectors, the water samples were observed with absence of coliform bacteria during dry season compared to their presence in some cases of wet season. Infiltration of surface water polluted with waste water could be the cause of positive cases during wet season.

Again, results showing the coliform bacteria during wet season mentioned the need of improving water quality of deep borings before drinking or other consumptions.

Table 6: Status of Total Coliform in Boring Water Samples

Description	Status of Coliform Bacteria		Remarks
	Dry Season	Wet Season	
Deep Boring 1-	-		Fulbari
Deep Boring 2-	-		Shreekrishna Chowk
Deep Boring 3-		Present	Rastra Bank Chowk
Deep Boring 4-	-		Lamachaur Boring
Deep Boring 5-	-		Bagar Boring
Deep Boring 6-	-		Ramghat Boring
Deep Boring 7-		Present	Phulbari Boring
Deep Boring 8-	-		Private Boring

(Source: Bhatta et. al. 2014)

5.5 Water Quality at Higher Education Institutions

Obviously, it could be an important aspect to know about the quality of water being consumed in the academic institutions where concerns of water are being discussed/analyzed. A study on water quality analysis at four higher education institutions/campuses at Pokhara revealed that the water samples were free from Escherichia coli at pre-monsoon samples against presence with significant numbers at post-monsoon samples (Shrestha, 2020).
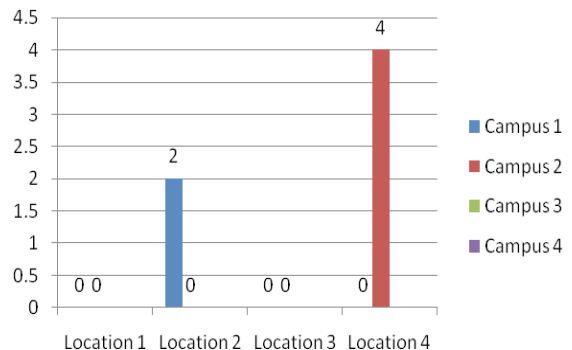

Figure 4: Presence of Escherichia coli in Post Monsoon Water Samples from Higher Education Institutions (Source: Shrestha, 2020)

This scenario of microbiological contamination in ground water at these academic institutions could be due to contamination of such water sources demanding greater depth to extract water without influence of pollution during rainy season.

5.6   Water Quality at Lakes and River

Corresponding studies on water quality analysis of three lakes and Seti River in Pokhara also pointed out poor conditions with presence of Escherichia coli (E.coli) in water samples collected at all sampling locations of Seti River (20 sampling locations), Phewa Lake (20 sampling locations), Begnas Lake (23 sampling locations) and Rupa Lake (21 sampling locations) as per Paudel (2019) and Sadadev (2019).
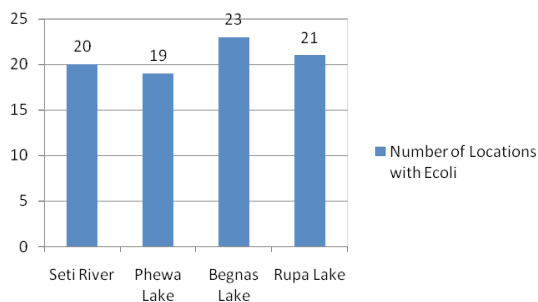

Figure 5: Presence of Escherichia coli in Water Samples of Lakes and River

(Source: Paudel, 2019 and Sadadev, 2019).

Of course, observation of all water samples with presence of E.coli in Seti River and three lakes of Pokhara could be a vital issue. It would be significant to mention the examples of directly visible cases of disposing toilet/septic tank effluents from households/commercial structures in Seti River/Lake. Moreover, improper management or even lack of management of fecal waste in surroundings of the sources and direct discharge of produced waste water from many areas could be major reasons beyond the scenario with great challenge in government policy of reviving the water bodies in pristine condition. Also, lack of water quality in such major tourist destinations of Pokhara might influence the hesitation in recreational activities with direct impact on socio-economic and cultural aspects.

5.7 Summary of Water Quality Results

While analyzing data concerned with microbiological water quality results in various sources/sectors of water supply in Pokhara, most of the samples showed the condition of pollution while comparing with the standard value to be nil as per National Drinking Quality Standard (MoPPW, 2005) as well as guidelines from WHO (WHO, 2017).

