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Study of Physico-Chemical Parameters of Bagmati River, Kathmandu, Nepal

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Abstract
The Bagmati River runs through the Kathmandu Valley of Nepal and separates Kathmandu from Patan. It is considered holy by both Hindus and Buddhists. A number of Hindu temples are located on its banks. The importance of Bagmati also lies in the fact that Hindus are cremated on the banks of this holy river, and Kirants are buried in the hills by its side. According to the Nepalese Hindu tradition, the dead body must be dipped three times into the Bagmati River before cremation, so that the reincarnation cycle may be ended. The chief mourner (usually the first son) who lights the funeral pyre must take a holy river-water bath immediately after cremation. Many relatives who join the funeral procession also take a bath in the Bagmati River or sprinkle the holy water on their bodies at the end of cremation. The Bagmati River purifies the people spiritually. River Bagmati is the major River of the Kathmandu valley that passes across the north and south. It originates at Bagdwar just below the Summit of Shivpuri Hill on the northern side of Kathmandu valley and crosses Chobar gorge, on the south of the valley, to flow out of the Kathmandu valley to finally reach terai. Domestic water, solid wastes, industrial effluent from various areas is dumped into the river through different drains. Thus water samples from different sites of river were collected and analyzed for physico-chemical parameters to assess the quality of the river system. The study reveals that as per physico-chemical parameters exceed the permissible limits render the water of the holy river to be unfit for drinking purpose and it is also unhealthy for the aquatic life.

Keywords: Physio-chemical parameters, temperature, turbidity, conductivity, pH, Bagmati River, Nepal

1. Introduction
The Bagmati is the largest of the Himalayan kingdom's 6,000 rivers, celebrated in music, poetry and literature. Its source at Bagdwar is believed to be the product of divine powers. But it is threatened by pollution, having effectively become a vast rubbish dump. The water is black and poisonous, crawling with flies and contaminated with sewage [1]. It supposedly purifies bodies and souls, yet gives off a terrible stench. The Bagmati River runs through the Kathmandu Valley of Nepal and separates Kathmandu from Patan. It is considered holy by both Hindus and Buddhists. A number of Hindu temples are located on its banks [2]. However, threatened by pollution, it has been transformed into a vast rubbish dump. The water is black and poisonous, crawling with flies and contaminated with sewage. It supposedly purifies bodies and souls, yet gives off a terrible stench. The river waters start getting polluted right at the source. The commercial exploitation of the river has risen in proportion to the rise of population [3].

In the 1991 census, the total Basin population was recorded as 1.6 million of which 61.5 per cent inhabit the Upper Bagmati sub-basin, where as in addition to the Kingdom of Nepal, other four municipalities comprising a number of village development committees, are situated. It is also reported that a total of 2174 out of 4271 water polluting industries operating in the country are now in operation in the Upper Bagmati sub-basin. Indiscriminate disposal of untreated wastewater (domestic, industrial, solid waste, agricultural runoff etc.) has surpassed the assimilative capacity of the river [4]. Likewise, deforestation, soil erosion and landslides have been causal factors of Basin degradation which is being increasingly threatened by damage to the infrastructure of reservoir, barrage, canals, bridges and roads from debris, tree and logs carried by the river during the monsoon season [5].

The most visible impact of pollution in Bagmati has been the damage to its aesthetic value. The degradation of Bagmati has severely defaced the beauty of Kathmandu. Socio-cultural and religious aspects are at risk. The practice of taking holy ablution in the Bagmati River has vanished around the city as people fear the water of Bagmati instead of respecting it.

The source of the Bagmati River is in Shivapuri - Nagarjun National park, Nepal, and flows to Bihar, India, where it joins the Koshi River near Badla Ghat (Khagaria, India); and finally joins the Ganges River. The Bagmati Basin lies between the latitudes N26°23'18" and N27°49' 11" and longitudes E85°1'25" and E85°57'10". The length of the river within Nepal is 204km and the area of the basin is around 3828km² from about 2700m altitude to 53m [6]. Thus, the present study comprises collection, identification, and compilation of existing information in bibliography related to the ecology of Bagmati River. The approach is to analyze its water quality. This information has been analyzed, interpreted and evaluated in a meaningful way to meet the study objects.

