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Assessment of Spatial Variation of Water Quality in Seti River, Pokhara, Nepal

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Abstract
Water is one of the largest natural resources in Nepal. A major source of pollution of water resources is disposal of waste, which is growing due to ever-increasing domestic, commercial, municipal and industrial areas. The analysis of variation in water quality of Seti River in Pokhara (Nepal) could be important in this context. The water samples were collected from twenty different sampling location of Seti River, Pokhara during mid of June and first week of July 2019. The study area extended from 28°9'40.53"N and 84°0'24.24"E to 28°18'25.14"N and 83°56'52.39"E. Sampling was conducted from upstream and downstream of Pokhara City. Twelve samples were collected from upstream of Seti gorge and eight samples were collected from Ramghat area and downstream of Pokhara City. Physical, chemical and bacteriological parameters (TDS, EC, pH, Turbidity, TH, Ca^{++}, Cl^{-}, NH_3, DO and E-Coli) of collected water samples were examined in laboratory. Spatial variation of water quality parameters was observed by analyzing the obtained result as per sampling location. Turbidity and hardness values of water samples were recorded very high; 913 NTU and 801mg/l respectively. The E-coli counts were increasing towards the downstream which showed the increment of fecal contamination. The average pH value was recorded as 8.14. Similarly, TDS and EC values were observed 113 mg/l and 232 µS/Cm respectively. The seasonal variation in water quality has great significance in overall quality monitoring of water. During monsoon season discharge of river normally remains high so impurities discharged into river water would be diluted frequently. Though anthropogenic activities can influence in city area, there was no substantial variation of water quality on monsoon season observed by this study.

Keywords
Seti River, Water quality parameters, Spatial Variation, Monsoon Season

1. Introduction

The rapid development of urban economy, human settlements and industrial activity, and lacking adequate environmental protection control, have contributed to the progressive deterioration of the river water quality in urban localities of Nepal including Seti River. Almost all the urban areas have not sufficient wastewater treatment facilities. The cumulative effects of wastewater discharge have a striking negative impact, particularly, in the rivers flowing through the major urban areas of Nepal. In Nepal, like other developing countries; "a water quality assessment" has always been a matter of discussion at both scientific and conservation policy level. Seti River, which is located on the lap of Pokhara valley, could have variation in water quality due to natural as well as anthropogenic causes. Obviously, deteriorating water quality may harm significantly in ecosystem. Poor quality of water can cause frequent cases of water born disease.

Water quality assessment programs in Nepal have concerned generally with public health issues and therefore, safe drinking water has been the primary emphasis. On the other hand, conservation of river water quality has received little attention in terms of its development. To the extent that rivers are being used as drinking and washing water resources, physiochemical as well as biological contamination of public water supplies could become an important issue. Reliable pollution studies were very rare in Nepal and limited in the areas they cover. However, for the last few decades, the numbers of studies have focused this issue due to growing public concern

about pollution and its impact on human health and the environment.Studies showed that pollution level was increasing both in terms of area contaminated and intensity, posing a serious threat to human health and the environment [1]. The main objective of this study was to analyze spatial variation of the water quality parameters along the stretch of Seti River at Pokhara, Nepal.In addition to that physiochemical parameter of Seti River was accessed and the water quality parameters were compared with water quality parameters for different water uses. Moreover, water quality variation along river depth, across cross section of river and temporal variation were not considered in this study. Spatial analysis of water quality not only describes about the water quality parameter but also entails the cause of variation in water quality which helps in decision making in the concerned issues.

Pokhara Valley is lying in the southern flank of Annapurna Himalayan range in Gandaki Province Nepal. The Pokhara metropolitan is the capital city of Gandaki Province and extends over an area of 464.2 km². Water-bodies running through the Pokhara valley are the Seti Gandaki River and its tributaries. The river has its origin near the base of the Mount Machhapuchhre (6,997 m) and the Mount Annapurna IV (7,525 m) and are fed by the glaciers [2]. The Seti and its major tributary the Mardi are glacier-fed streams on the south slopes of Annapurna Himal and therefore their head waters lie outside the Pokhara basin. In this research to access the spatial variation of water quality parameters in Seti River (Pokhara, Nepal), study areas were divided into three regions (A) upstream of the starting point of Seti gorge having length 12 km, (B) along the Pokhara valley in Fulbari (1.34 km) and Ramghat Area (0.80km) and (C) downstream of Pokhara City up to Dobilla (3.5km) for accessibility of sampling. Tributaries of Seti River in this study area are Phurse, Kali, Mardi, Yamdi, Lasdi and Bhurjung. The upstream and downstream of river confluence and anthropogenic activities locations were major station for sampling. The study area extends from Dobilla (28° 9'40.53"N, 84° 0'39.47"E) to confluence of Bhurjung Khola and Seti itself (28°18'25.14"N, 83°56'52.39"E). The study area for this study has been presented in Figure 1. Total running span covered in this study was 24.3 km including seti gorge.