Table 7: Summary of Microbiological Water Quality Results

Description	Sampling Locations	Positive Result of Microbiological Analysis	Status of Micro-biological Pollution
Sources(Dry Season)	8	Nil	
Sources (Dry Season)	8	8	
Hospitals (Dry Season)	14	5	
Hospitals (Wet Season)	14	9	
Bottled Water	21	21	
Boring Water (Dry Season)	8	Nil	**Polluted**
Boring Water (Wet Season)	8	2	
Higher Education Institutions (Pre-monsoon)	12	Nil	
Higher Education Institutions (Post-monsoon)	12	6	
Seti River	20	20	
Phewa Lake	20	19	
Begnas Lake	23	23	
Rupa Lake	21	21	

5.8 Discussions for Quality Improvement

The scenario of microbiological pollution essentially demanded immediate need of efficient water purification method to be applied before consumption of water from the mentioned sources/locations challenging the current measures (with chlorination applied in government supply only).

In this consequence, CAWST (2009) has stated chlorination to be efficient for removal of bacteria and effective for killing virus, protozoa and helminthes as well.

As per Drinking Water Quality Guidelines of World Health Organization (2017), appropriate Methods for water purification are chlorination as well as filtration. Though membrane technologies as well as granular activated carbon treatments are the advanced ones, cost effectiveness as well as technical complexity is key issues associated.

Table 8: Appropriate Water Purification Process Recommended by WHO

Ranking	Treatment Process
1	Simple Chlorination
2	Plain Filtration (Rapid Sand, Slow Sand)
3	Pre-chlorination + Filtration, Aeration
4	Granular Activated Carbon (GAC) Treatment, Ion Exchange
5	Ozonation
6	Advance Oxidation Processes, Membrane Treatment

(Source: WHO, 2017)

While using appropriate treatment for removal of microorganisms, one crucial aspect is to consider the effect of disinfection by product (DBP) mainly after chlorination. Since formation of Trihalomethane (THM) can form if chlorine combines with Humic Acid/

Fulvic Acid from organic content in water which may lead for carcinogenic conditions (https://www.cdc.gov). Such scenario shall be addressed by considering short term (including chlorination) and long-term Methods (sand filtration, membrane technology) of killing microorganisms in water.

Table 9: Removal efficiencies of various Point of Use (PoU) Treatment System Options

Water treatment method	Removal of Turbidity	Removal efficiency of Fecal Coliform	Reference
Bio-sand filter	98 %	99.1 – 99.9 %	Sagara, 1999
Ceramic filter	94 %	92 %	Shrestha *et al.*, 2007
Chlorine solution (0.5%)	NA	>99 %	https://www.who.int/water_sanitation_health
SODIS	NA	90 – 95 %	Shrestha *et al.*, 2007
Boiling (5 minutes)	NA	99.999 %	https://www.who.int/water_sanitation_health

On the other hand, application of point of use (PoU) water treatment at household/ institutional level could also be a valuable option. Since most of the water samples were observed with the coliform bacteria, Bio-sand filter, use of chlorine solution (with managing the effect of DBP) or even boiling (in small level) could be precious to cope the issue of microbiological contamination since all these Methods are stated to have efficiency more than 99% to remove fecal coliform.

6.   Conclusions

The water quality studies undoubtedly mentioned the apparent status of microbiological pollution in major water sources including samples from underground water sources, Seti River and three lakes in Pokhara. With the background of commonly spreading usual water borne diseases, immediate actions shall be executed to prevent/control the possible situation. Chlorination, being the easiest approach, can be applied as a immediate solution with due consideration of possible negative consequences of disinfection by products. However, long term strategy shall be valuable to plan and execute including efficient sand filters or even membrane technology. Ongoing construction of filtration works shall be expected to be significant to manage the crucial condition following timely completion with efficient results for purification to provide clean and safe water in Pokhara. Of course, regular analysis of water quality through academic studies/research could be precious for monitoring and addressing such critical issue directly related to the public health in the metropolitan city towards fulfilling the people's right for obtaining safe water.

Limitations

This review article was based upon analysis of water quality from various sectors in Pokhara with laboratory results of collected water samples during various studies including academic project works/dissertations. The corresponding results at particular period of time/season were consulted following the experimental analysis with available procedures. Detailed analysis applying standard procedures with sufficient and frequent samples could be important for more precise results.

Acknowledgment

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