Assessment of river water quality in Kathmandu valley: A physico-chemical and microbial analysis

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Abstract: Water pollution is emerging as a serious environmental issue, challenging public health and ecological integrity. The present study was carried out to evaluate the physico-chemical and microbiological parameters of the Bagmati River and some of its tributaries (Dhobikhola, Manohara and Tukucha rivers) following American Public Health Association (APHA) standard methods. The Most Probable Number (MPN) method was used for the enumeration of coliforms. Furthermore, Water Quality Index (WQI) was calculated for the river water samples to determine if the quality of water is suitable for human consumption. Altogether 24 water samples were collected from 4 different sampling sites from December 2023 to February 2024. The pH of the water samples was observed to be slightly basic in nature (6.5 to 8.16). The physico-chemical parameters such as temperature, pH, Total Hardness (TH), and Chloride (Cl^-) were within the limits prescribed by National Drinking Water Quality Standard (NDWQS) of Nepal. The dissolved oxygen (DO) values, alkalinity and Biological oxygen demand (BOD) in the river water samples were variable, i.e. (1.02 - 3.50) mg/L, (130 – 235) mg/L, and (76.8 – 285) mg/L, respectively. The coliform count ranged between 210 - 2400 cfu/100 mL, was above NDWQS threshold limit indicating high microbial load in river water. The bacterial species isolated were *Escherichia coli* (79%), *Salmonella* (67%), *Enterobacter* (42%), *Citrobacter* (42%), *Klebsiella* (33%). The presence of thermotolerant *E. coli* in 45.83 % of the samples indicated the recent contamination of the river water with fecal matter. Antibiotic susceptibility test by Kirby Bauer disc diffusion method showed that all the bacterial isolates were resistant to Ampicillin. Similarly, the observed WQI values of river water samples were found to be in a range (13.52 - 37.52). Though, WQI values were low, the river water samples exhibited very low DO values, high alkalinity and high BOD values as well as high microbial load which indicated Bagmati river and its tributaries are highly polluted and unsafe for consumption without further treatment.

Key words: Antibiotic susceptibility; Most probable number; Physico-chemical and microbial parameters; Water pollution; Water quality index (WQI).

Introduction

Water is a vital resource constituting a huge portion of earth, influencing sustainability of biota, biodiversity and ecosystem. Rivers are important sources of freshwater used for human consumption, domestic uses, agricultural, industrial and recreational purposes[1]. Water pollution has emerged as the critical unsolved issue around the world as a result of population growth, industrialization and urbanization. It causes alteration in the physical, chemical and microbial properties of water.

Surface water sources get polluted by biological and chemical contaminants arising from point and non-point sources. Many natural factors such as local climate, geology, irrigation practices as well as human activities such as dumping of sewage, effluents or chemical contaminants near the water sources intensify the level of pollutants in

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water[2].

The surface water quality is changeable and get influenced by various physico-chemical parameters such as temperature, pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Alkalinity, and Total Hardness (TH)[3]. Temperature is an important water quality parameter which affects different physical process, solubility, microbial growth and biochemical reactions[4]. The acidic, basic or neutral nature of water is indicated by pH, which depends on different physico-chemical conditions of water[5]. The hardness of water is mostly due to the carbonates and bicarbonates of calcium and magnesium ions prevalent in water[4,5]. Chloride is the predominant anion indicating the level of organic pollution in water[5]. Similarly, TDS is the measure of dissolved substances including inorganic salts and organic matter in water which is influenced by electrical conductance[6]. Alkalinity is the measurement of buffering capacity of water which mostly depends on the bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and hydroxides (OH^-) ions present in water[7]. The DO is the measure of oxygen gas dissolved in water which indicates the biological pollution[8]. The BOD refers to the dissolved oxygen consumed by the microorganisms for the decomposition of the organic matter in the water[6,8].

Surface water is easily susceptible to microbial contamination including saprophytes and pathogens such as bacteria, algae, protozoa and nematodes[9]. The bacterial species such as *Escherichia coli*, *Salmonella*, *Shigella*, *Pseudomonas* are the biological indicators of water pollution[10]. The prevalence of high bacterial load in water results in various water borne diseases like diarrhea, meningitis and pneumonia[11]. Due to inappropriate and uncontrolled use of antibiotics, antibiotic resistance of bacterial isolates is increasing which cause potential risk to human health. Bagmati River was highly contaminated with antibiotic resistance genes tetA and sul1; 90.6% of these genes were detected from multi-drug-resistant *E. coli*, *Klebsiella spp.*, *Staphylococcus aureus*, *Salmonella Typhi*, *Pseudomonas aeruginosa*, and *Alcaligenes fecalis*[12].