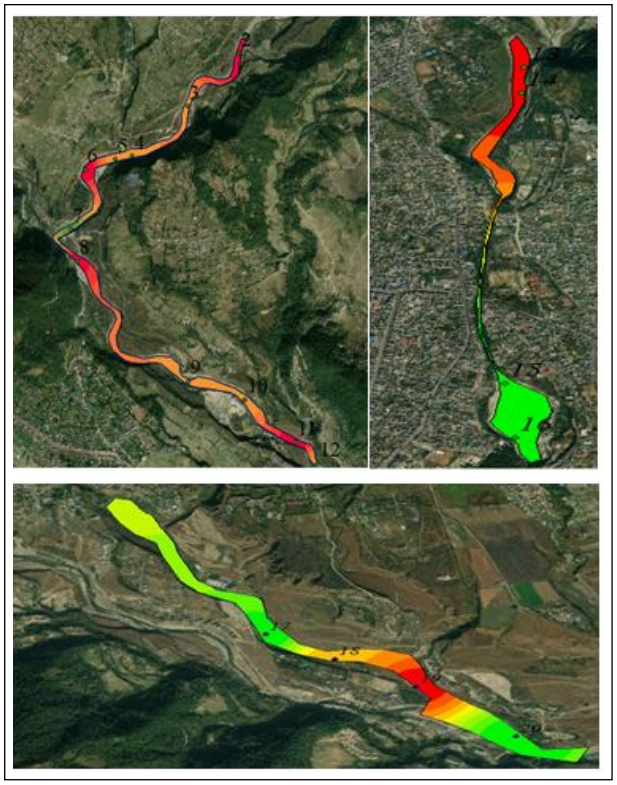

Figure 1: Study Area; (a)Upstream of Pokhara city (top left)(b) Along Pokhara City (top right) and (c) Downstream of Pokhara City (bottom)

2. Material and Methods

2.1 Sampling

For this study, field reconnaissance was carried out in study area. Upstream and downstream location of river stretch was inspected and sampling locations were selected. Consideration of sampling location was based on anthropogenic activities carried out in study area and confluence of different river tributaries. sampling of water was conducted during the mid-June and first week of July 2019 for the examination of water quality parameters. During monsoon season, sampling was difficult due to the flood and fragile landside in river corridor. Sampling was performed at day time with no rainfall and mostly sunny weather condition. Prior to sample collection, all sampling bottles were sterilized in autoclave then rinsed with distilled water. The sample bottles were rinsed three times with same river water before sample collection. The samples were collected approximately 25 centimeters below the surface of river using sampling bottles. The sample bottles were labeled with date and sampling location. The details of sampling location have been presented in Table 1. The sampling of