2. Materials and Methods

2.1 Study area and geological settings

This study was conducted in the Bagmati River and its tributaries in the Kathmandu Valley, Central Nepal. Kathmandu lies in the middle mountain region of Nepal. It is roughly circular bowl-shaped valley with diameter of about 25 to 30 km [7]. It covers an area of approximately 650 km^2 with an average altitude of 1340 m [8]. The Bagmati is not a snow-fed river and most of its water is contributed by runoff. The origin of Bagmati is at Shivapuri and surrounding mountain range. There are 24 main tributaries originating from Mahabharat and Siwalik range which feed the Bagmati River [9]. The Bagmati River system drains about 3,500 km^2 before crossing the boundary of India and eventually draining into the Ganges [10]. The Bagmati river system consists of three major rivers flowing through the Kathmandu Valley, namely, Bagmati, Bishnumati, and Manahara. Kathmandu Valley was a lake during Plio/Pleistocene times and silted up by lacustrine and deltaic river sediments [11]. The basin filled sediments are mainly loam and composed of unconsolidated clay, silt, sand, and gravels. The headwaters of Bagmati river contain mica gneiss and biotite schist with muscovite, whereas the southern part of the river consists of thick clay formation and basal gravel [12] and the bed rock downstream contains fine grained phyllite, quartz containing argillaceous limestone, slates, shales, claystones, and mudstones [13].