Bagmati River is a sacred river with religious, cultural and geographical significance[13]. Bagmati River along with its seven tributaries: Bishnumati River, Manohara River, Dhobikhola River, Nakkhu River, Balkhu River, Hanumante River, and Tukucha River are the main source of surface water in the Kathmandu valley[14]. The direct disposal of huge quantities of industrial wastes, domestic wastes and sewage into the Bagmati River and its tributaries has degraded the water quality of river[15].

The quality assessment of the river is very significant as it indicates the utility of water for consumption and aquatic life by determining physico-chemical and microbial parameters[16]. Water quality of Bagmati River is of great concern as it is closely related to the health of people living in Kathmandu. The water analysis of Bagmati River in previous studies mainly focused on the physico-chemical parameters[17-20]. There are limited studies on microbial parameters of Bagmati River[13,21,22]. Similarly, the studies on water quality index of Bagmati River is also limited[23]. The quality assessment of river water is a continuous process and different water quality parameters must be regularly assessed to know the quality of river water for its effective conservation, monitoring and management. Hence, the present study was carried out with two purposes: to assess the water quality by determining the physico-chemical and microbial characteristics of the Bagmati River and some of its tributaries along with WQI (Water Quality Index) and to characterize the bacterial isolates and find their antibiotic susceptibility pattern.

Materials and Methods

Study area and sampling sites:

The sampling area is situated northwest to Kathmandu valley in Bagmati province of Nepal. It experiences sub-tropical climate with mean annual rainfall of 1740 mm, relative humidity 75% and temperature in a range -2 ^oC to 32 ^oC[24,25]. It is a densely populated metropolitan city with a population of 2,041,587[26]. In the present study, a total of 24 water samples were collected from the sampling sites (Tukucha River, Manohara River, Dhobikhola River and Bagmati River) which is shown in Figure 1.

Sample collection

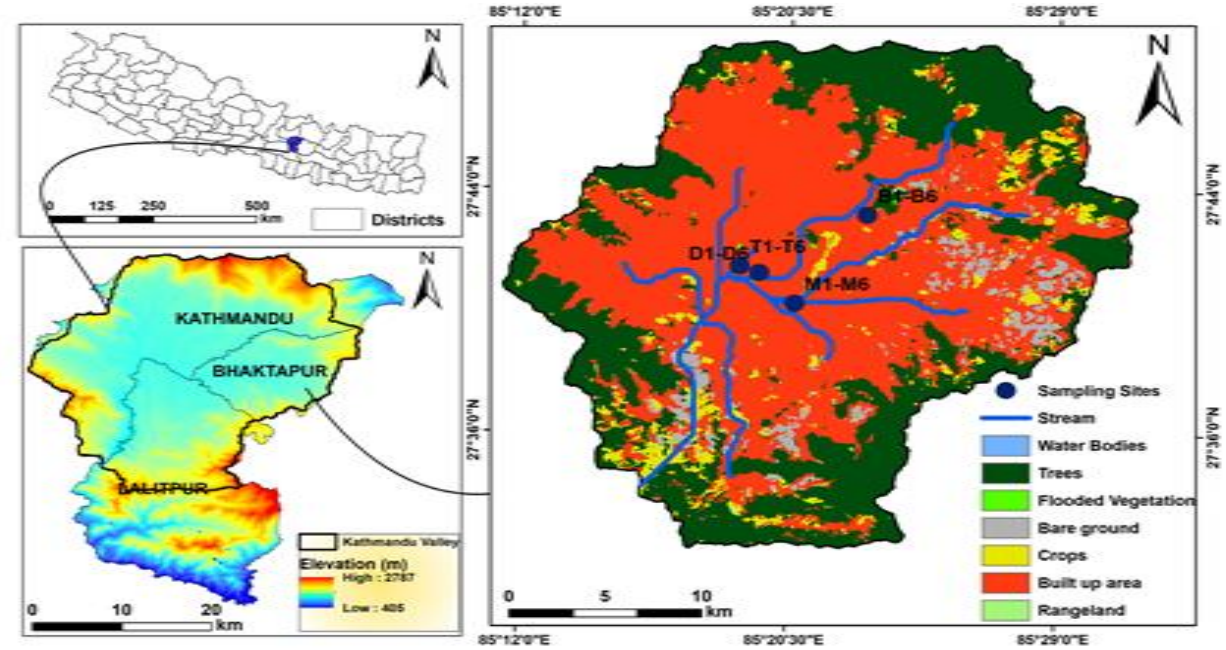

Figure 1: Study area along with the sampling sites.

