Post-Earthquake Survey of Bagmati River Seepage Through Physicochemical Analysis of Water

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ABSTRACT

Bagmati river has a great cultural, economic and mythological significance. It has also been related to the civilization of Kathmandu valley. Due to the rapid and unmanaged urbanization and industrialization the river has been heavily polluted leading to the water borne hazards and water shortage problem in the capital. Amidst this problem there was a major earthquake in Kathmandu in 2015 which disturbs the land masses in the valley. This research was conducted to assess the physico-chemical parameters of Bagmati river water and ground water from its corridor at about 50 m and 100 m distance for comparison to detect the post-earthquake seepage status of river water from October 2019 to March 2020. In total 10 sites (A-J) were selected from Gokarna to Chovar. From each site 1 river and 2 ground water samples at approximately about 50 m and 100 m radial distance from river were taken. The range of temperature, turbidity, conductivity, TDS, pH, chloride, total hardness, total acidity, total alkalinity, total iron content, total ammonia content, dissolved oxygen content and biochemical oxygen demand (BOD) were recorded to be 13-22 ºC, 150.5-395.5 NTU, 121.1-825 µs/cm, 77.56-528 ppm, 6.5-7.84, 4.97-114.3 mg/l, 34-180 mg/l, 10-224 mg/l, 70-382 mg/l, 0.55-4.156 mg/l, 5-150 mg/l, 0-4.5 mg/l and 5.35-320 mg/l respectively for river water samples and 16-21 ºC, 3.8-52.1 NTU, 25.2-745 µs/cm, 16-476.8 ppm, 6.08-7.61, 5.68-134.9 mg/l, 6-328 mg/l, 10-140 mg/l, 30-340 mg/l, 0.02-5.101 mg/l, 0.026-0.9 mg/l, 2.63-8.1 mg/l and 1.62-16.3 mg/l respectively for ground water samples at 50 m distance from river and 16-20 ºC, 3.1-60 NTU, 25.6-697 µs/cm, 12.8-446.08 ppm, 5.49-8.78, 5.68-44.02 mg/l, 10-300 mg/l, 10-160 mg/l, 14-294 mg/l, 0.015-4.37 mg/l, 0.028-0.54 mg/l, 3.1-8.7 mg/l and 0.63-14.2 mg/l respectively for ground water samples at 100 m distance from the river. As there were significant differences in turbidity, chloride, total acidity, iron, ammonia and BOD among Bagmati and ground water samples, direct mixing of polluted Bagmati river water with nearby ground waters through seepage was not detected. Thus, irrespective of earlier condition, the land masses near the Bagmati territory has not been affected so as to allow deeper seepage of river water by the earthquake of 2015.

Keywords: Bagmati river, underground water, earthquake seepage

Introduction

The Bagmati river, an important water resource of Nepal, is facing biological, chemical, and other ecological challenges due to uncontrolled population growth and unplanned urbanization (Tandukar et al., 2018). This holy river Bagmati originates from Baghdwar situated at the top of Shivapuri hill in the north of Kathmandu valley which flows from Kathmandu to the Terai in the south and finally joins the Ganga river in India (Bhandari et al., 2017). Kathmandu valley comprises three districts, Kathmandu, Lalitpur and Bhaktapur which is located between mountain ranges lying in the central part of Nepal with coordinates 85° 11' -85° 34' E Longitudes and 27° 32' -27°49°N Latitudes (Pokhrel & Lee, 2014).

