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Assessment of River Water Intrusion at the Periphery of Bagmati River in Kathmandu Valley

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Abstract

The present study was carried out to find out the possible impact of Bagmati river water on its nearby ground water resource within Kathmandu valley (KV). For this, five sampling stations were selected viz. Gokarna, Tilganga, Sankhamul, Teku and Sundarighat . From each station, one river water sample and six ground water samples from both sides of the river were taken on proportion basis by dividing the strata lying within 50 m, 50-100 m and 100-150 m distance from the river collected. River water analysis showed that it was less polluted during winter season as compared to other seasons and got severely degraded as it entered to the urban core. Regression analysis showed that the mean value of ground water parameters like pH, conductivity, chlorides, free carbon dioxide, alkalinity, hardness, nitrate, ammonia, iron, and ortho-phosphate were decreased from within 50 m to 50-100 m, and 100-150 m distance from the river bank. Microbial analysis of ground water showed that 88% of the samples were contaminated with fecal matter. So the ground water along Bagmati river should could not be used as consumptive purposes without treatment. The finding showed that the ground water was more contaminated along the river banks and towards the urban corridor than the upstream parts which might be due to intrusion of nearby polluted river water.

Key words: dummy variable, regression analysis, water intrusion, water quality assessment

Introduction

Water is a key element in sustaining human and environmental health. Water quality is vital concern for mankind since it is directly linked with human welfare. Water quality refers to the set of concentrations, speciation and physical partitions of inorganic and organic substances including the composition and state of aquatic biota in the water body (APHA 1998). Water quality is used to refer the suitability of water to sustain living organisms and other uses such as bathing, washing, irrigation, industry and so on. For this, it should be suitable in terms of physical, chemical, biological and aesthetic characters. When the water quality parameters shift beyond the range of water quality standards for various purposes, then the water is said to be polluted. Water pollution is any physical, chemical or biological change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses (Miller 2002). Water pollution, today is one of the most serious environmental issues of all over the world. Polluted water is responsible for very large number of mortalities of organisms when it becomes a vehicle for transmission of diseases. Thousands of people suffer and die from water and sanitation related diseases in the world (WHO 2010).

Ground water can be contaminated through varieties of mechanisms by numerous contaminants from a point and non point sources. Ground water can be contaminated by localize release from sources such as hazardous waste disposal sites, municipal landfills, surface impoundments, underground storage tanks, gas and pipelines, and back siphoning of agricultural chemicals into wells. Ground water may also be contaminated by substances released at or near the soil surface in more dispersed manner, including pesticides, fertilizers, septic tank lechate and contamination from other non point sources (Mays 1996). Once contaminants reach the ground water they are not effectively diluted and dispersed because the rate of movement of ground water is very low. It may take decades or centuries for naturally returns to a useable resource from the contaminated ground water. The restoration of ground water systems through engineered treatment is also slow and costly (Miller 2002).

Nepal has abundant water resources. Despite this, the potable water supply in most of the rural and urban areas of Nepal is still inadequate in quantity and poor in quality. The urban areas, especially in KV there is a constant short supply of water. Until last three decades, Bagmati and its tributaries, traditional stone spouts and natural springs were able to fulfill the drinking, irrigation and various other needs of the valley but now they are used as sewage dumping sites. Due to high scarcity of pipeline drinking water in Kathmandu, people are reliant on the underground water which is not the sustainable one. Now almost every house, hotel, institution etc. have tube wells, dug wells and borings which results over extraction of underground water resulting in depletion and degradation of water quantity and quality. Although the extent of water is being drawn out from the ground is indeed at alarming rate, there are no statistics or any government policy to bind and control its haphazard use.

The land coverage of KV is decreasing due to increasing settlements and infrastructure development. Due to these developments ground water recharging area is confined only along the river bank. On the other hand, pollution level in the river has been increasing day by day. Excessive withdrawal of ground water results drawdown of its levels, which can trigger intrusion of nearby river water through ground water and river water levels interaction, leading to pollution of ground water source and very less study has been done on this regards in Kathmandu.

The objective of the study was to find out possible change in ground water quality from intrusion of river water, and to assess water quality of Bagmati river and its nearby ground water at different stations in terms of physico-chemical parameters and microbiological parameters.