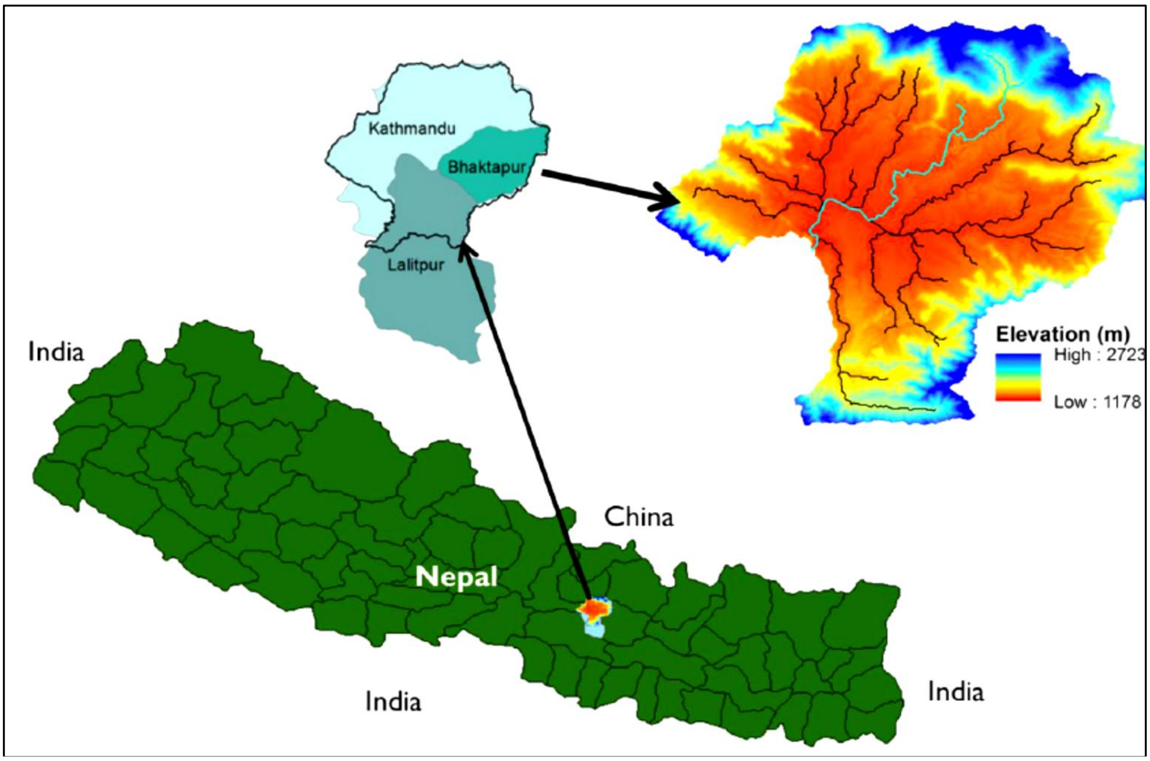


Fig 1: Location of Bagmati River in Kathmandu Valley

In this study a total of 90 water samples were collected from five different spots during different seasons over a period of two years (November 2015 to October 2017) and we consider samples from 5 major tributaries as *Site 1. Gokarana:* Bagmati River enters in the valley near Sundarijal just before this site. It is located near the Gokarna village east of the Gokarna temple, extends about 17-18 km. Land near the banks is covered with sparse vegetation. There are few local residents and no visible point sources of pollution but human activities like washing and bathing are quite common. Pollution of river starts as human activities begins from this location. *Site 2. Bagmati bridge:* This site is located after the Bagmati bridge near the Tilganga Eye Hospital, about 21 km from the source. Water is contaminated with the ash of cremated human bodies with pebbles, coarse and fine sand with silt at the substratum. It receives the effluents from small carpet industries of Boudnath and Chabhil and also the untreated sewage of the city, thereafter, the river receives more than fifteen sewage, household outlets, a lot industrial wastes, cremation left outs, and huge piles of solid wastes damaging the aquatic environment. *Site 3. Shankhmul:* It is located just before the confluence of Manohara and Bagmati, approximately 26 km. away from source. Here the anthropogenic activities are higher than the site no. I. It receives huge amount of effluent from sewages being surrounded by dense human population. The flow rate of water becomes slower than site no. I. The substratum is composed of sand, silt and a variety of disposables. *Site 4. Teku:* This site is located near the Bagmati Bridge and before the Kalopul which joins the Thapathali of Kathmandu and Kopundole of Lalitpur. There are series of temples and human residences on the north bank of river but on the south bank a few human settlements and agriculture land are situated. Effluents from carpet factories, other small factories as well as untreated sewage of Thapathali, Teku and Kopundole are poured here. Activities like bathing and washing are performed aptly. The substratum is composed of muddy sand and disposables. *Site 5. Chovar:* This site is located near the Ganesh temple (Shidhi Binayak Mandir), the outlet to the valley. It is about 32 km south from the source. Human activities like washing, bathing clothes and fishing (only during rainy season) were observed. The substratum is composed of muddy sand, silt and gravel. The study stretch in the main stream of Bagmati River is about 27 km in length from Gokarna to Chobhar.

Kathmandu Valley comprises three districts, Kathmandu, Lalitpur, and Bhaktapur. The valley encloses the entire area of Bhaktapur, 85% of Kathmandu, and 50% of Lalitpur District. The total population of Kathmandu Valley is more than 2.5 million according to the population census of 2011. The climate of Kathmandu Valley is subtropical cool temperate with maximum temperature of 35.6 °C in April and minimum of −2.5 in January and 75% annual average humidity. The temperature on average is 19 °C to 27 °C in summer and 2 °C to 20°C in winter; the average rainfall is 1400 millimeters, most of which falls during monsoon. Monsoon is generally observed during June–September. There has been rapid urbanization in Kathmandu Valley as it is the capital city and center of attraction to the Nepalese population. This can have an immense effect on the river water quality.

2.2 Sampling and laboratory analysis

Water samples were collected from the Bagmati River and its tributaries from each site three times a year (summer, rainy and winter seasons) during November 2015 to October 2017. Alltogether, 34 samples were collected from different tributaries of Bagmati river basin. Measurements were carried out for water temperature, pH, conductivity, turbidity, DO, and TDS. A WagTech pH meter [14], WagTech conductivity meter [14], and turbidity meter [15] were used in the field for in situ measurements. Water samples were collected into 20 mL Ultraclean HDPE (High Density Polyethylene) bottles after filtering through 0.45 μm polypropylene membrane filters. The sampling bottles were rinsed with river waters thrice before the original samples were taken. All samples were taken at a depth of approximately 30 cm below water surface. The sampled bottles were packed inside the double polyethylene zip-lock bags and kept in refrigerator at 4°C until the laboratory analysis. Similarly, total hardness, calcium, magnesium, chloride, sulphate, ammonia, total nitrogen, nitrate, nitrite and iron in water sample were determined by APHA [16].