Water being one of the important sources of sustainable development goals, the groundwater which is easily available, cost effective, reliable and affordable source are mostly used by people. Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals (Otieno et al., 2012). Furthermore, it is characterized by low temperature, low redox potential, high carbon dioxide, high mineral content, a smaller number of suspended solids, and free from microbial contaminants (Pant, 2011). The quality and quantity of ground water is affected by urbanization (Wakode et al., 2018). Over four million people in this valley rely on groundwater (Pandey et al., 2012). The major supplier of water throughout the valley KUKL is fulfilling only 19% of the demand in the dry season and 31% in wet season (Thapa et al., 2018). Water serves as the commonest vehicle of transmission of a number of infectious diseases when get contaminated with various pathogenic as well as opportunistic microflora and toxic chemical compounds (Jayana et al., 2009). Shaking of earth surface i.e., earthquake struck central Nepal on 25 April 2015 on local time 11:56 am with moment magnitude of (Mw) 7.8 (Goda et al., 2015). The devasting earthquake can bring a lot more changes in geology where it struck. The seismic waves produced at the time of earthquake may collide water-rock, water-soil or clay particle which may affect in quality of water and underground water too. Similarly, drying of water and new water sources have also been observed at different places of world due to the earthquake (Nakagawa et al., 2020). Groundwater and river water are two interconnected components of one single resource and impacts on either of these components will inevitably affect the quantity or quality of the other (Malla et al., 2015). As in a survey conducted by U. S. Bureau of Reclamation along the Sacramento river, the degree to which the river contributes water to the underground varies greatly from place to place along the river depending upon the geology of the area and on the extent to which river stages are above or below the level of adjoining land. In those areas, that have sand strata connecting to the river the river makes large and rapid contributions to the groundwater as the river rises. And in other areas, where the river channel is in heavy clay, the river contributes water to the ground very slowly during periods of high river stage and does not create groundwater problems unless the river stages are maintained at high levels for a month or longer (Todd et al., 1959). This is known as seepage of water where slow escape of a liquid through small holes is passed. Thus, the main aim of this study is to survey on Bagmati river seepage through ground and river water analysis performing physico-chemical analysis. The findings of the study might be able to suggest the impacts of 2015 earthquake on the geography of the river and nearby underground water surfaces too.

Materials and methods

Study design and study sites

A descriptive study was carried out in Kathmandu valley to assess the physico-chemical parameters of Bagmati river water and its peripheral underground water from Gokarna to Chovar. The study was conducted in Microbiology Laboratory of St. Xavier's College, Maitighar, Kathmandu from October 2019 to March 2020. Total 30 water samples were collected in duplicates from different places lying inside the valley i.e., Bagmati river, 2 ground water samples at approximately about 50 m and 100 m radial distance from river. Then the samples were processed following standard procedures.

Sample collection

Ten sites in the Bagmati river were selected randomly and the corresponding sites were selected for ground water samples. The sites were Gokarna, Guheshwari, Gaushala, Tinkune, Shankhamul, Thapathali, UN park, Teku, Balkhu, and Chovar and were labelled from A to J respectively.

For river water samples, during sample collection, the bottle caps were opened and the bottles were lowered into the water with their mouth directed against the water current.

Ground water samples were obtained from tubewells, borings and wells. The ground water sample to be collected from well was thoroughly mixed with a bucket before collection whereas the water samples to be collected from tubewells and borings were let to run off for about a minute and then only collected in collection vessels (APHA, 2000).

Temperature was determined on the sites.

Sample preservation/transportation

The water samples were transported to the laboratory within 18 hours of collection and processed as soon as possible.

Experimental methods

Physico-chemical analysis

The physico-chemical parameters such as temperature, turbidity, conductivity, total dissolved solids, pH, chloride, total hardness, total acidity, total alkalinity, iron, ammonia, DO and BOD were assessed as per the standard guidelines given by APHA (2000).

Mercury thermometer was used to determine the temperature. The bulb of thermometer was dipped in the water surface and final reading was noted. The unit of measurement used was degree centigrade (˚C).

Turbidity meter was used to measure the turbidity of water. Distilled water as blank was used to set the instrument and then, samples were processed accordingly.

Conductivity meter was used to measure the conductivity of water. The conductivity meter was dipped in water, and the reading was recorded.

TDS was determined by evaporation method.

Standard buffer of pH 7 was used to calibrate pH meter. Electrode to be used was uncapped and rinsed thoroughly with distilled water, dried with a soft tissue paper and dipped in the water sample then pH meter reading was recorded.

Chloride

It was determined by Argentometric titration. Then chloride concentration was calculated by using formula i.e., $S_2 = V_1 \times S_1 \times 1000 \times 35.55 / V_2$

Where, S_2 = Chloride concentration (mg/l)

V_1 = Volume of $AgNO_3$ (ml)

S_1 = Concentration of $AgNO_3$ (Normality)

V_2 = Volume of sample (ml)

Total hardness

It was measured by EDTA titrimetric method. Hardness was calculated by using formula i.e.

$$\text{Total hardness (mg/l)} = \frac{\text{Volume of EDTA consumed (ml)} \times 1000}{\text{Volume of sample (ml)}}$$

Total acidity

It was determined by titration method where phenolphthalein as indicator was used. Then total acidity was calculated as:

$$\text{Total acidity (mg/L)} = \frac{(N \times V) \text{ of NaOH} \times 1000 \times 50}{\text{Volume of sample (ml)}}$$

N= Normality of NaOH solution used for titration.