Methodology

Study area

The study area is located in KV in the Central Development Region of Nepal at 85°12'- 85°33' E longitude and 27°35' - 27°48'N latitude. The valley is bounded by Kavrepalancowk district in the east, Dhading and Nuwakot districts in the west, Sindhupalchok district in the north and Makwanpur district in the south. The altitude of the district ranges between 1262 to 2732 m above the sea level. The temperature fluctuates between 32°C in summer (June-July) to -2 °C in winter (December-January). Annual rainfall of the district is 176.4 ml (DHM, 2009).

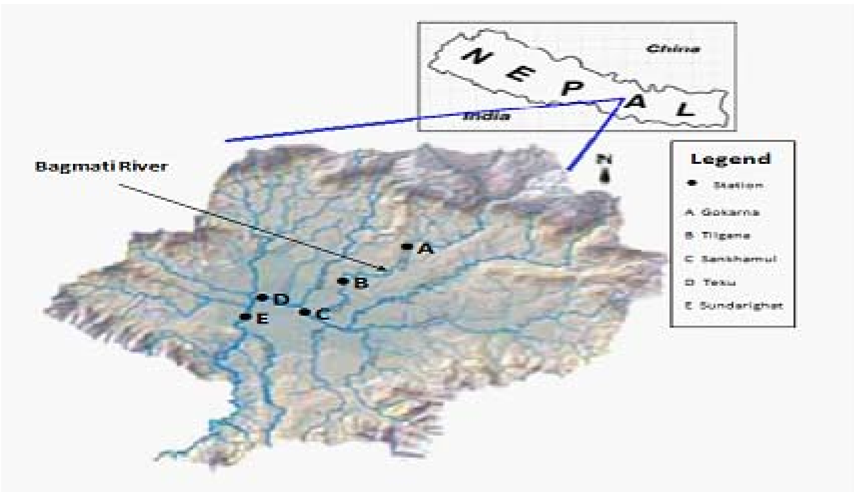

Fig. 1. Map showing the location of sampling stations (*Source: Field Visit, 2009*)

Sampling units and methods

The sampling stations for the study were selected on the Bagmati river and along its course to downstream. The reference station at upstream considering a remote point free from pollution was established and other sampling stations were identified at downstream of Bagmati river where the settlements are growing (Fig. 1). Considering these, five different sampling stations of river water and nearby ground water were identified viz. Gokarna-Jorpati(A), Tilganga(B), Sankhamul(C), Teku(D) and Sundarighat(E) respectively. The ground water sampling points were confined in three strata: a) within 50 m, b) 50-100 m and c) 100-150 m distance from river bank on both sides. The water samples were taken from different sources of the existing wells and tube wells on the same proportions so that six ground water samples and one river water sample were collected at each station. Overall 90 ground water samples and 15 river water samples were taken during three seasons (winter, monsoon, and post- monsoon seasons of 2009/10).

Data collection and analysis

Both primary and secondary data that addressed the water quality were collected. The relevant secondary source of information were gathered from different organizations such as Forum for Urban Water and Sanitation, Water Aid Nepal, Central Department of Environmental Science, Tribhuvan University; UN Habitat, Environment and Public Health Organization, and websites etc. For water samples collection, clean plastic bottles were used for physico-chemical analysis, while for microbial analysis, water samples were collected in sterilized glass bottles and they were kept in ice-box for coliform count by Membrane Filter Technique within six hour of sample collection. Some parameters like pH, temperature, conductivity, chloride content, free CO_2, DO, and alkalinity were analyzed *in-situ* and other remaining analyses were done in the laboratory. The parameters such as conductivity, chloride, free CO_2, DO, BOD, COD, alkalinity and hardness were analyzed by titration methods and remaining parameters such as ammonia, nitrate, iron and ortho-phosphate were analyzed by spectrophotometric methods. The process of sample collection, preservation and analysis were done by following APHA/AWWA/WEF. (1998). For data processing, Microsoft Excel 2007 was used as the main tool. One way analysis of variance (ANOVA) test was applied to test the significance of difference of spatial (stationwise i.e. upstream to downstream, and distancewise i.e. within 50 m to 50-100 m, and 100-150 m distance from riverbank) and temporal (seasonal) variation of physic-chemical parameters of ground water at the periphery of Bagmati river by using statistical software SPSS 16.0. Regression analysis by means of dummy variables was done to establish the variation in water quality according to spatial and temporal pattern. The regression model in dummy form can be expressed as:

$$Y= b_o + b_1D_1 + b_2D_2 +\ldots\ldots+ b_nD_n$$

Where, Y= Qualitative Parameter

D_1 = 1 for the presence of first categorized variables
= 0 for otherwise

D_2 = 1 for the presence of second categorized variables
= 0 for otherwise

D_n = 1 for the presence of n^{th} categorized variables
= 0 for otherwise

The estimated regression equation is

$$v_i= b_o + b_1D_1 + b_2D_2 +\ldots\ldots+ b_nD_n$$

During analysis if the variable has m category, only m-1 dummy variables are admissible. The category in which dummy variable is not assigned is known as base or comparison categories. The intercept of the estimated regression equation gives the mean or base value of that parameter of the omitted category. These coefficients attached to the dummy variables are known as the differential intercept coefficients. These coefficients give the difference between the mean value of the dependent variables for omitted category and mean value of the dependent variables for the coefficient attached category.

Results and Discussion

Physicochemical parameters of water

Temperature of ground water ranged between 26 to 15 ^{0}C and that of river water ranged between 23.8 to 11 ^{0}C. There was no drastic change in temperature with respect to station but high fluctuation of water temperature from monsoon to other season was observed due to intensity of solar radiation. For temperature, only seasonal variation (Table 1) was significant at 10 % confidence levels of F- test.

pH of ground water ranged between 7.8 to 5.45 and that of river water ranged between 7.61 to 6.9. Seasonal variation showed that pH of ground water was slightly increasing from monsoon to winter season. The distancewise variations showed that pH values were slightly decreased from river bank to outward. pH in 47% samples exceeded (WHO, 1993) guideline values of 6.5 to 9.5 for drinking water. For pH, only seasonal variation (Table 1) was significant at 10 % confidence levels of F- test.

Conductivity of ground water ranged between 1372 µS/cm to 159 µS/cm and that of river water ranged between 990 µS/cm to 165 µS/cm. The conductivity of river water increased from monsoon to post- monsoon and from upstream to downstream. Conductivity of ground water was found slightly higher close to river bank than outwards; and towards urban cores than upward (Fig. 2), which might be from intrusion of chemicals from river and open dumping sites. Conductivity of river water was minimum in Gokarna and maximum in Teku followed by Sundarighat and Tilganga, which may be due to diluting capacity of water on chemicals. Pradhan, (2009) also found higher values along urban corridor. For conductivity only stationwise variation (Table 1) was significant at 10 % confidence levels of F- test.

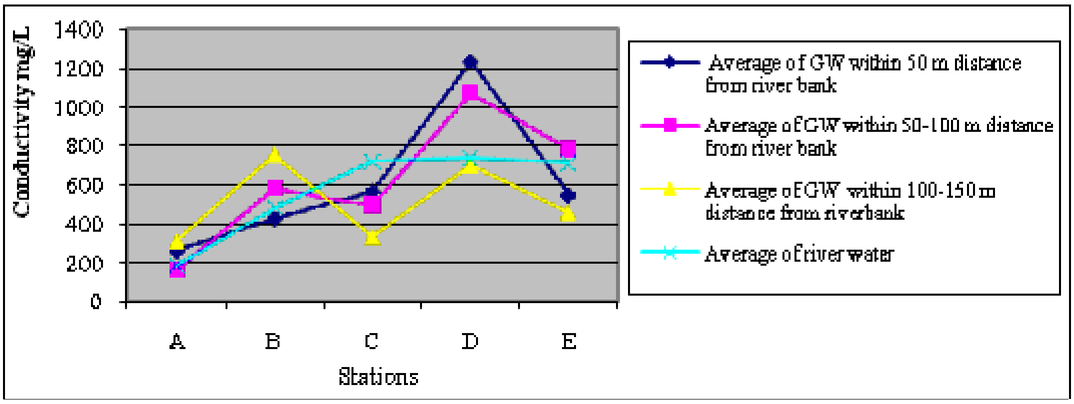

Fig. 2. Spatial variation of conductivity of ground water from river bank

Dissolved oxygen (DO) of ground water ranged between 6.48 mg/l to 1.01 mg/l and that of river water ranged between 5.1 mg/l to 0 mg/l. In general, ground water showed decreasing trend from monsoon to winter season while reverse was found on river water. DO contents were lower within 50 m distance from river bank at Teku and Tilganga than other stations. The zero value of DO below Tilganga except in monsoon season indicates Bagmati river is highly polluted and there is no possibility for the existence of fresh water organisms (Trivedy and Goel, 1986). The reason behind this may be due to mixing of untreated sewage and effluents in the river water. Average value of DO content was low within 50 m distance from river bank at Teku and Tilganga compared to other stations. This might be due to intrusion of wastes from river and dumping sites, which leads to high microbial activity (respiration) occurring during degradation of organic matter. For DO only seasonal variation (Table 1) was significant at 10 % confidence levels of F- test.