2.3 Statistical analysis

Statistical analysis of data was done using One way and Two way ANOVA [16] followed by Duncan‘s Multiple Range Test at $P<0.05$ level of significance. The data were processed as per SPSS software (version 20) to compare the target parameters.

3. Results

3.1 Physical chemical properties of water

Analyses of physical properties of Bagmati River (**Table 1)** at five sites (SI, to SV) in three seasons (rainy, winter and summer) were carried out. The mean seasonal data collected at all five selected sites are presented in tables 1-5. The observations made for two years and three seasons show that the colour of the water of Bagmati River ranged between 27.8 hazen in the summer and 22.40 hazen in the rainy season. The observations made for two years and three seasons show that maximum value of turbidity was found to be 672 NTU in summer and minimum 46 NTU in winter. Almost the similar trend was recorded during the successive year. In terms of conductivity, the maximum value for conductivity was found to be 505μs/cm in the winter during two years of observation and minimum 150μs/cm) during the rainy season. Likewise, the water temperature was maximum 25.60 ± 0.33°C in rainy season and minimum 14.60 ± 0.79°C in winter during the first year of observations. The same trend was recorded during the second year also.

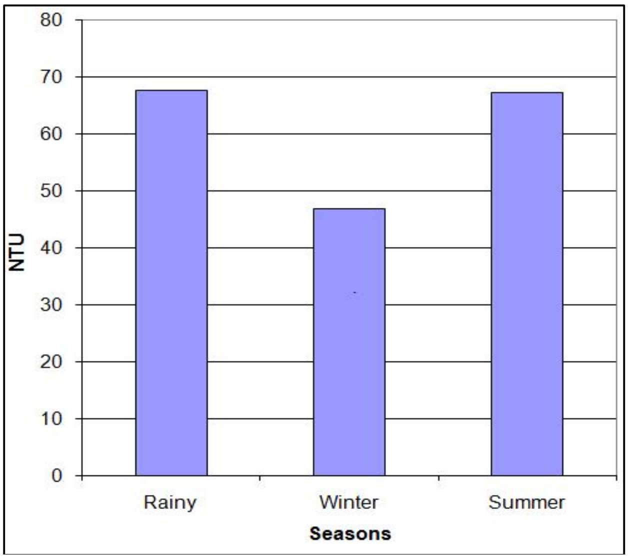
Table 1: Analysis of water for physical parameters

Parameters	Rainy Season	Winter Season	Summer Season	F value
Colour (Hazen)	22.40 ± 2.39	23.8 ± 10.75	27.8 ± 6.90	2.41 ns
Turbidity (NTU)	67.60 ± 21.59	46.8 ± 6.79	67.2 ± 331.02	1.17 *
Conductivity (μs/cm)	150.40 ± 38.71	505.0 ± 94.58	240.8 ± 47.91	8.89 *
Temperature (°C)	25.60 ± 0.33	14.60 ± 0.79	24.04 ± 0.69	7.81 *

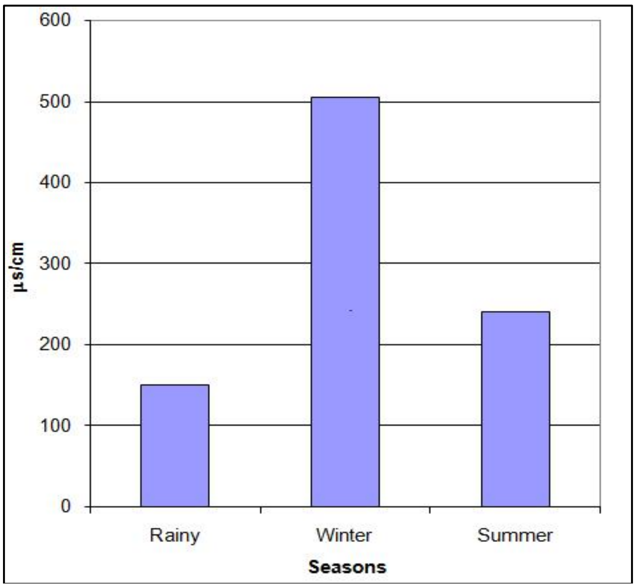
Values are expressed as mean ± SE (n= 5); F values denotes the variance amongst three seasons
* denotes significant difference amongst the values. ns denotes non-significant amongst the values.