V= Volume of NaOH used for titration in ml.

Total alkalinity

It was determined by titration method where bromocresol green was used. Alkalinity of water sample was calculated by:

$$\text{Total alkalinity (mg/L)} = \frac{B \times \text{Normality of } H_2SO_4 \times 1000 \times 50}{\text{Volume of sample (ml)}}$$

B= Volume of sulfuric acid consumed (ml).

Iron

Iron was determined by 1, 10-phenanthroline method.

a. 50 ml of sample was taken in a conical flask.

b. 2 ml of Conc. Sulfuric acid and 1 ml of Hydroxylamine was added on it.

c. Then, few glass beads was grinded in clean mortar and were added to mixture content. Mixture content was boiled and reduced to 20-25 ml.

d. It was allowed to cool at room temperature and transferred to 100 ml volumetric flask excluding glass beads.

e. 10 ml of ammonium acetate buffer and 4 ml of Phenanthroline was added into it.

f. The solution was diluted upto 100 ml using distilled water and allowed to leave for 10 minutes.

g. Then, absorption was observed using spectrophotometer at 510 nm.

h. Absorption of light by standard solutions of ferrous ammonium sulfate (10, 8, 6, 4, 2, 1 μg/ml Fe) were plotted in standard graph and iron content in water samples were determined corresponding to the absorbance.

Ammonia

Nessler's reagent method was used to determine ammonia.

a) Standard ammonium sulphate solution was prepared by dissolving 4.718 gm of dried ammonium sulphate to 1 L of ammonia free distilled water (1 ml= 0.01 mg N).

b) The stock solution was too concentrated for most purposes. So, standard solution was prepared by diluting 10 mL of this solution to 1L with ammonia-free distilled water.

c) A series of standards containing the following volumes of standard ammonia nitrogen solution diluted to 50 mL with water: 0.0, 1.0, 3.0, 5.0, 8.0, and 10.0 mL were prepared.

d) 1 ml of Nessler 's reagent was added to 50 mL of the standard series and filtered water sample respectively.

e) After 25 minutes absorption was measured using the spectrophotometry technique at 425 nm. Blank was prepared by using ammonia free water and Nessler's reagent.

f) Absorption of light by solutions were plotted in standard graph obtained by plotting absorption value of standard ammonia solutions and ammonia content in water samples corresponding to absorbance were determined.

Dissolved oxygen (DO)

DO was determined by Azide modification method.

a) 1 ml $MnSO_4$ was added to sample water in a BOD bottle, followed by 1 ml of alkali-iodide-azide solution.
b) The bottle was stoppered and content mixed by inverting bottle a few times.
c) Once the precipitate settled sufficiently, 1 ml conc. H_2SO_4 was added.
d) The bottle was restoppered and mixed by inverting several times until dissolution is complete.
e) 201 ml of sample (after correction for sample loss by displacement with reagents) was titrated against 0.025M Na_2S_2O solution to a pale straw color.
f) Few drops of starch solution was added and titration continued to first disappearance of blue color.

DO was calculated accordingly: in 200 ml sample, 1 ml 0.025M $Na_2S_2O_3$ = 1 ml DO/l.

Biochemical oxygen demand (BOD)

It was determined using 5-Day BOD test.

a) 1 ml of each of phosphate buffer, $MgSO_4$, $CaCl_2$, and $FeCl_3$ was added for each liter of dilution water and was mixed thoroughly. The water was bubbled by using compressed air for about 30 minutes.
b) pH of the sample was adjusted to 7 using dilute H_2SO_4 or dilute NaOH as needed.
c) Sample water was diluted with dilution water as needed (based on DO of sample water), and mixed solution was dispensed in two BOD bottle and stoppered.
d) DO of one of the bottle was determined.
e) The other bottle was incubated at 20°C for 5 days.
f) DO was determined after 5 days.
g) BOD was calculated as
BOD_5 (mg/l) = (DO_1 –DO_5)/dilution factor

DO_1 = DO of diluted sample immediately after preparation

DO_2 = DO of diluted sample after 5 days incubation at 20 °C

Quality control

Laboratory grade chemicals not exceeding expiry date were used. Fresh chemicals were prepared as required. Instruments were calibrated using their respective chemicals.