Table 1: Detail Description of Sampling Locations

Sample No.	Coordinates		Details	Remarks
	Lattitude	Longitude		
1	28°18'25.14"N	83°56'52.39"E	Upstream of Bhurjung Khola	Left Bank
2	28°18'20.93"N	83°56'50.61"E	Downstream of Bhurjung khola	Left Bank
3	28°18'7.87"N	83°56'35.39"E	Seti dawa Bridge (Downstream of manual sand Mining activities)	Left Bank
4	28°17'55.61"N	83°56'19.01"E	Upstream of Lasdi Khola	Left Bank
5	28°17'54.93"N	83°56'14.10"E	Downstream of lasdi khola	Left Bank
6	28°17'52.48"N	83°56'5.33"E	Near to sand mining activities	Left Bank
7	28°17'37.46"N	83°56'0.77"E	Upstream of Mardi River	Left Bank
8	28°17'29.54"N	83°56'2.28"E	Downstream of Mardi River	Right Bank
9	28°16'58.53"N	83°56'33.57"E	Upstream of Crusher Plant	Right Bank
10	28°16'53.41"N	83°56'49.74"E	Downstream of Crusher Plant	Right Bank
11	28°16'42.35"N	83°57'4.18"E	Upstream of kholsi	Right Bank
12	28°16'36.85"N	83°57'10.29"E	Downstream of kholsi	Right Bank
13	28°14'25.46"N	83°59'40.62"E	Downstream of Kali khola confluence	Left Bank
14	28°14'18.68"N	83°59'40.07"E	Nearby Manipal hospital fulbaari area	Left Bank
15	28°13'1.51"N	83°59'34.85"E	Ramghat at downstream of seti gorge	Right Bank
16	28°12'47.01"N	83°59'36.22"E	Ramghat at Upstream of seti gorge	Right Bank
17	28°10'4.75"N	84° 0'1.39"E	Below mahatgaunda area	Right Bank
18	28° 9'58.87"N	84° 0'11.94"E	Dobilla	Right Bank
19	28° 9'52.45"N	84° 0'24.24"E	Dobilla, Upstream of Phurse Khola	Right Bank
20	28° 9'40.53"N	84° 0'39.47"E	Downstream of Phurse khola	Right Bank

water was performed from the 20 different locations of study area. The water samples were carefully transported to the laboratory and were preserved for physical, chemical as well as biological analysis.

2.2 Water Quality Examination

Collected samples were taken in water quality laboratory at Pokhara. The water quality parameters such as pH, Turbidity (T), Electrical Conductivity (EC),Total dissolved solids (TDS), Total Hardness (TH), Ammonia (NH_3), Calcium (Ca^{++}), Chloride (Cl^-), Dissolved Oxygen (DO) and Escherichia coli (E-coli) were examined and variation of different parameters along the river stretch in study area was observed. Result of laboratory examination was documented and spatial analysis was conducted using graphical and statistical representation. Standard methods of water examination were followed for examination of water quality as per APHA[3]. Comparisons of parameters with National Drinking Water quality standard was conducted based on the National Drinking Water Quality Guidelines[4]. Observed parameters also compared with water quality standard for different water uses using standard Guidelines published by Government of Nepal[5]. Quality parameters of water samples that were examined in laboratory and their methodology has been presented as follows.

- Turbidity
  Turbidity meter was calibrated with distilled water. The water was placed in small vessel and then placed in turbidity meter. The result displayed on device was noted.
- Total Dissolved Solids (TDS)
  The electrode was immersed into sample solution until a steady reading was reached and then value was observed.
- Electrical Conductivity (EC)

The electrode was immersed into sample solution until a steady reading was reached and then value was documented.

- pH Level (pH)
  The pH electrode was first calibrated with standard buffer solutions with known pH values. To make a pH measurement, the electrode was immersed into the sample solution until a steady reading was reached. The pH value was recorded and documented.
- Ammonia (NH_3) by Calorimetric Method
  10 ml of sample was taken in test tube. Ammonia tablet 1 and 2 were successively mixed in test tube containing water sample. Again 10 ml of water sample was taken in another test tube. Two test tubes were placed in color comparator disk and concentration of ammonia was determined.
- Total hardness (TH) by EDTA Complexometric Method
  5 ml of water sample was taken in conical flask and 20 ml of distilled water was added to it. 2 ml of buffer solution was added to water sample in conical flask. Eriochrome black T indicator was added to the sample solution to acquire wine red colour. EDTA solution was taken in Burette and titration has been done till wine red colour was changed to blue which was end point.
- Calcium (Ca^{++}) by Complexometric Titration Method
  5 ml of water sample was taken in conical flask and 20 ml of distilled water was added to it. 2 ml of 1M NaOH was added to water sample in conical flask. Murexide indicator was added to the sample solution to acquire pink colour. EDTA solution was taken in Burette and titration was continued till red pink was changed to violet which was end point.
- Chloride (Cl^-) by Mohr Method
  25 ml of water sample water was taken in conical flask and 1 drop of potassium chromate indicator was added to the sample solution to acquire color. Silver nitrate solution has taken in Burette and titration has been done till turbidity occurred. The volume of silver nitrate used was noted from the concurrent reading.The chemical equation for the chloride determination using Mohr method has been presented below.
  $Ag^+ + Cl^- \longrightarrow AgCl$
  $2\,Ag^+ + {CrO_4}^{2-} \longrightarrow Ag_2CrO_4$
- E. coli by Membrane Filter Method
  Membrane filter apparatus was sterilized by using methanol. 100 ml of sample was filtered through membrane filter paper having pore size 0.45µm and diameter of 47mm. After filtration membrane filter paper was placed on the surface of absorbent pad saturated with M-lauryl Sulphate Broth. The absorbent pad along with membrane filter paper was placed in culture media plate was incubated at 44.5ºC for 24 Hours. After completion of the incubation period the plate was observed for yellowish colony and numbers were recorded.
- Dissolved Oxygen (DO) by Winkler Method
  The DO probe was inserted into water sample then the dissolved oxygen was observed. DO was measured from four sampling location only. Two samples were from the river along city area and two samples were from downstream of Pokhara city.