The water samples were collected by convenience sampling technique. The sampling was conducted twice each month for each sampling site from December 2023 to February 2024 using Grab sampling method. A total of 24 water samples were collected in sterile plastic bottles of 1-liter capacity for physico-chemical analysis. Similarly, for determining Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and for microbial analysis sterile glass bottles were used. The physico-chemical parameters such as temperature and pH were noted at the site. The samples were placed in an ice box and transported with great precaution to the laboratory of Padma Kanya Multiple Campus for further analysis. For those physico-chemical parameters whose analysis could not be performed instantly, water samples were preserved at 4°C.

Sample Analysis:

1. Physico-chemical analysis:

The analysis of physico-chemical parameters such as temperature, pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Total Hardness (TH), Alkalinity, Chloride (Cl^-) were carried out using standard method of American Public Health Association (APHA)[27]. The temperature, pH, TDS and Electrical Conductivity (EC) were measured by mercury thermometer, digital pH meter (HANNA INSTRUMENTS, HI98107, Romania) and digital TDS meter (EI model- 651, India), and conductivity meter (EI model- 601, India), respectively. The total hardness (TH), alkalinity and chloride (Cl^-) were analyzed by Ethylene Diamine Tetraacetic Acid (EDTA) Titrimetric method, Acid base titrimetric method using double indicators (methyl orange and phenolphthalein) and Argentometric titration, respectively. The DO and BOD were determined by Winkler's iodometric method.

2. Microbial analysis:

The microbial analysis including, quantification of the microbial load, isolation, identification, and antibiotic Susceptibility Test (AST) were performed following APHA (2017) guidelines[27]. Most Probable Number (MPN) Method[27] was followed to determine the number of coliforms per 100 mL of the samples using 3 sets of 3 tubes each containing lactose broth and Durham's tubes. After appropriate incubation at 37^0 C for 24 hours, the tubes were observed for gas production and color change. The initial presumptive test, if positive, was followed by sub-culture on EMB (Eosin Methylene Blue) Agar (Confirmed test).

For the completed test, the colonies thus observed on EMB Agar were further cultured and identified by Gram staining and capsule staining as well as other biochemical tests (Catalase, Oxidase, Oxidative/Fermentative, Indole, Methyl Red, Voges Proskauer, Citrate utilization, Urease, Triple Sugar Iron Agar tests) following Bergey's Manual of Determinative Bacteriology[28]. All the positive results for gas production at 37 °C indicated the Most Probable Number of Coliforms per 100 mL of water after comparing with the standard chart[27].

The colonies with green metallic sheen on EMB Agar were suspected to be *Escherichia coli* and were further confirmed by their Gram negative nature which were short rods on microscopic examination and biochemical characteristics. The identification of thermotolerant *E. coli* was done on the basis of their ability to grow at 44.5 °C[27]. Other colonies lacking greenish metallic sheen on EMB agar were identified by their colonial characteristics on MacConkey Agar, Nutrient Agar, Gram staining results and the results of a series of biochemical tests such as Catalase test, Oxidase test, Oxidative Fermentative test, Indole test, Methyl Red test, Voges Proskauer test, Citrate test, Triple Sugar Iron Agar test and Urease test.

For the isolation of *Salmonella* species, an enrichment Procedure was carried out by mixing 45 mL of Selenite "F" broth with 5 mL of water sample and incubated at 37 °C for 24 hours[27]. After enrichment, a loopful of broth's upper portion was subcultured on Xylose Lysine Deoxycholate (XLD) Agar. Black centered colonies were chosen and phenotypic identification was done with the help of biochemical tests. Antibiotic Susceptibility Test (AST) was performed using the Kirby Bauer disc diffusion method in adherence to Clinical and Laboratory Standards Institute (CLSI) guidelines[29] in order to determine the antibiotic resistance profiles of the bacteria. The antibiotics such as Gentamicin (30 mcg), Ampicillin (10 mcg), Ciprofloxacin (5 mcg), Nitrofurantoin (30 mcg), Co-trimoxazole (25 mcg) and Chloramphenicol (30 mcg) were used for the test. The antibiotics used for evaluation were selected in such a way that each of them belong to a different class and are conveniently available in the market as they are commonly used.