Alkalinity of ground water ranged between 555 mg/l to 20 mg/l and that of river water ranged between 165 mg/l to 25 mg/l. In overall, alkalinity content of surface and ground water increased from monsoon to winter season and from upstream to downstream site. The alkalinity content for ground water decreased from; within 50 m distance of riverbank to outward but stationwise, there was fluctuation. In both surface water and ground water, alkalinity is due to bicarbonate only which is dominant in most of the surface water (UNESCO. 1996). Only stationwise variation (Table 1) was significant at 10 % confidence levels of F- test.

Chloride content of ground water ranged between 170.4 mg/l to 9.94 mg/l and that of river water ranged between 145 mg/l to 14.3 mg/l. The chloride content of river water was found higher in winter season and lower in monsoon season, whereas a reverse trend was found in groundwater. Chloride concentration of both river water and ground water contained lower values in upstream area and increased towards the urban core (Fig. 3). Devkota. (2006) and Pradhan (2009) observed similar trend along Bishnumati and Bagmati river corridor in Kathmandu. Among all sites, Teku, and Sundarighat were most contaminated sites followed by Tilganga, where other parameters like ammonia, nitrate, etc were high. For chloride content, stationwise variation and distancewise variation was significant at 10 % confidence levels of F-test (Table 1).

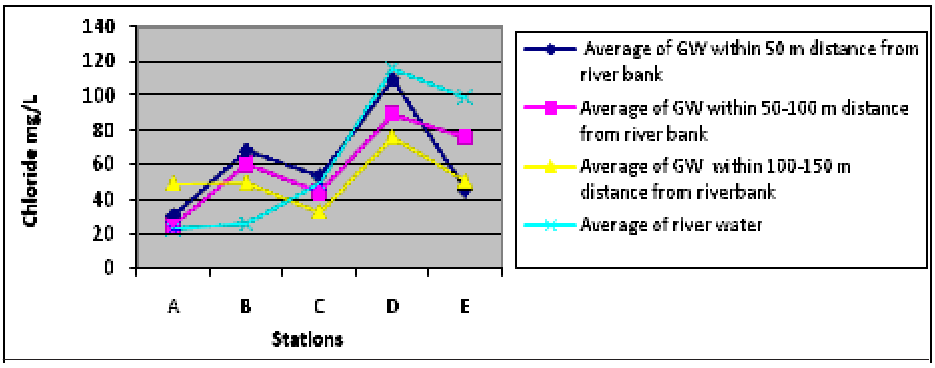

Fig. 3. Spatial variation of chloride content of ground water from river bank

Table 1 showed spatial and seasonal variation of ground water by means of regression analysis.