3. Results and Discussion

3.1 Water Quality Parameters

Water quality parameters of water sampled from Seti River in Pokhara have been presented in Table 2. The Total Dissolved Solids (TDS) was observed to be minimum 98 mg/l at 15th sampling location(Ramghat) and the TDS was observed to be maximum 128 mg/l at 14th sampling location (Fulbari area). There was no substantial spatial variation of TDS in study area. The permissible value of TDS for drinking water as per Nepal Drinking Water Quality standard (NDWQS) is 1000mg/l. Total Dissolved solids (TDS) was observed within the permissible concentration limits of NDWQS, 2005. The mean electrical conductivity of water was recorded to be 232 µS/cm in study area.

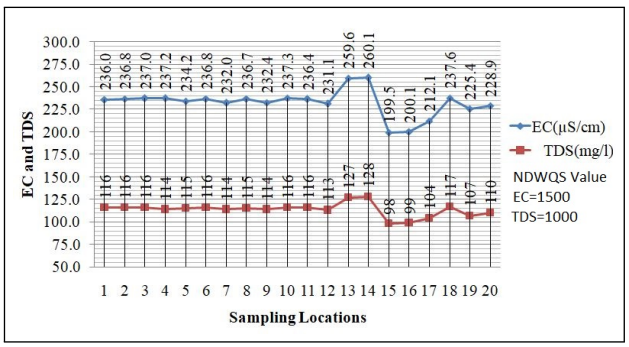

Figure 2: Variations of EC and TDS in Different Sampling Locations

Table 2: Spatial Variations of Water Quality Parameters at Different Sampling Locations

Locations	TDS (mg/l)	Turbidity (NTU)	EC (µS/cm)	pH	TH (mg/l)	Ca^{++} (mg/l)	Cl^{-} (mg/l)	NH_3 (mg/l)	DO (mg/l)	E Coli (CFU/100ml)
1	116	934	236.0	8.12	740	56	13	<0.1		2
2	116	990	236.8	8.20	720	48	13	<0.1		4
3	116	990	237.0	8.01	700	48	15	<0.1		8
4	114	850	237.2	8.11	700	48	15	<0.1		15
5	115	930	234.2	8.13	760	64	15	<0.1		18
6	116	952	236.8	8.05	740	56	13	<0.1		30
7	114	878	232.0	8.06	780	64	17	<0.1		13
8	115	830	236.7	8.14	720	64	13	<0.1		18
9	114	858	232.4	8.06	760	64	15	<0.1		28
10	116	834	237.3	8.03	780	64	15	<0.1		90
11	116	941	236.4	8.30	740	56	13	<0.1		85
12	113	905	231.1	8.10	720	48	15	<0.1		108
13	127	850	259.6	7.95	730	52	14	<0.1		113
14	128	845	260.1	7.99	820	56	13	<0.1	8.1	127
15	98	942	199.5	8.32	960	96	15	<0.1	8.4	147
16	99	960	200.1	8.30	940	88	11	<0.1		167
17	104	930	212.1	8.19	920	84	12	<0.1		78
18	117	945	237.6	8.28	960	96	10	<0.1		53
19	107	965	225.4	8.27	930	72	9	<0.1	9.2	40
20	110	950	228.9	8.25	910	80	12	<0.1	8.7	45
Mean	113.6	913.95	232.36	8.14	801.5	65.2	13.4	<0.1	8.6	59.45
Maximum	128	990	260.1	8.32	960	96	17		9.2	167
Minimum	98	830	199.5	7.95	700	48	9		8.1	2
SD	7.41	52.97	15.03	0.11	95.55	15.79	1.96		0.47	51.31
Varience	54.89	2806.16	225.93	0.01	9129.2	249.43	3.83		0.22	2633
NDWQS Value	1000	5	1500	6.5-8.5	500	200	250	1.5		0