Chemical parameters of water

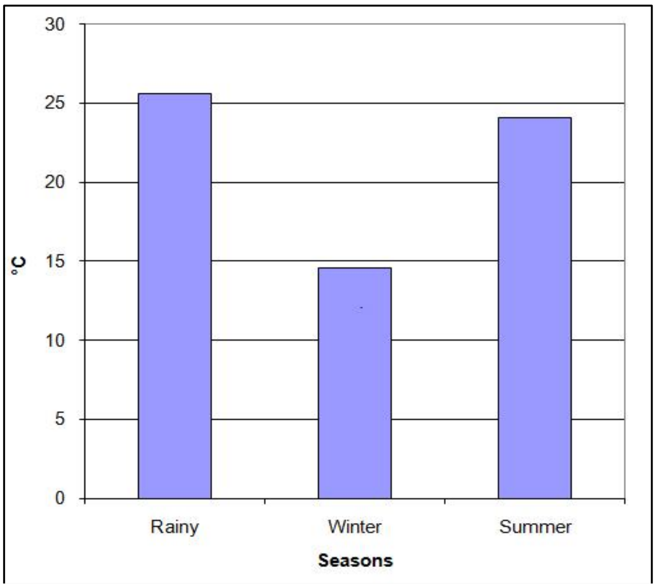
An alyses of chemical properties of Bagmati River (Table 2) at five sites (SI, to SV) in three seasons (rainy, winter and summer) were carried out. The maximum value of pH was found to be 6.94 ± 0.10 in winter and minimum (6.68 ±0.12) in rainy season during the first year of observation. Similar observations were recorded in second year also. Similarly, the mean value of bicarbonate alkalinity for two years was found to be maximum 61.28 ± 29.308 mg/l in summer and minimum 59.6 ± 11.33 mg/l in rainy season during the study period. Likewise, the chlorides were found to be 46.02 ± 9.43mg/l in winter and 13.2 ± 2.73 mg/l in rainy season during two years of study. In terms of ammonia, the concentration of ammonia was found to be maximum (28.42 ± 6.49mg/l) in winter and minimum 3.92 ± 1.59 mg/l in rainy season. There was no significant difference in the concentration of ammonia in the observation period of second year. Likewise, the iron values were maximum (5.24 ± 1.21 mg/l) in rainy season and minimum (2.08 ± 0.42 mg/l) in winter season for two years.



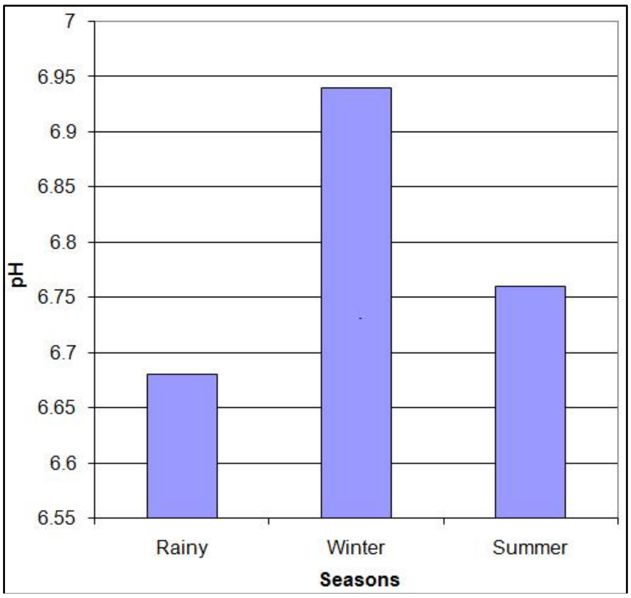
Graph 1b: Analysis of water for Turbidity (NTU)