Table 1. Spatial and seasonal variation of ground water

Parameters	Distancewise variation			Seasonal variation			Stationwise variation				
	b_0 (<50 m distance)	b_1D_1 (50-100)m distance	b_2D_2 (100-150)m distance	b_0 (monsoon season)	b_1D_1 (Post-monsoon season)	b_2D_2 (winter season)	b_0 (Gokarna)	b_1D_1 (Tilganga)	b_2D_2 (Sankhmul)	b_3D_3 (Teku)	b_4D_4 (Sundharighat)
Temperature °C	18.93	$0.12D_1$	$0.08D_2$	23.90*	$-6.97D_1$	$-7.75D_2$	18.67	$1.44D_1$	$0.22D_2$	$0.27D_3$	$-0.31D_4$
pH	6.46	$0.10D_1$	$-0.66D_2$	6.20*	$0.41D_1$	$0.34D_2$	6.51	$-0.13D_1$	$-0.03D_2$	$0.08D_3$	$-0.14D_4$
Conductivity mg/l	608.4	$9.56D_1$	$-95.70D_2$	555.53	$33.33D_1$	$39.13D_2$	246.2*	$342.44D_1$	219.66 D	$755.27D_3$	$349.66D_4$
DO mg/l	3.73	$0.46D_1$	$0.14D_2$	4.22	$-0.37D_1$	$-0.67D_2$	3.84	$-0.36D_1$	$0.62D_2$	$-0.08D_3$	$0.32D_4$
Chloride mg/l	66.29*	$-8.33D_1$	$-17.24D_2$	57.37	$2.43D_1$	$-1.24D_2$	31.78*	$27.75D_1$	$12.83D_2$	$59.11D_3$	$30.17D_4$
Carbondioxide mg/l	70.14*	$-2.30D_1$	$-19.63D_2$	57.15	$7.53D_1$	$9.49D_2$	55.85*	$31.86D_1$	$-8.61D_2$	$22.10D_3$	$-10.5D_4$
Alkalinity mg/l	184.95	$-7.53D_1$	$-16.96D_2$	178.23	$-4.78D_1$	$0.43D_2$	77.52*	$156.83D_1$	$15.17D_2$	$208.36D_3$	$115.94D_4$
Total hardnes mg/l	224.86	-13.2D	$-29.26D_2$	187.53	$30.23D_1$	$39.23D_2$	106.1*	$126.67D_1$	$49.56D_2$	$223.11D_3$	$124.04D_4$
Nitrate mg/l	4.08*	$-2.71D_1$	$-3.48D_2$	1.49	$0.57D_1$	$1.00D_2$	0.368*	$0.66D_1$	$0.15D_2$	$3.91D_3$	$3.50D_4$
Ammonia mg/l	0.22*	$-0.05D_1$	$-0.08D_2$	0.26*	$-0.10D_1$	$-0.14D_2$	0.11*	$0.11D_1$	$0.03D_2$	$0.08D_3$	$0.10D_4$
Iron mg/l	1.39*	$0.04D_1$	$-0.43D_2$	0.94*	$0.37D_1$	$0.56D_2$	1.24*	$0.05D_1$	$-0.48D_2$	$0.17D_3$	$0.35D_4$
Phosphate mg/l	1.05*	$-0.91D_1$	$-0.51D_2$	0.36	$0.14D_1$	$0.50D_2$	0.27*	$0.18D_1$	$0.44D_2$	$-0.02D_3$	$0.91D_4$

(*) sign in the table indicate, the spatial and seasonal variation of groundwater is significant at 10 percent of confidence levels of F test. For example, on looking distancewise variation of chlorides; the estimation of b_0 gives the value of chloride of whole ground water within 50 m distance from the river bank. Similarly the coefficients b_1 and b_2 suggest the differences in the quantity of chloride contents within 50-100 m and 100-150 m distances from -50 m distance of river bank values. (Here the chloride values are 66.29 mg/l, 57.96 mg/l and 49.05 mg/l within 50 m, 50-100 m, and 100-150 m distance from river bank respectively). Likewise distancewise variation value of chloride is significant at 10 percent of confidence levels of F- test (Table 1).

Free carbon dioxide (CO_2) of ground water ranged between 176.96 mg/l to 11.2 mg/l and that of the river water ranged between 172.48 mg/l to 31 mg/l. The spatial variation showed that free CO_2 in river water increased from upstream to downstream, and in case of ground water higher values were observed towards river banks than outwards (Fig. 4). In general, free CO_2 of ground water and river water increased from monsoon to winter seasons. According to Cole, (1975), and Saxena, (1989), CO_2 has negative correlation with pH but in the case of present study, exact negative correlation was not found, which may be due to unpredicted pH changes due to various kinds of chemicals present in polluted water. For CO_2, both stationwise and distancewise variation was significant at 10 % confidence levels of F- test (Table-1)