Maximum and Minimum EC values were observed at Ramghat and Fulbari area respectively. In upstream of Pokhara city area, more Electrical conductivity values were observed than that of downstream. The Variation of EC and TDS along the different sampling location has been illustrated in Figure 2.

Turbidity value of water samples was recorded very high. Average turbidity value was observed as 913 NTU. Since the water samples were collected during monsoon season, river water was influenced by frequent rainfall, landslide and erosion in upstream area resulting considerable amount of turbidity in river water. Appropriate treatment shall be required to meet the turbidity limits with drinking water quality standard. Turbidity level might be less in other season because of less erosion and debris. The Spatial variation of Turbidity in different Sampling locations of study area has been represented in Figure 3.

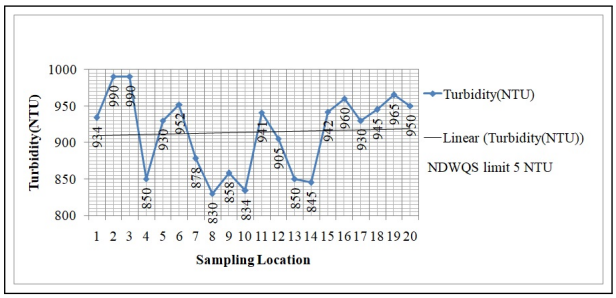

Figure 3: Variation of Turbidity (NTU) along Different Sampling Locations

The water was observed as alkaline and pH value was noted minimum of 7.95 to maximum 8.32. Spatially, there was no significantly change in pH of water The SD of pH values was calculated as 0.11. Ramghat area showed the relatively greater pH value. Minimum pH value was recorded at downstream of Kali and Seti confluence. The mean pH in study area was 8.14 which were in the range of National Drinking Water Quality Standards (6.5-8.5), permissible range for aquatic life and irrigation water. Figure 4 has demonstrated the

variations patterns of pH.

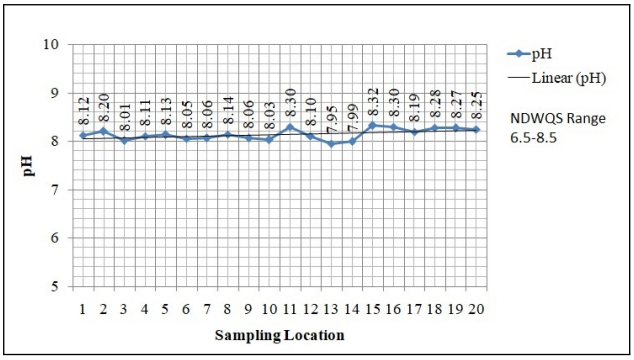

Figure 4: Variation of pH along Different Sampling Locations

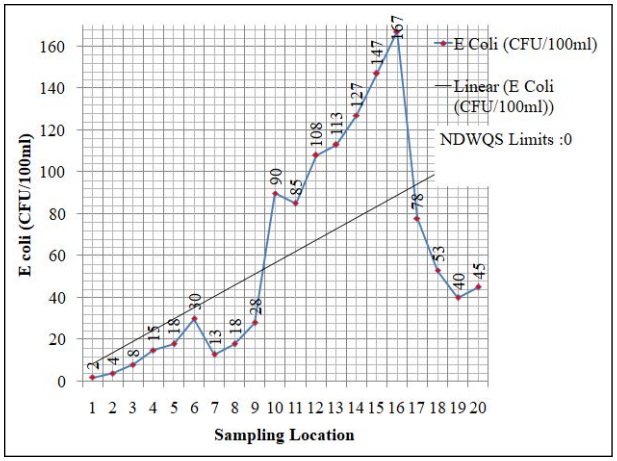

Figure 5: Variation of E-Coli along Different Sampling Locations

Total hardness of water samples was observed very high. As the water had high turbidity there might be the high amount of insoluble calcium bicarbonate resulting with high total hardness. Because of high hardness in water sample, 5ml of water sample was taken and it was diluted with 20 ml distilled water and then titrated with EDTA. Though the total hardness was high but there was no substantial spatial variation of hardness in different sampling locations. Mean total hardness was recorded as 801.50 mg/l which was greater than NDWQS limit i.e. 500mg/l.