Graph 1c: Analysis of water for conductivity (us/cm)



Graph 1d: Analysis of water for temperature (c)



Graph 1a: Analysis of water for pH

Similarly, the mean value of nitrite was 0.302 ± 0.08 mg/l in summer and 0.03 ± 0.00 mg/l in rainy season. Same values were observed in second year also. The maximum value of nitrates (8.88 ± 1.14 mg/l) was recorded in summer and minimum (3.72 ± 0.29 mg/l) in winter season during two years observation. Similarly, the amount of calcium was found to be 18.76 ± 5.21mg/l in winter and 5.52 ± 2.25 mg/l in rainy season. The same trend was observed in the second year also. Similarly, the concentration of magnesium was found to be 6.92 ± 3.89 mg/l in winter and 1.688 ± 0.64mg/l in rainy season in a study of two years. Similar observations were recorded in second year also. Likewise, the maximum value of sulphate was found to be 8.39 ± 1.11mg/l in summer and 5.0 ± 0.00 mg/l in both rainy and winter seasons during the study period of two years. In terms of dissolved phosphate, the concentration of dissolved phosphate was found to be 0.67 ± 0.19 mg/l in summer season and 0.02 ± 0.14mg/l in winter during present observations. Likewise, the mean value of total phosphate was 3.026 ± 0.98mg/l in summer and 0.21 ± 0.06 mg/l in rainy season. The same

Pattern was observed in the second year also. Similarly, the value of total Kjedhal nitrogen (42.58 ± 7.74 mg/l) was highest in winter season and lowest in (18.06 ± 2.72 mg/l) in rainy season during the study period of two years. The same trend was recorded in the successive year also.

Table 2: Analysis of water for chemical parameters

Parameters	Rainy Season	Winter Season	Summer Season	F value
pH	6.68 ±0.12	6.94 ± 0.10	6.76 ± 0.16	11.65 *
Carbonate alkalinity (mg/l)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.0
Bicarbonate alkalinity (mg/l)	59.6 ± 11.33	137.6 ± 26.43	61.28 ± 29.30	1.11 *
Chloride (mg/l)	13.2±2.73	46.02±9.43	38.48±5.41	7.49 *
Ammonia (mg/l)	3.92±1.59	28.42±6.49	8.22±1.89	2.95 *
Iron (mg/l)	5.24 ± 1.21	2.08 ± 0.42	4.182 ± 0.60	1.65 ns
Nitrite (mg/l as NO_2)	0.03 ± 0.00	0.272 ± 0.14	0.302 ± 0.08	0.50 *
Nitrate (mg/l as NO_3)	8.06 ± 0.74	3.72 ± 0.29	8.88 ± 1.14	2.15 *
Calcium (mg/l)	5.52 ± 2.25	18.76 ± 5.21	8.68 ± 2.15	7.69 *
Magnesium (mg/l)	1.688 ± 0.64	6.92 ± 3.89	3.50 ± 1.01	2.61 ns
Sulphate (mg/l)	5.0 ± 0.00	5.0 ± 0.00	8.392 ± 1.11	1.0 *
Dissolved Phosphate (mg/l)	0.03 ± 0.00	0.0262 ± 0.14	0.678 ± 0.19	0.99 *
Total Phosphate (mg/l)	0.21 ± 0.06	0.326 ± 0.08	3.026 ± 0.98	1.23 *
Total Kjedhal nitrogen (mg/l)	18.06 ± 2.72	42.58 ± 7.74	22.44 ± 3.35	5.72 *

Values are expressed as mean + SE (n= 5); F values denotes the variance amongst three seasons; * denotes significant difference amongst the values; ns denotes non-significant values.

4. Discussion

River is an open ecosystem. They always attract the ecologists or limnologist due to their diverse geological, hydrological and community formations. Each river is largely influenced by anthropogenic influences. Measurement of physico-chemical parameters offers valuable information about the ecobiological interactions going on in the ecosystem, which affect aquatic life. The community composition is also based upon water quality which ultimately makes the system sustainable. The other significant contributions made on the limnology of flowing water bodies include Mills *et al.* [17], Hynes [18], Stumn and Morgan [19] and Wetzel and Likens [20]. In India as well, several workers have made systematic limnological studies. They include Ganpati [21], Roy *et al* [22]; Dutta *et al*. [23]; Sunder; [24]; Julka *et al*. [25] and Sharma *et al*. [26].