Statistical Analysis

Data were entered in the MS-Excel version 2013. For statistical analysis, manual test was performed for each sample to be analyzed. F test was performed for detecting statistical significance between parameters of different samples.

Results

Temperature

Minimum temperatures of the river water sample and ground water samples at about 50 m and 100 m distance from river were recorded to be 13 ºC, 16 ºC and 16 ºC respectively whereas maximum temperatures were recorded to be 22 ºC, 21 ºC and 20 ºC respectively. There was no difference in the temperature of among Bagmati river water and ground waters at 50 m and 100 m distance from the river. (Table 1)

Turbidity

Minimum turbidity values of river water and ground water samples at about 50 m and 100 m distance from river were recorded to be 150.5, 3.8 and 3.1 NTU respectively whereas the maximum turbidities were recorded to be 395.5, 52.1 and 60.0 NTU respectively. There were significant differences in the turbidities of Bagmati river water and ground water at 50 m distance from the river and between the Bagmati river water and ground water at distance of 100 m from the river but not between ground waters. (Table 2)

Conductivity

Minimum conductivity values of river water and ground water samples at about 50 m and 100 m distance from river were recorded to be 121.1, 25.2 and 20 µs/cm respectively whereas the maximum conductivity values were recorded to be 825, 745 and 697 µs/cm respectively. For conductivity, there was no significant difference among the Bagmati river water and ground water samples at 50 m and 100 m distance from the river. (Table 3)

Total Dissolved Solids

Minimum TDS values of river water and ground water samples at about 50 m and 100 m distance from river were recorded to be 77.56, 16 and 12.8 ppm respectively and the maximum values were recorded to be 528, 476.8 and 446.08 ppm respectively. For total dissolved solids, there was no significant difference among the Bagmati river water and ground water samples at 50 m and 100 m distance from the river. (Table 4)

pH

The minimum pH of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 6.5, 6.08 and 5.49 respectively and the maximum pH were recorded to be 7.84, 7.61, and 8.78 respectively. There was no significant differences among the pH of Bagmati river water and ground waters at 50 m and 100 m distance from the river. (Table 5)

Chloride

The minimum chloride content of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 4.97, 5.68 and 5.68 mg/l respectively. Highest chloride concentration of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 114.3, 134.9 and 44.02 mg/l respectively. There were significant differences between the chloride contents of Bagmati river water and ground water at 100 m distance (Gw100) from the river only. (Table 6)

Total Hardness

The minimum total hardness of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 34, 6 and 10 mg/l respectively Maximum hardness of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 180, 328 and 300 mg/l respectively. For total hardness, there was no significant differences among the Bagmati river water and ground waters at the distance of 50 m and 100 m respectively. (Table 7)

Total Acidity

The minimum total acidity of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 10, 10 and 10 respectively Maximum total acidity of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 224 mg/l, 140 mg/l and 160 mg/l respectively. For total acidity, there were significant difference between the Bagmati river water and ground water samples 100 m distance from the river. (Table 8)

Total Alkalinity

The minimum total alkalinity of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 70, 30 and 14 respectively Maximum alkalinity of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 382 mg/l, 340 mg/l and 294 mg/l respectively. For total alkalinity, there was no significant difference among the Bagmati river water and ground water samples at 50 m and 100 m distance from the river. (Table 9)

Iron

The minimum iron content of the river water sample and ground water samples at about the distance of 50 m and 100 m from river were recorded to be 0.55, 0.02 and 0.015 mg/l respectively. Maximum concentration of iron in river water and ground water samples at about 50 m and 100 m distance from river were determined to be 4.156, 5.101 and 4.37 mg/l respectively. For iron content, there were significant difference between the Bagmati river water and ground water samples at 50 m and between Bagmati river water and ground water samples at 100 m distance from the river. (Table 10)

Ammonia

The ammonia content in river water sample ranged from 5 mg/l –150 mg/l and in ground water samples from 0.026 mg/l - 0.9 mg/l at 50 m distance from the river and from 0.028 mg/l-0.54 mg/l at 100 m distance from the river. For total ammonia content, there were significant differences between the Bagmati river water and ground waters at distance of 50 m and 100 m respectively. (Table 11)