Water quality assessment:

The water quality of the river water samples was determined by calculating the Water Quality Index (WQI) which was introduced by Brown et al[30].

WQI was calculated by using given equation (i).

$$WQI = \frac{\Sigma q_n W_n}{\Sigma W_n} \quad \text{..... (i)}$$

Where, q_n *and* W_n refer to the quality rating and Unit weight of n^{th} water quality parameter. The quality rating (q_n) is calculated by using following relation[31]

$$q_n = \frac{[(V_n - V_{io})]}{[(S_n - V_{io})]} \times 100 \text{..... (ii)}$$

Where, V_n, V_{io} *and* S_n are the estimated value, ideal value and standard permissible value of the n^{th} parameter. The ideal values (V_{io}) for all physico-chemical parameters were taken as zero for drinking water except for pH = 7.0 and DO = 14.6 mg/L.

The unit weight (W_n) is calculated using the relation given in Equation (iii)

$$W_n = \frac{K}{S_n} \quad \text{.....(iii)}$$

Where, K= proportional constant and it is calculated by following equation:

$$K = \frac{1}{\Sigma(S_{n=1,2,3.....})} \text{.....(iv)}$$

Result and Discussion

Analysis of physico-chemical parameters:

The mean, minimum and maximum values of all the physico-chemical parameters tested are summarized in Table 1.

Temperature: In the present study, the temperature of the river water samples ranged from 11 ^{0}C to 17 ^{0}C. The highest mean temperature of 14.25 ^{0}C was observed for Dhobikhola River and the lowest mean temperature of 13.30 ^{0}C was obtained for water samples from Tukucha River. The temperature range in present study is in agreement with the value reported in previous literature[20,21]. The higher temperature of 19 ^{0}C, 23.8 ^{0}C, 27 ^{0}C, 29 ^{0}C exceeding the upper limit of the present study was reported in earlier studies[13,19,22,32] but the lower limit of temperature

in these studies was consistent with the present study. The differences in temperature may be due to change in intensity of solar radiation, time, place and season of sampling[19,32].

pH: The pH of tested water samples was in a range of 6.5 to 8.16 of which 79.17% of water samples were above pH 7 indicating slightly basic nature of water samples. The pH of all the water samples were within the permissible limits of NDWQS[33] standard which was in good alignment with the reports in earlier studies[17,18,19,20,22,32]. Extreme high and low pH causes damage and eye irritations, high chemical reactions, metal toxicity, increase in chemical toxin in water which negatively affect aquatic life[34].

Electrical conductivity (EC): The EC of all the water samples ranged from 728 µS/cm to 1250 µS/cm which were within NDWQS standard. The water samples from Tukucha River, Manohara River and Dhobikhola were with higher conductance value of 1250 µS/cm, 1200 µS/cm and 1178 µS/cm, respectively, which was in line with the previous study[13]. Conductance of water samples much lower than the present study were reported in earlier studies[20,32]. The higher EC values correspond to the presence of high concentration of dissolved ions or solutes and plant nutrients from industrial waste, sewage or pesticides in river water samples[35].

Total hardness (TH): The TH of the water samples were found to be in a range of (80 to 180) mg/L, within the threshold limit of NDWQS suggesting soft nature of water in the sites under study[36] The hardness value (40 - 178) mg/L reported by Gautam et al[32] was lower than the present study. Similarly, Poudel et al[13] reported higher hardness values ranging from (56 - 312) mg/L exceeding the present study. In the present study, TH of water samples from Bagmati River were low in comparison to Tukucha, Dhobikhola and Manohara Rivers since its EC and TDS values were also low[37].

Total dissolved solids (TDS): All the examined water samples revealed the TDS value in a range (183 - 549) mg/L which was within NDWQS limit. The water samples of Manohara River, Dhobikhola and Tukucha River showed higher TDS of 549 mg/L, 546 mg/L and 510 mg/L, respectively. The TDS in the earlier findings of KC et al[22], Poudel et al[13] and Kunwar et al[19] was found to be in a range (9.4- 684.1) mg/L which was lower than the current study. The higher TDS values affect different physical properties of water such as color, taste and turbidity and cause negative impact to human health and ecology[37].

Alkalinity: The water samples from Bagmati River exhibited low alkalinity with mean value of 182.8 mg/L and range (130 - 235) mg/L. The mean values of alkalinity were obtained as 303 mg/L, 342 mg/L, 345 mg/L and 182 mg/L for water samples from Tukucha River, Manohara River, Dhobikhola and Bagmati River. Higher values of alkalinity reported in present study was in good agreement with the earlier reports[13,32,38,] in which alkalinity was found to be 165 mg/L and 288 mg/L and 360 mg/L, respectively. The higher alkalinity is due to high concentration of bicarbonate ions (HCO_3^-) which is predominant in surface water[39].