In Nepal limnological studies on the rivers of Kathmandu valley have been made by Dey, *et al.* [27] who observed the degrading water quality of Bagmati River. Similarly, Sharma [26] also showed high value of physico-chemical as well as bacteriological parameters. Khatiwada *et al*. [28] reported that Bagmati River became highly polluted after passing through the Pashupatinath temple. Tuladhar [29] has reported that the rivers of Kathmandu valley have high numbers of coliform bacteria (720,000/100ml.). Tuladhar [30] studied the rain fall runoff characteristics and flow frequency of Bagmati River. Vaidya and Labh [30] studied the resource biology and ecology of freshwaters of Kathmandu valley; he also investigated the biological indicators of pollution in the river Bagmati in Kathmandu valley.

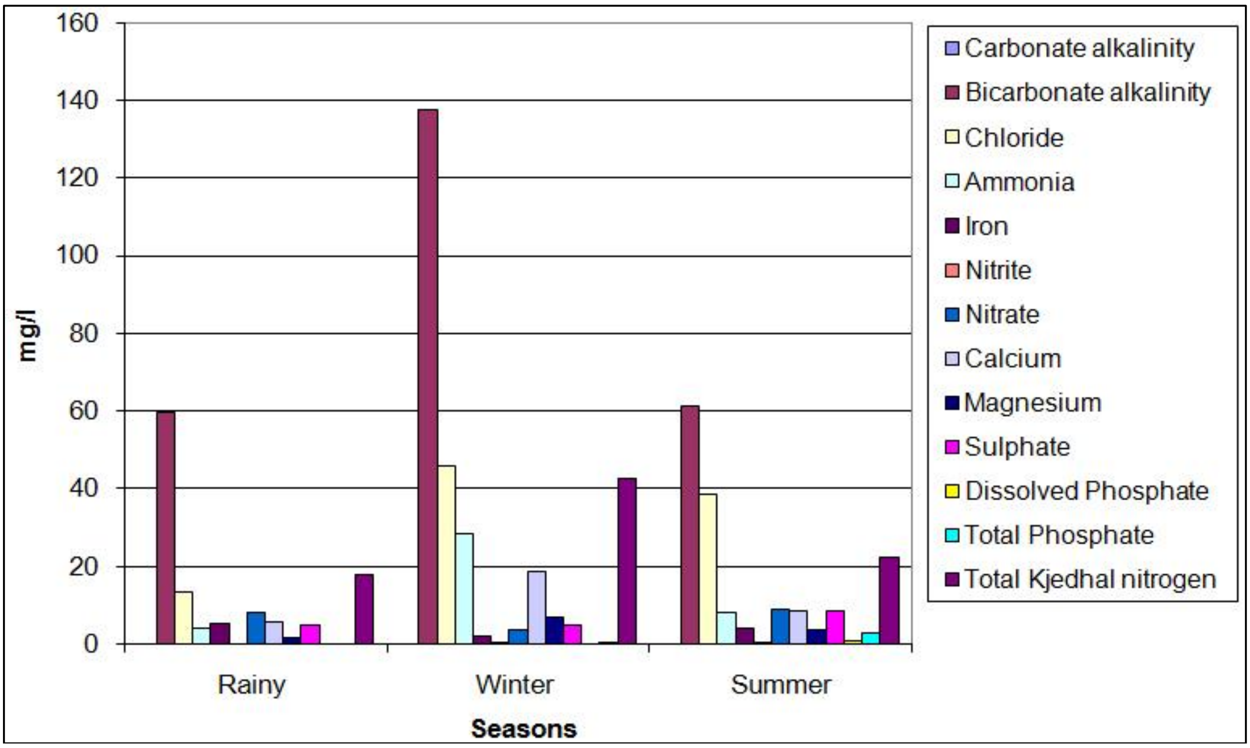


Fig 2: Analysis of water for chemical parameters

The variations of temperature though large, are not considered significant due to wide range of thermal tolerance by the aquatic biota. Ghosh and Basu [31] and David [32] pointed out that there is no direct effect of temperature on aquatic life. Throughout, the period of present investigation, the temperature maxima was never high at any station and was found within the prescribed limit for bio-life. The temperature difference may not be of any importance to the aquatic life, especially the fishes, but in the polluted state, it has a profound effect on dissolved oxygen and biochemical oxygen demand. The solubility of oxygen decreases very rapidly with increasing temperature, and the temperature coefficient of reaction velocity of most of the chemical reactions are positive and high, with the result that the rate of immediate oxidation becomes higher at increased temperature [33]. The rate of biochemical oxidation also increases with the increase of temperature owing to the increased metabolic activity of the bacteria [34].

Turbidity is of importance to aquatic biologists, as the bottom conditions viz. light, penetration, bacterial concentration and various other factors are usually altered by the amount of suspended matter in water. Turbidity in Bagmati River in the clean water zone at site I and II in summer, pre-summer and winter months is low (46.8±6.79). It increases abruptly in the region containing large quantity of suspended matter at confluence of the river. The suspended matter consists of the particles of different types ranging from coarse cellulose fibers to fine colloidal particles of various organic complexes. The coarse particles settle down very quickly, showing an abrupt fall in turbidity along the stretch of 8 to 10 kilometers. After the Chovar (site V) turbidity decreases slowly and the original clear water conditions reappear. The deposition of organic matter is appreciable up to the station IV; Tyagi [35] has made similar observations.