The SD of TH in study area was computed as 95.55. Total hardness of water might have been reduced by lowering the turbidity of water and removal of suspended impurities.

Chloride concentration was observed less as compared to NDWQS. There was a significant variation of chloride values in water samples with maximum concentration of 17 mg/l and minimum concentration 9 mg/l. The permissible range for National Drinking Water Quality standard is up to 250 mg/l. The bacteriological examination of water showed that there was presence E-coli in water. The E-coli increased towards the downstream of River. Again, high E-coli concentration was observed near to human settlements. The data showed that fecal contamination increased in downstream. The lowest E-coli concentration was noted at first sampling location with value of 2 CFU/100 ml. There was decreased concentration of E-coli in Dobilla area than that of city area. Such variation of E-Coli has been presented in Figure 5.

Variation of chemical aspects of water quality parameters such as, Ca^{++} has been presented in Figure 6. Study area was divided into three closed boundary to plot the variation of water quality parameters.The variation of water quality parameters like calcium has been presented thorough map using ArcGis. There was variation of calcium concentration ranging minimum 48 mg/l to the maximum 96 mg/l. The mean value of calcium concentration in study area was 65.2 mg/l which was within the permissible range of Nepal Drinking Water Quality Standards (NDWQS) value of 200 mg/l. Colour diagram illustrated the calcium concentration, which varies from 48 mg/l to 64 mg/l in upstream area. The minimum value was represented by red colour and maximum value by green color.

Similarly concentration varies from 52 mg/l to 96 mg/l in city area. Moreover the calcium concentration along downstream area was varied from 72 mg/l to 96 mg/l. There was observed no significance of ammonia in Seti River water. As per examination conducted using ammonia comparator disk, ammonia concentration was recorded less than 0.1 mg/l. in all sampling locations. The recorded value was within the permissible value of NDWQS, which is 1.5 mg/l.

3.2 Comparison of Water Quality Parameters

The global mean value of TDS was 269 mg/l [6]. The study on Gandaki River Basin was mentioned with TDS 115 mg/l[7]. The average value of TDS in Seti River was observed 113 mg/l which was near to GRB mean value and less than Global mean of River water. Comparison of TDS and EC with global mean value and mean value of Gandaki River Basin has been