Chloride (Cl^-): The concentration of chloride in all the water samples were observed to be in a range (26.27 to 91.66) mg/L. The highest chloride content was obtained for water samples in Tukucha River with range (64.20 - 91.66) mg/L with mean value of 82.38 mg/L. Similarly, water samples from Bagmati River exhibited low chloride content with mean value of 44.50 mg/L and range (26.27 – 58.93) mg/L in the current study. The chloride concentration in water samples under investigations was within the NDWQS standard as well as in agreement with the previous findings[13,19,20,22,32]. The low chloride concentration in present study may be due to less contamination of water with the chlorinated pesticides, and other domestic and industrial waste containing chlorine[6]. The low chloride concentration can be attributed to the absence of the practice of treating river water with chlorinating agents as river water is not used for human consumption[40].

Dissolved oxygen (DO): The DO values ranging from (1.02 - 3.50) mg/L was obtained for the water samples under study. The water samples from Tukucha River, Manohara River, Dhobikhola and Bagmati River showed low DO values with mean 2.27 mg/L, 1.58 mg/L, 2.27 mg/L and 3.10 mg/L, respectively. The low DO in present study was consistent with the reports of Poudel et al[13], Gautam et

al[32] and Bhatt et al[41] and suggests high organic pollutants as well as bacterial activity in the river water. However, higher DO was also reported in the earlier literatures[17,19,20,22].

Biological oxygen demand (BOD): The BOD values in examined water samples ranged from 76.8 mg/L to 285 mg/L. Higher BOD values were observed for the water samples from Tukucha River, Manohara River, Dhobikhola

Table 1: Physico-chemical parameters under study.

Sampling sites	Statistical parameters	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	TH (mg/L)	Cl$^-$ (mg/L)
Tukucha (n = 6)	Mean	13.30	7.32	1075.33	445.17	2.27	182.43	303.67	133.33	82.38
	Min	11.00	6.50	977.00	398.00	1.80	121.60	239.00	94.00	64.20
	Max	16.00	7.88	1250.00	510.00	2.90	225.00	396.00	180.00	91.66
Manohara (n =6)	Mean	14.00	7.60	1091.70	504.80	1.58	177.50	342.70	152.00	71.60
	Min	12.00	7.18	977.00	475.00	1.02	108.00	303.00	140.00	60.41
	Max	17.00	8.05	1200.00	549.00	2.19	285.00	380.00	166.00	76.86
Dhobikhola (n = 6)	Mean	14.25	7.50	1054.00	495.67	2.27	209.40	345.80	135.30	66.90
	Min	12.00	6.88	950.00	379.00	1.76	189.20	300.00	119.00	60.50
	Max	16.50	8.16	1178.00	546.00	2.90	258.00	376.00	156.00	80.94
Bagmati (n=6)	Mean	13.40	7.20	807.83	297.67	3.10	93.65	182.80	97.80	44.50
	Min	11.50	6.90	728.00	183.00	2.80	76.80	130.00	80.00	26.27
	Max	16.50	7.52	955.00	369.00	3.50	108.40	235.00	120.00	58.93
NDWQS, 2022		-	6.5 - 8.5	1500	1000	-	-	-	500	250

and Bagmati River with mean values of 182.43 mg/L, 177.50 mg/L, 209.4 mg/L and 93.65 mg/L, respectively. The higher BOD values in our study were in line with the BOD reported in the previous studies[13,17,19,20,22,32]. The high BOD is due to high organic pollutants, organic wastes from untreated sewage and industrial effluents and microbial activity[42].

Microbial analysis:

The Most Probable number method (MPN) shows that coliforms were present in all the river water samples tested and the counts ranged from 210 cfu/100 mL to 2400 cfu/100 mL (Figure 2). MPN results ranged from 0 - 150 cell/100 mL and 0 - 240 cell/100 mL at two different water treatment plants in Baghdad, Iraq[43]. The concentrations of total coliforms ranged from 4.8 to 10.3 whereas that of *E. coli* was 3.5 - 10.0 log MPN/100 mL in Bagmati River water samples[44].

Among the different coliform bacteria and *Salmonella* spp isolated, *E. coli* was most frequently isolated and occupied 29% of the total isolates, followed by *Salmonella* spp (18%), *Citrobacter* spp (15%), *Enterobacter* spp (15%) and *Klebsiella* spp (12%) (Figure 3).