Dissolved Oxygen

Maximum and minimum DO values of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 4.5 mg/l and 0 mg/l, 8.10 mg/l and 2.63 mg/l and 8.71 mg/l and 3.10 mg/l respectively. For dissolved oxygen, there was significant difference between the Bagmati river water and ground water samples at 50 m and 100 m distance from the river but not between the ground water samples. (Table 12)

Biochemical oxygen demand

Maximum and minimum BOD values of river water and ground water samples at about 50 m and 100 m distance from river were determined to be 320 mg/l and 5.35 mg/l, 16.3 mg/l and 1.62 mg/l and 14.2 mg/l and 0.63mg/l respectively. For BOD, there are significant differences between the Bagmati river water and ground waters at distance of 50 m and 100 m and between ground waters. (Table 13)

Table 1: Temperature of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	20	17	18	0.921	0.713	0.509
B	18	21	19			
C	22	18	18			
D	17	20	19			
E	16	17	18			
F	13	18	16			
G	18	20	17			
H	21	18	20			
I	17	16	18			
J	21	19	17			

Table 2: Turbidity of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	150.5	3.8	3.1	0.00	0.00	0.517
B	184.2	6.6	60			
C	395.5	38.05	5.3			
D	179.85	33.59	5.15			
E	208.32	8.5	10.1			
F	354.29	9.67	11.67			
G	292.2	14.2	20.1			
H	204.8	52.1	12.9			
I	301.7	25.8	21.3			
J	347.2	30.1	16.8			

Turbidity limit according to NDWQSD, 2005 is 5-10 NTU.

Table 3: Conductivity of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	121.1	25.2	25.6	0.118	0.073	0.927
B	131	470	100			
C	280	292	383			
D	527	364	678			
E	294	745	20			
F	456	124	697			
G	649	35	191			
H	734	126	264			
I	722	218	21			
J	825	169	81			

Conductivity limit according to NDWQSD, 2005 is 1500 µs/cm.

Table 4: TDS value of water sample from each sites

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	77.56	16	17	0.112	0.083	0.895
B	83.84	300.8	64			
C	179.2	186.88	245.12			
D	337.28	232.96	433.92			
E	188.16	476.8	12.8			
F	291.84	79.36	446.08			
G	415.36	22.4	122.24			
H	469.76	80.64	168.96			
I	462.08	139.52	13.44			
J	528	108.16	51.84			

TDS limit according to NDWQSD, 2005 is 1000 ppm.

Table 5: pH of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	6.72	6.08	6.49	0.135	0.932	0.427
B	7.84	6.9	8.78			
C	6.5	7.1	8.1			
D	6.94	6.59	7.12			
E	6.72	6.8	6.5			
F	7.34	7.08	7.3			
G	7.4	6.21	6.96			
H	7.19	6.81	7.35			
I	7.09	7.61	5.49			
J	7.16	6.74	6.57			

pH limit according to NDWQSD, 2005 is 6.5-8.5.

Table 6: Chloride concentration in water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	4.97	7.1	12.78	0.329	0.004	0.075
B	39.05	60.35	35.5			
C	41.89	36.21	44.02			
D	88.04	127.09	31.95			
E	53.25	134.9	7.1			
F	80.94	107.92	24.85			
G	112.18	5.68	19.17			
H	114.31	31.35	26.27			
I	112.78	12.78	5.68			
J	111.47	10.65	5.68			

Chloride limit according to NDWQSD, 2005 is 250 mg/l.

Table 7: Total hardness of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	34	120	138	0.644	0.748	0.898
B	110	260	220			
C	68	80	154			
D	126	216	94			
E	82	328	14			
F	106	74	300			
G	140	6	174			
H	124	70	128			
I	160	112	20			
J	180	50	10			

Total hardness limit according to NDWQSD, 2005 is 500 mg/l.

Table 8: Total Acidity of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	10	48	40	0.067	0.032	0.811
B	40	24	20			
C	30	70	40			
D	56	42	46			
E	14	14	10			
F	224	140	160			
G	124	10	10			
H	80	10	10			
I	62	12	20			
J	94	20	24			

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Table 9: Total Alkalinity of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	70	154	186	0.202	0.185	0.947
B	180	340	180			
C	146	168	256			
D	184	156	294			
E	106	180	14			
F	208	140	178			
G	300	30	100			
H	300	70	110			
I	260	112	44			
J	382	96	62			

Table 10: Iron content in water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	3.5	5.101	4.37	0.034	0.044	0.365
B	3.87	2.98	3.1			
C	2.932	3.97	4.1			
D	2.1	0.03	0.062			
E	3.732	0.011	0.016			
F	0.55	0.033	0.045			
G	1.23	0.02	1.5			
H	2.01	0.113	0.015			
I	3.97	0.055	0.071			
J	4.156	0.097	0.9			

Iron limit according to NDWQSD, 2005 is 0.3-3mg/l.