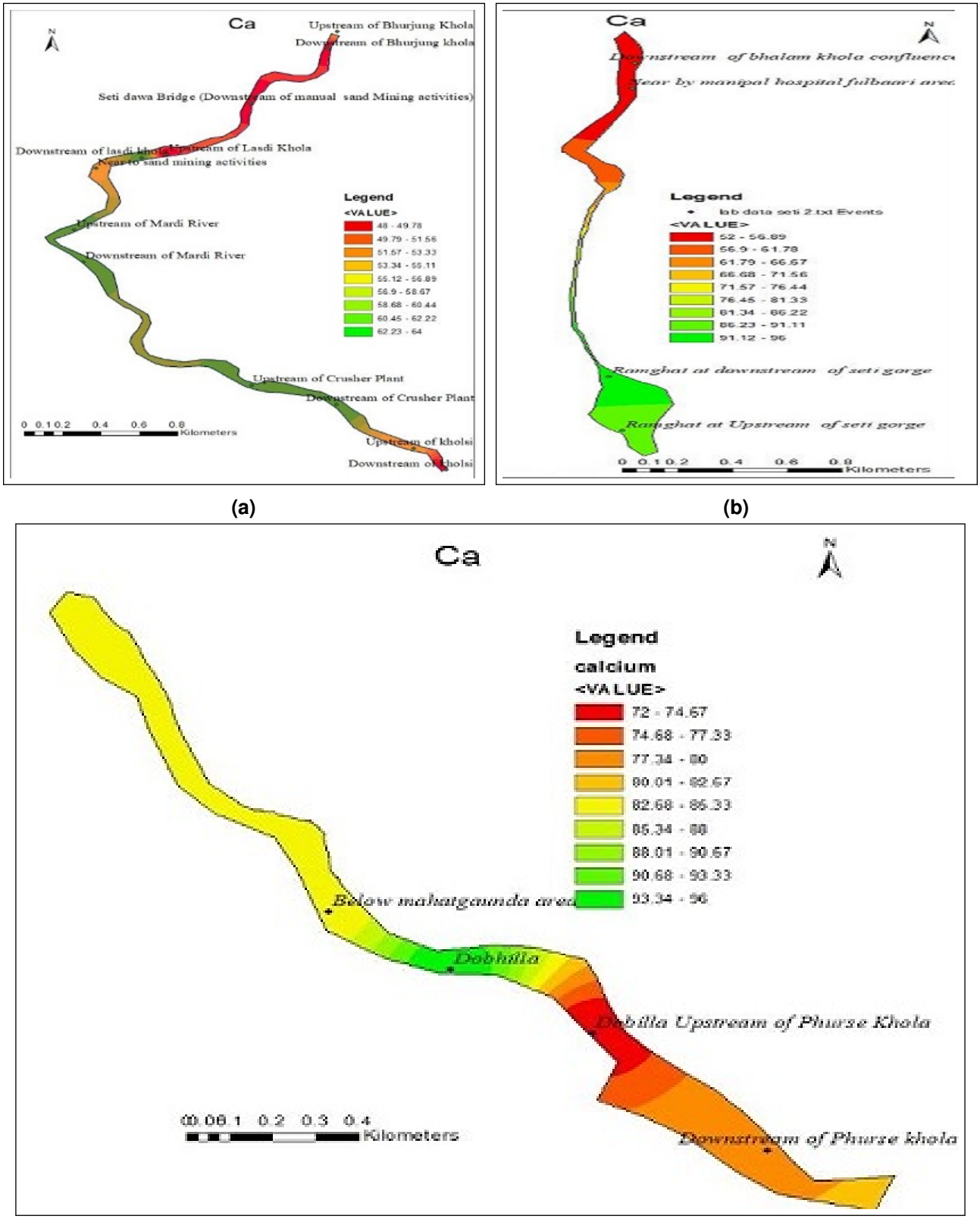

Figure 6: Variation of Ca^{++} (mg/l) along Different Sampling Locations; (a)Upstream of Pokhara city, (b) Along Pokhara City and (c) Downstream of Pokhara City

presented in Table 3. The EC in Seti River at Pokhara was observed less as compared to Gandaki River Basin.

Table 3: Comparison of parameters with Gandaki River Basin (GRB) and Global Mean

Parameters	Seti River	Global Mean[6]	GRB[7]
TDS (mg/l)	113.55	269	115
EC(µS/cm)	232.36	Not Defined	530

The average calcium concentration of water samples was 65.20mg/l which was greater than the average of calcium concentration in Gandaki River Basin (GRB) 39.65 mg/l . The comparison with data obtained in GRB and Global mean has been presented in Figure 7. The Global mean concentration of calcium in world river was 15 mg/l. As compared to global mean of calcium ion concentration 15 mg/l, its concentration in Seti River was recorded high. The chloride concentration varied from 9 mg/l to 17 mg/l and mean value of 13.40 mg/l which was near to chloride concentration of Gandaki river basin 16.02 mg/l [5]. The chloride concentration of water samples was observed less than global mean value 7.8 mg/l.

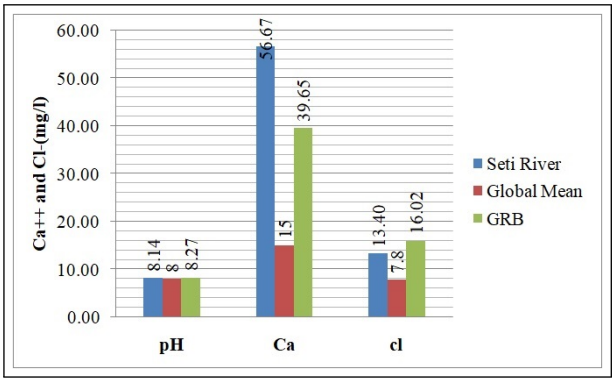

Figure 7: Comparison of Chemical Parameters in Gandaki River Basin, Seti and Global mean