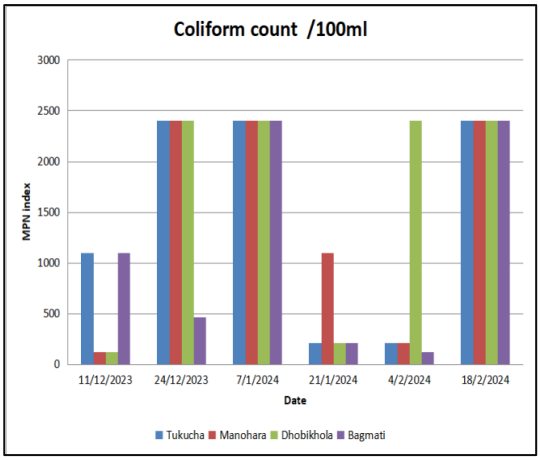

Figure 2: Microbiological analysis of river water.

Eleven of the samples (45.83%) showed the presence of thermotolerant *E. coli* indicating fecal pollution in these rivers. River-wise comparison shows that highest number of bacteria was isolated from Manohara, followed by Tukucha and Dhobikhola, with almost equal number of isolates and the least number of isolates from Bagmati River. The sampling site of Bagmati River was further below the wastewater treatment plant in Guheswari, Kathmandu which discharges the treated water to the river, hence the bacterial load must have been lesser in comparison to other sampling sites.

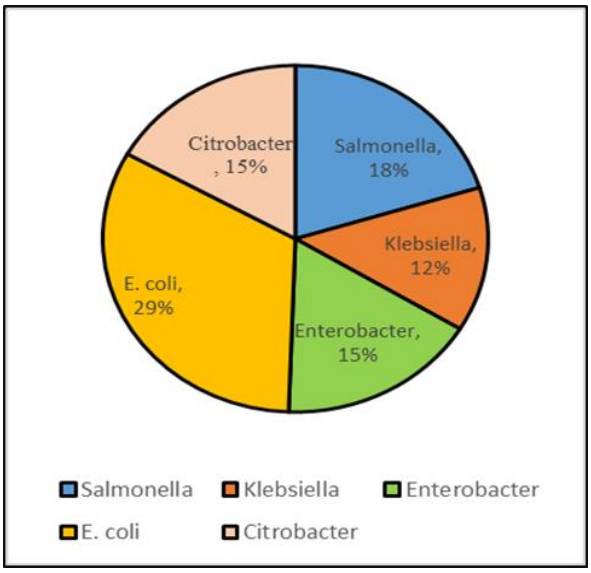

Figure 3: Distribution of bacterial isolates from river.

Out of the 24 river water samples tested, 79% of the samples showed the presence of *E. coli*, 67% showed the presence of *Salmonella* spp, 42% samples showed the presence of *Enterobacter* spp, 42% showed the presence of *Citrobacter* spp and 33% showed the presence of *Klebsiella* spp. *E. coli* are more of fecal origin than other coliforms, and the detection of thermotolerant *E. coli* in water is indicative of recent fecal contamination[45]. Total coliforms and *E. coli* were detected in all 18 samples from 3 sites in Bagmati River[44]; *E. coli* and other coliforms were detected from 180 water samples from up-, mid- and down-stream of Bagmati River in Kathmandu[46].

In a similar study, *S. enterica* ser. Typhi was identified in 171 (45%) and *S. enterica* ser. Paratyphi A in 152 (42%) samples out of 380 river water samples in Nepal[47]. People were seen cleaning vegetables for the Kathmandu markets, taking baths in the rivers, and washing their clothes which could be the reason for the spread of infection in community. Different classes of antibiotics (Ciprofloxacin- Fluoroquinolones, Gentmicin - Aminoglycosides, Cotrim-oxazole- Sulfonamides, Azithromycin - Macrolide, Ampic-illin - Aminopenicillin & Nalidixic acid - Quinolones) were used for antibiotic susceptibility test which showed that all the bacterial isolates were found to be resistant against Ampicillin. 50% of the *Salmonella enterica* isolates were resistant towards Azithromycin, 33.3% of them were resistant towards Gentamicin and 28% of the isolates showed resistance against Cotrimoxazole. *Salmonella* isolates were more sensitive towards Ciprofloxacin (83%), and Nalidixic acid (66.7%). The study conducted in eastern Nepal also showed that the *Salmonella* spp isolated from river and tap waters were highly resistant to Ampicillin[48]. The antibiotic susceptibility pattern of thermotolerant *E. coli* showed that 45.45% and 27.27% of the isolates were resistant to Amikacin and Nalidixic acid respectively (Table 2).