The blackish-brown industrial wastes impart brown colour to the river water. The brown colour of the water decreases slowly but persists up to site V. The brown colour of the water inhibits the penetration of light and affects the wave length of light which penetrates into the river water. The change in the wave length and its reduction in intensity, limits the growth of phytoplankton and other aquatic plants which are of great importance, not only because they form an important link in the food-chain but they also produce oxygen by photosynthetic activity which plays an important role in reaeriation of water [36].

David and Ray [32] pointed out that dissolved solids when present in excess may create an imbalance-a sudden change in the osmotical regulation or cause suffocation to fish even in the presence of high D.O. When dissolved solids are present in right concentration, a good fish-yield can be expected [37]. According to them, about 95% of U.S. fish ponds, supporting a good fish fauna, possess total dissolved solids value under400 mg/l.

The conductivity was found to be low in upstream of site I which is due to high flow rate of water current. But site II, III and IV had high conductivity. Again at site V its value increased. Dahal. *et al*. [38] recorded very low conductivity (average between 100.30 us/cm to 137.50 us/cm), In present study, conductivity decreased in urban area usually at sites II, III, and IV and again slightly decreased from site V. It suggests that maximum pollution load increases after the river crosses urban area. It has been found that the conductivity is lower during rainy season. It might be due to dilution of metallic ions in the water [39].

The natural waters contain small quantities of dissolved salts like chlorides, sulphates, carbonates of sodium, potassium, calcium and magnesium. However when the water is polluted, chemical wastes containing excess of dissolved salts, their level may rise which is dangerous for aquatic life. Specific conductance measurements offer a very quick and convenient way of determining the total amount of ionisable salts in water and have been used as valuable aids for studying this type of electrolytic pollution. As specific conductivity of inland-fresh water, supporting a good fish-fauna lies between 150 to 500 x 10-6 mhos [40], there appears to be danger of pollution from sites III, IV and V after which no potential danger could be noticed.

The determination of pH serves as a valuable guide for showing the acid-alkali balance of water and in the case of pollution by acidic or alkaline wastes, serves as an index to denote the extent of pollution.

Pandey *et al*. [41] stated that the fish and the common aquatic organisms prefer the pH values between 6.5 and 8.4. pH values below 5.0 or more than 8.8 are definitely detrimental or even lethal. Warner *et al*. [42] plotted the curves between the pH and percent-age avoidance frequency and showed that the fish likes to stay in the water, having pH of 6.2 to 7.6. The pH of the water of Bagmati at sites I to V lies towards the alkaline side and ranged among 6.5 to 7.5.

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