Comparison of water quality parameter for different water uses has been presented in Table 4. Similarly, Electrical Conductivity and TDS values were recorded less as compared to water quality standards for aquaculture, irrigation water and livestock uses guidelines. On the other hand, Turbidity value of water samples was observed high 913.95 NTU being excessively greater than the specified ranges for clear water species in Nepal Water Quality Guidelines for Livestock Watering. Moreover, pH value of water samples was observed within the permissible range as compared with water quality standard for different uses presented in table 4. On the contrary, Total Hardness was recorded greater than the standard range for aquaculture as per Nepal Water Quality Guidelines for Aquaculture. Total hardness range has not defined in Irrigation water and livestock uses. Again, Chloride and Ammonia Concentration were observed less as compared to different water uses mentioned in Table 4.

Table 4: Comparison of Water Quality Parameters with Water Quality Standard for Different Uses

Parameters	Seti River	NDWQS[4]	Aquaculture[5]	Irrigation Water[5]	Livestock Uses[5]
TDS (mg/L)	113.55	1000	<2000	<40 -<540 (maxiMum for some species	<2800
EC(µS/cm)	232.36	1500	Not Defined	400	1500
Turbidity (NTU)	913.95	5	Not Defined	<25 for clear water Species	Not Defined
pH	8.14	6.5-8.5	6.5-9	6.5-8.5	6.5-8.5
TH(mg/l)	801.50	500	20-100	Not Defined	Not Defined
Ca^{++}(mg/l)	56.67	200	Not Defined	Not Defined	<1000
Cl^{-}(mg/l)	13.40	250	<600	<100	Not Defined
NH_3(mg/l)	<0.1	1.5	0-30	Not Defined	Not Defined
DO(mg/l)	8.60	Not Defined	5.0-8.0	Not Defined	Not Defined
E Coli (CFU/100ml)	60	0	Not Defined	Not Defined	<200

However, Dissolved Oxygen in the water samples from the study area was observed 8.6 mg/l which was greater than normal range required for aquaculture. There was not great spatial variation in most of the parameters. As the sampling was conducted at mid of June and first week of July, 2019, discharge in Seti River was high as compared to dry season. Effluent discharged from anthropogenic activities in study area might have been sufficiently diluted for negligible influence in quality variation. This study data may help to validate and compare the further research data how the river water quality changes to due increased urban settlements and other anthropogenic and natural causes.

4. Conclusion and Recommendation

This study included analysis of the physiochemical and biological parameters of water samples from Seti River, Pokhara (Nepal) during monsoon season. Sampling of water was conducted from different locations in Seti River. Likewise, the study area was divided into three regions: one was upstream of Pokhara City and next two were towards city and downstream. The discharge in River was high including debris during sampling. Key water quality parameters including Turbidity and Hardness values were observed excessively higher (913.95 NTU and 801.50mg/l respectively) in Seti River. As per comparisons with water quality standard for different purposes, chloride concentration along with Electrical conductivity and TDS values were comparatively less. In contrast, the pH value of water sample was

observed within the maximum limit of different water uses.

Since the water sampling was conducted only during the rainy season, the recommendation of this study for further researcher could be collect the samples during different seasons from study area following the analysis for the seasonal and spatial variation. Also, data from this study might be useful to validate the data for monsoon season and compare how water quality fluctuates during different time period due to change in land use land development plan. Though values documented form different sampling location had deviation, there was no significant variations patterns was observed in this study. Due to excessively high values of total hardness and turbidity in water samples of Seti River comparing with the National Drinking Water Quality Standard, required treatment process such as plain sedimentation followed by sedimentation with coagulation along with hardness removal processes (e.g. Addition of Lime and Soda, Permutit Process) might be needed for maintaining the water quality for use of water to the intended purpose. Again, fecal contamination in Seti River water has shown necessity of disinfection techniques like chlorination, sand filters. Furthermore, water quality analysis including remaining parameters shall be conducted for confirming the water quality standards for use of water. Again, highly turbid water might have the problem of siltation in irrigation canal and agriculture field therefore sediment trapping mechanism shall be adopted to supply water for irrigation purpose. Of course, excessive Hardness and Turbidity values of water might not be suitable for aquatic life demanding corresponding water treatment prior to supply towards the aquaculture

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