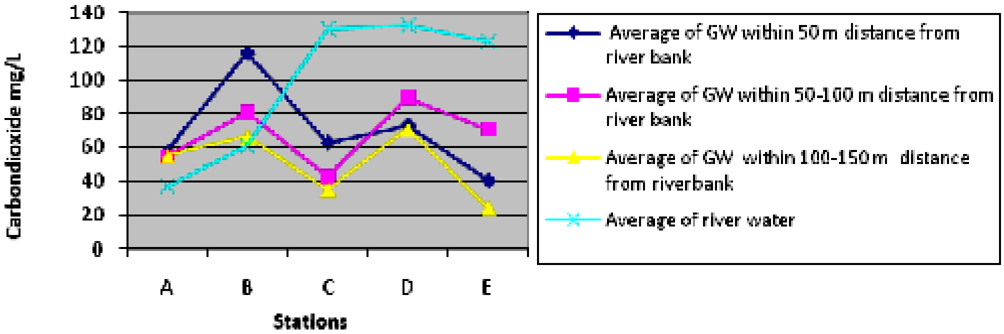

Fig. 4. Spatial variation of free carbon dioxide of ground water from river bank

Total hardness of ground water ranged between 500 mg/l to 56 mg/l and that of river water ranged between 178.6 mg/l to 40 mg/l. In overall, hardness content of ground water increased from monsoon to post monsoon and winter season but with regards to stationwise and distancewise, there was fluctuation. In general, magnesium hardness of natural water is lower than calcium hardness (Saxena, 1989). In the present study, Mg hardness was found lower than Ca hardness in ground water. But higher value of Mg hardness in river water may be due to ion equilibrium phenomenon. Only stationwise variation (Table 1) was significant at 10 % confidence levels of F- test (Table 1).

Nitrate content of ground water ranged between 21.23 mg/l to 0.132 mg/l and that of river water ranged between 3.95 mg/l to 0.414 mg/l. The nitrate content in river and ground water increased from upstream to downstream and from monsoon to winter seasons. The

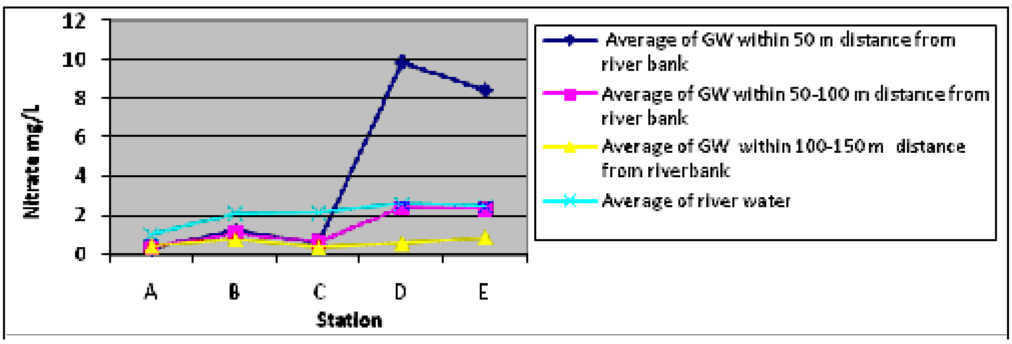

Fig. 5. Spatial variation of nitrate content of ground water from river bank

mean value of nitrates of ground water was higher within 50 m distance of riverbank and decreased away from the river bank. Teku region contained maximum value followed by Sundarjghat and Tilganga (Fig. 5), which may be due to leached out of pollutants in these areas, where other parameters were also high. Pradhan, (2009) and ENPHO, (1999) revealed high level of nitrate in ground water of Kathmandu. For nitrate, both stationwise variation and distancewise variation was significant at 10 % confidence levels of F-test (Table 1).

Ammonia content of ground water ranged between 0.623 mg/l to 0.061 mg/l and that of river water ranged between 109.33 mg/l to 5 mg/l. High values of ammonia along urban core indicate mixing of untreated sewage without treatment. The ammonia content in river water increased from monsoon to winter season but the trend was reverse in ground water. Distancewise variation of ammonia content for ground water showed decreasing trend from riverbank to outwards. The WHO guideline value for drinking water is 0.5 mg/l, which was exceeded by all river water samples and 3.35% of ground water samples. For ammonia, both spatial and seasonal variation was significant at 10 % confidence levels of F-test (Table 1).

Iron content of ground water ranged between 4.149 mg/l to 0.035 mg/l and that of river water ranged between 3.859 mg/l to 0.44 mg/l. Iron content of river water increased from monsoon to winter season but stationwise there was fluctuation. Unlike other parameters, iron content of ground water in Gokarna region contained higher concentration (Fig. 6). Pradhan, (2009) also found high concentration of iron in Gokarna region. The high concentration of iron in ground water of Kathmandu had observed by ENPHO, (1999). The high concentration of iron in ground water may be due to underlying lithology and natural property. Out of 90 samples of ground water, 83% samples exceeded WHO, (1993) guideline value and NDWQS, (2062 BS) of 0.3 mg/l for drinking purpose. For iron, both stationwise and seasonal variation was significant at 10 % confidence levels of F- test (Table 1).