All *Klebsiella* spp were resistant towards Cefoxitin, 50% of them were resistant towards Amikacin and 37.5% were resistant towards Azithromycin (Figure 4). All the *Klebsiella* isolates were sensitive to Chloramphenicol which is in line with the results of a study done in *Klebsiella* spp isolated from the groundwater samples in Kathmandu[49]. *Enterobacter aerogenes* isolates were more sensitive towards the antibiotics tested as compared to other isolates with resistance towards Ampicillin (100%) and Nitrofurantoin (40%).

All *Citrobacter* spp showed resistance towards Ampicillin, 70%, 20% and 10% of them were resistant towards Nitrofurantoin, Ciprofloxacin and Gentamicin respectively. Five out of eight (62.5%) *Klebsiella* isolates, 44.4% of *Salmonella* isolates, 30% of *Citrobacter* spp and 26.36% *E. coli* isolates were found to be Multi Drug Resistant as they showed resistance towards three or more than three antibiotics of different classes[50]. The results of microbial study are solely based on phenotypic characteristics and further confirmation based on the genotypic studies will add to the importance of the findings.

The presence of pathogenic bacteria in the river water system indicates that these bacteria are circulating in the environment and also points towards the source of these infectious agents so that proper public health intervention can be targeted to the concerned area.

Table 2: Antibiotic susceptibility pattern of Thermotolerant *E. coli.*

Antibiotic Used	Sensitive		Intermediate		Resistant		Total
	No	%	No	%	No	%	
Nalidixic acid	8	72.73	0	0	3	27.27	11
Amikacin	1	9.1	5	45.45	5	45.45	11
Chloramphenicol	9	81.82	0	0	2	18.18	11
Ciprofloxacin	9	81.82	2	18.18	0	0	11
Co-trimoxazole	10	90.90	0	0	1	9.1	11
Ampicillin	0	0	0	0	19	100	11

Correlation analysis:

Correlation matrix was calculated to determine the relationship between the various physico-chemical and microbial parameters (Table 3). From the correlation analysis, EC showed significant positive correlation with TDS (r = 0.714), alkalinity (r = 0.830), TH (r =0.788) and Chloride (r =0.717) indicating a similar source of their origin[37,51]. Similarly, moderate significant positive correlation was obtained for (Temp and TH), (EC and BOD), (TDS and BOD), (TDS and TH), (TH and Cl). Moreover, significant negative correlation was observed for (EC and DO), (BOD and DO), (TDS and DO), (DO and Chloride), (Alkalinity and DO), (TH and DO). The number of *E. coli* showed positive correlation with pH (r = 0.105) and negative correlation with DO and temperature indicating the number of *E. coli* increases with the increase in pH but decreases with the increase in DO and temperature. The present correlation analysis was consistent with the previous findings[37,51,52,53,54].

Water quality index (WQI):

The WQI of river water samples were calculated (Table 4) from the mean values of the selected physico- chemical parameters which were compared with NDWQS standard. Only 5 water quality parameters (EC, pH, Cl^-, TDS, TH) were used to analyze WQI of water samples as DO, BOD and alkalinity do not have surface water standards in Nepal The WQI value was highest for Manohara (37.52) followed by Dhobikhola (31.31), Tukucha (20.02) and Bagmati (13.32) which is shown in Figure 5.

The water quality status of studied rivers were of good category (<50)[55] which was in line with some of the other

Table 3: Correlation matrix among different water quality parameters.

	Temp	pH	EC	TDS	DO	BOD	Alkalinity	TH	Cl^-	E. coli
Temp	1									
P^H	-0.14	1								
EC	0.207	0.225	1							
TDS	-0.111	0.277	0.714**	1						
DO	-0.234	-0.163	-0.514*	-0.625**	1					
BOD	-0.28	0.254	0.584**	0.612**	-0.513*	1				
Alkalinity	0.158	0.072	0.830**	0.781**	-0.661**	-0.525*	1			
TH	0.406*	0.281	0.788**	0.560**	-0.629*	0.475*	0.727**	1		
Cl^-	0.038	0.105	0.717**	0.603**	-0.480*	0489*	0.668*	0.445*	1	
E. coli	-0.205	0.105	0.153	0.306	-0.218	0.376	0.058	0.194	-0.003	1