Table 11: Ammonia content in water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	5	0.026	0.028	0.00	0.00	0.132
B	75	0.12	0.095			
C	150	0.9	0.51			
D	100	0.501	0.32			
E	73	0.051	0.033			
F	112	0.62	0.54			
G	91	0.2	0.25			
H	93	0.41	0.37			
I	97	0.043	0.067			
J	102	0.501	0.48			

Ammonia limit according to NDWQSD, 2005 is 1.5 mg/l.

Table 12: Dissolved Oxygen value of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	4.5	2.63	3.1	0.00	0.00	0.416
B	2.2	5.1	3.8			
C	0	5.41	3.82			
D	0.12	5.01	4.7			
E	0	4.9	4.87			
F	0.1	5.3	4.9			
G	0.87	7.7	8.71			
H	1.1	7.09	5.06			
I	0.74	8.1	6.08			
J	4.13	7.7	7.49			

Table 13: BOD values of water samples from each site

Sites	River	Gw50	Gw100	P-value (River and 50m Gw)	P-value (River and 100m Gw)	P-value (Gw50 and Gw100)
A	5.35	1.62	0.63	0.00	0.00	0.012
B	55.21	13.21	2.5			
C	320	14.21	6.32			
D	125.26	10.05	3.44			
E	175.6	15.15	8.01			
F	190	14.1	10.02			
G	283	6	8.1			
H	307	16.3	14.2			
I	293	6.9	5.7			
J	177	10.5	9.4			

Discussion

The analysis of the quality of river water and the peripheral underground water on the basis of the above mentioned parameters revealed that the quality of the river water undergoes progressive degradation as it passes from semi urban area to the core urban area of the Kathmandu valley. The values of the different physical and chemical parameters of the sites from C-J shows the degrading condition of the river water as it was downstream. Also the ground water of core city areas showed more degradation. However, some of physico-chemical parameters such as conductivity, TDS, pH, chloride, and total hardness concentration for most of the river as well as underground waters were within the desired limits of National Drinking Water Quality Standard and Directives, 2005 of Nepal. Ammonia concentration of ground waters were well below the standard value.

The minimum and the maximum temperature of the Bagmati river recorded was 13 ºC and 22 ºC respectively. This variation in temperature can be because of different factors such as season, time place and human activity (Kelleher, 2021). It is surprising that temperature of non polluted water upstream and polluted water downstream had similar temperatures. It can be an area of future research. Similarly, altitudinal variation might also have an impact on the temperature of the sample. Ground water samples showed the temperature variation between 16 ºC-21 ºC. Ground water temperature is affected by seasonal change of ground surface temperature and infiltrating water (Federal office for the Environment, 2022). Also during the day the temperature of surface water increases.

High turbidity of the river sample (150.5 NTU - 395.5 NTU) is due to the pollution by industrial and agricultural effluents. Therefore, water downstream is more turbid as compared to the upstream water. Also the open discharge of sewage and direct dumping of solid wastes into the river is a major contributor of increased turbidity of the surface water whereas the higher turbidity of the underground water is mainly due to presence of inorganic constituents such as iron, arsenic, etc. If the ground water contains higher amount of organic components its turbidity increases. Higher turbidity of river water was also reported by Pant (2011).

The conductivity of the river water increased from upstream to downstream and maximum conductivity was recorded at the farthest point which was similar to the finding of Gautam et al. (2013). Salts in sewage can be attributed the most to the increase of conductivity in the downstream water. Ground waters conductivity were within limits although it was high which might possibly be due to the intrusion of pollutants (inorganic or organic) from river or sewage lines.

The highest value of TDS was recorded at downstream sampling locations and lowest was obtained nearer to the origin site of river. This drastic change in the parametric value might be due to the confluence of more polluted tributaries of the river and more pollution in the core urban area (Poudyal, 2016). All the samples processed showed acceptable TDS value. Factors contributing to the TDS value of ground water are salts such as chlorides, carbonates, bicarbonates, sodium, potassium, iron, etc.