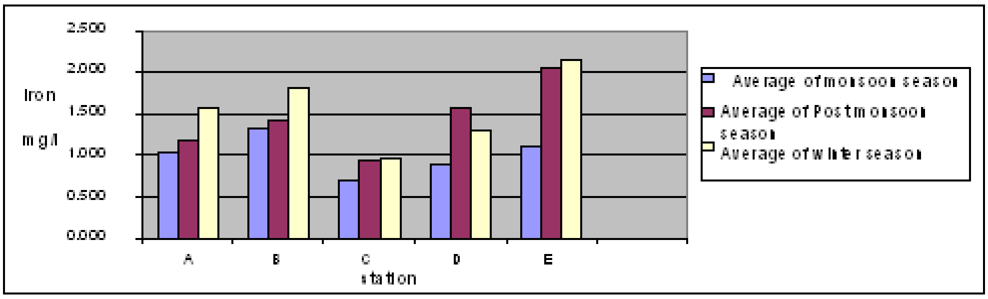

Fig. 6. Temporal variation of iron content of ground water from river bank

Ortho-phosphate of ground water ranged between 6.154 mg/l to 0.006 mg/l and that of river water ranged between 8.36 mg/l to mg/l. High phosphorus concentration in shallow water along with chloride and nitrate indicates domestic pollution ENPHO, (1999). Regression analysis of ground water showed that mean value of ortho-phosphate of ground water was higher within 50 m distance of riverbank and slightly decreased outwards (Fig. 7). Both distancewise variation and seasonal variation of ortho-phosphate was significant at 10 % confidence levels of F- test (Table 1).

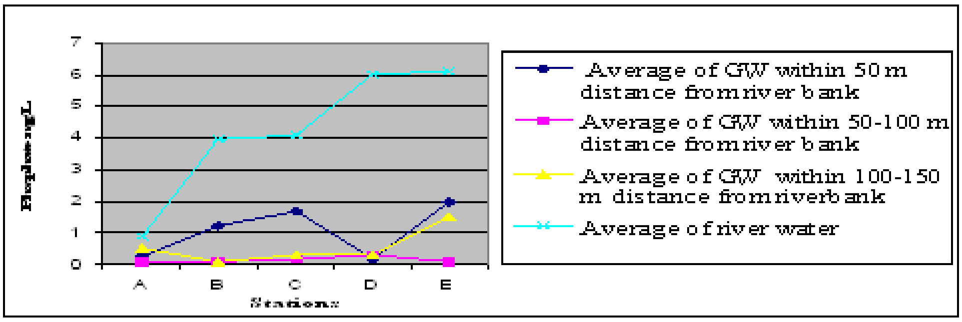

Fig. 7. Spatial variation of ortho-phosphate of ground water from river bank

Biological oxygen demand (BOD) of Bagmati river ranged between 293 mg/l to 11 mg/l and that of Chemical oxygen demand (COD) ranged between 517.2 mg/l to 20.5 mg/l. BOD and COD values increased from monsoon season to winter season and from upstream to downstream. Higher values of BOD and COD indicate the presence of more organic wastes or sewage pollution and industrial pollution APHA/AWWA/WEF, (1998). Both BOD and COD values were higher than MoPE, (2003) guideline value for wastewater and industrial effluents discharged into inland surface water at Sankhamul, Teku, and Sundarighat.

Microbial parameters of water

Coliform bacteria are the indicators of water pollution. Coliform count by membrane filter techniques showed that ground waters were highly contaminated with coliform bacteria. Microbial analysis showed that out of 20 samples, 6% were safe during monsoon, 17% were safe during post monsoon season, and 20% were safe during winter season based on WHO, (1993) guideline value of drinking water. Thus as a whole, 88% samples were contaminated with coliform bacteria, so the ground water along Bagmati river bank could not be used as consumptive purposes without treatment. Among different sampling sites, all well waters were contaminated by coliform bacteria. ENPHO, (1999) also found high contamination of coliform in dug wells (91%) than other sources. The percentages of contaminations at different seasons are given in (Table 2).

Table 2. Microbiological quality of ground water

No of samples at each	% of contamination with WHO guideline at different season			% of samples having 1-100 CFU/100 ml of water at different season			% of samples having 100-1000 CFU/100 ml of water at different season			% of samples having >1000 CFU/100 ml of water at different season		
season	Monsoon	Post-monsoon	Winter	Monsoon	Post-monsoon	Winter	Monsoon	Post-monsoon	Winter	Monsoon	Post-monsoon	Winter
20	93	83	80	45	26	35	28	40	35	21	17	10

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