*Correlation is significant at the 0.05 level(2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

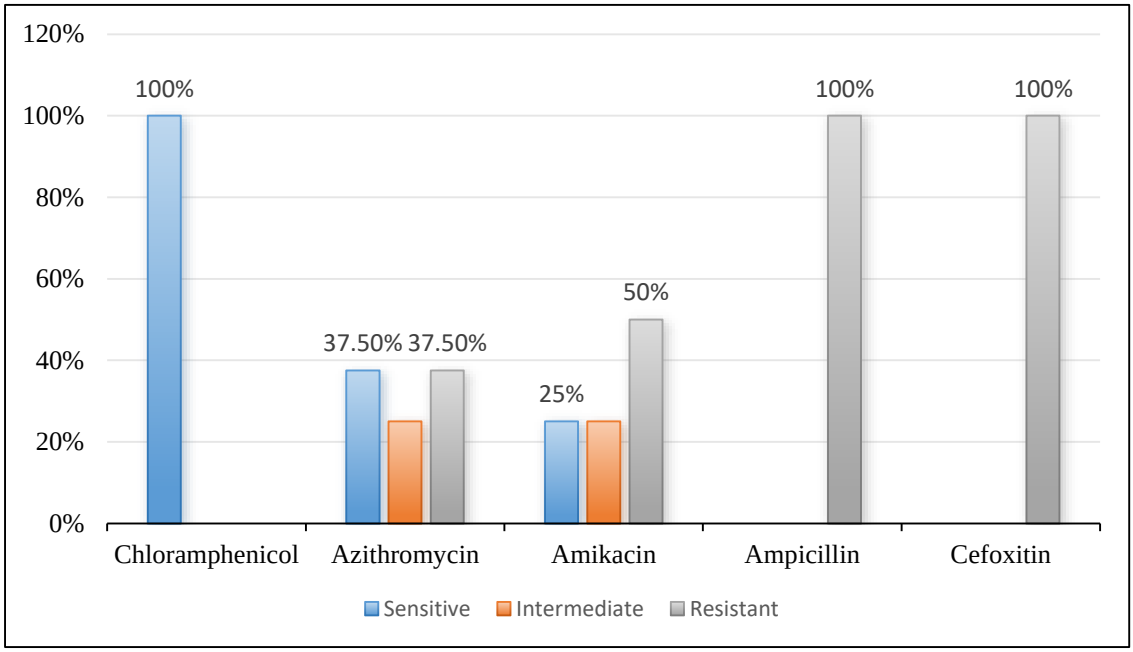

Figure 4: Antibiotic susceptibility pattern of *Klebsiella* spp isolated.

Table 4: Standard values with assigned agencies, unit weight (Wi) and quality rating (qi) for each parameter for river water samples.

Parameters	Standard value (Sn)	Agencies	Unit weight (W_i)	Quality rating (q_i)			
				Tukucha	Manohara	Dhobi-khola	Bagmati
pH	8.5	NDWQS	0.93900	21.33	40.00	33.33	13.33
EC	1500	NDWQS	0.00530	0.717	0.73	0.703	0.00285
TDS	1000	NDWQS	0.00798	0.445	0.51	0.496	0.00240
TH	500	NDWQS	0.01596	0.267	0.304	0.270	0.00280
Cl^-	250	NDWQS	0.03192	0.329	0.286	0.270	0.00570

studies[56,57]. However, the present WQI values was in contradiction to previous studies [5,23,58] since BOD, DO and alkalinity were not taken into account while calculating WQI. The absence of a single influencing parameter concentration can affect the value of WQI[57].

Conclusion

In the present study, physico-chemical and microbial parameters of the Bagmati River and its tributaries (Manohara, Dhobikhola and Tukucha) were assessed. The physico-chemical parameters like pH, temperature, Hardness (TH) and Chloride were within the NDWQS and standard limits. The WQI value for Manohara River was high and Bagmati River was low among the river water samples under study. However, the high value of BOD, TDS, alkalinity and low DO in the studies water samples indicated high organic pollution in all the rivers. High bacterial load in all river water samples referred to bacterial contamination in water indicating the risk of water borne diseases. All the bacterial isolates were resistant to Ampicillin. Based on the results of physico-chemical parameters and MPN index, the river water of Kathmandu is heavily polluted and not suitable for any human uses including religious rituals. Hence, proper treatment, monitoring and management of water is undeniable and water pollution control mitigation should be strictly implemented for the protection of water quality of Bagmati

River and its tributaries.

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