Most of the samples showed neutral to alkaline pH. The higher values of pH may be due to the higher production of bicarbonates as a consequence of higher organic inputs.

Chloride content in river water increased flowing from upstream to the downstream. This might be basically due to the untreated sewage dumping into the river water in urban areas and also may be due to industrial and agricultural effluents dumped in the river. Raut (1994) findings also supports this findings as it shows similar range of chloride content in river water samples. The chloride content in ground water is mainly affected by the presence of different chloride salts and leaching of chlorides from rocks to the ground water. The higher amount of chloride reported in this project might also be due to intrusion of fecal contaminants or inorganic chloride salts from soils or rocks.

Hardness of water is the property to avoid lather formation with soap. It has no harsh effect in health. Hardness of ground water may be due to dissolved calcium and magnesium salts of rocks beneath whereas hardness of river water may be influenced by carbonates and bicarbonates from hilly rocks or discharge from the surrounding. River water is flowing and accumulating water from different rivulets so it is diluted and has less hardness.

The acidity of the river water is greatly influenced by dumping of industrial wastes, solid wastes, laboratory effluents etc. The results obtained showed that the acidity of the water samples of both surface and ground water tends to increase from upstream to downstream. Similarly, the total alkalinity of the river sample ranged between 70 mg/l-382 mg/l. The result obtained showed that the alkalinity of the river sample tends to increase from upstream to downstream. Bicrabonates are the main components that determines the alkalinity of both the rivers and ground water samples.

The iron content in the river water decreased in the middle of downstream and increased later. This might be due to higher iron content in the upstream area as indicated by high iron content in ground water there and being diluted in the midstream and again receiving pollutants from human activity later. The higher concentration of iron in ground water of Gokarna (upstream) region was also noticed by Pradhan (2009).

The ammonia content in the river water was reported to be minimum at the site A which was recorded to be 5 mg/l and maximum ammonia content was recorded as 150 mg/l at the site C. Similarly, the ammonia content in ground water ranged between 0.026 mg/l to 0.9 mg/l. It was also analysed that the ground water samples nearer to the river were containing more ammonia which might be due to sewage pollution. Similarly, all the river water samples contained unacceptable limit of ammonia. Higher ammonia content in river water is the clear indication of pollution.

Dissolved oxygen of river water is lower due to pollution of the river from various sources which utilizes it for oxidation. Ground waters had relatively higher DO content as the samples might have been aerated while collecting samples from tube wells.

Biochemical oxygen demand increased downstream of the river indicating pollution of the river in the urban area of Kathmandu. This result corresponds to result of Mishra et al. (2017). Ground waters had significantly lower levels of BOD due to less content of organic substances. On overall analysis of the result it was noted that some of the physical parameters such as TDS and conductivity and some chemical parameters namely pH, total hardness and total alkalinity content showed no major difference between the river water and ground water at some particular sites. The TDS, conductivity and iron content of the water is greatly affected by the geology of the area where the water source exists. Thus, because of the similar geology no major difference in these parameters within the ground and river water might have been observed. Other physico-chemical parameters i.e., turbidity, chloride (100 m), total acidity (100 m), iron, ammonia, DO and BOD showed significant difference between river water and underground waters at 50 m and 100 m distance from the river which is suggestive of separation of river water and ground water. There seems no direct penetration of polluted river water down the soil to the water table. Otherwise there would not have been the differences in the concentration of the soluble constituents in river water and ground water. Irrespective of earlier condition, it seems earthquake has not affected the ground at the Bagmati river periphery to allow deeper leaching of the river water. However, study with larger sample size is needed for better clarity.

Conclusion

The four physicochemical parameters that fell within the range of national standard as well as WHO guidelines (2002, 2006, 2011, 2017) of all the water samples were conductivity, TDS, chloride and Hardness. Also, ammonia concentration of underground water at the distance of 50 m (Gw50) and 100 m (Gw100) were within the national standard guidelines. In addition, conductivity, TDS, pH, total hardness and total alkalinity of the water samples exhibited no notable variations among Bagmati river water and underground waters. There were sharp differences in concentrations of parameters such as turbidity, chloride, total acidity, iron, ammonia, and BOD among Bagmati and ground water samples. This is possible only when surface water of polluted Bagmati river do not get mixed with ground water. Therefore, irrespective of earlier condition, the disastrous earthquake of 2015 did not bring significant changes in geography of that area so as to allow seepage of Bagmati river water deeper into the water table.

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