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A COMPARATIVE ASSESSMENT OF WATER QUALITY INDEX OF SURFACE (RIVER) WATER AND GROUND WATER ALONG THE BUDHI GANDAK BELT USING CORRELATION ANALYSIS AT KHAGARIA (BIHAR)

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ABSTRACT

The present work deals with the assessment of the Water Quality Index (WQI) of the ground water (hand pumps) as well as surface water (Budhi Gandak River) in Khagaria town, Bihar in order to ascertain the quality of water for public consumption, recreation and other purposes. In this study, WQI was determined on the basis of seasonal variations in important water quality parameters such as pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), bicarbonate (HCO_3^-), phosphate (PO_4-P), nitrate (NO_3-N), chloride (Cl^-) and turbidity. The results in the present study indicated that most of the water quality parameters analyzed were within the WHO and BIS limits for drinking water except turbidity values that exceeded permissible limit in surface water and some samples of ground water. WQI values of surface water at all the three sites in all the three seasons were categorized in Excellent (40.09-42.35), Good (52.09-99.13) and Poor (103.67-126.76) categories whereas ground water samples in Excellent (42.92-49.85) and Good (51.23-73.79) categories. WQI was in good correlation with phosphate and turbidity in all the three seasons at all the three sites. The study suggests that river water is not suitable for human consumption during monsoon months. Ground water is suitable for drinking in all the three seasons at all the three sites.

KEY WORDS
River Budhi Gandak & floodplain
Surface Water, Ground Water, WQI

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INTRODUCTION

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. The quality of any body of surface or ground water is a function of either or both natural influences and human activities. Rivers and ground water are the important sources of fresh water. These fresh water resources are essential for sustainable development. Rivers play critical role in the quality and supply of drinking water by ensuring a continuous flow of surface water and helping recharge underground aquifers. The changes in the natural interaction of ground water and surface water caused by human activities and that can potentially have a significant effect on aquatic environments (Winter *et al*., 1998). Disposal of industrial effluent and sewage into surface water cause ground water pollution. Ground water contamination is generally irreversible i.e. once it is contaminated; it is difficult to restore the original water quality of the aquifer by stopping the pollutants. It therefore becomes imperative to regulate and monitor the quality of ground water and river water to devise ways and means to protect. Water Quality Index (WQI) may be an important tool for understanding of the interaction of ground water and surface water, in terms of their quality for human consumption for drinking purposes. Many workers have studied on comparative WQI of surface water and ground water on the basis of physico-chemical results (Mahananda *et al*., 2010, Maheshwari *et al*., 2011, Meitei *et al*., 2013, Solanki *et al*., 2014). Some works are also reported on physico- chemical analysis of ground water in river floodplains (Abbas *et al*., 2012, Mumtazuddin *et al*., 2012). Budhi Gandak is one of the important tributaries of the Ganga in north Bihar. The origin of Budhi Gandak is at the West Champaran near Ramnagar and Bagaha. It is a rain fed river and flows through West Champaran, East Champaran, Muzaffarpur, Samastipur, Begusarai and flows into the Ganges near Khagaria. The Budhi Gandak river water and ground water in the river floodplains and in urban areas near Khagaria have multiple uses. The major sources of pollution of the river include agricultural runoff containing fertilizers, pesticides and insecticides from the floodplain containing toxic chemicals, abstraction of river water for irrigation, navigation by motorized country boats, burning of dead bodies at cremation ghats on the river bank and other anthropogenic activities which may deteriorate natural interaction of river water and ground water. Thus the objective of present study is to assess comparative status of the water quality of Budhi Gandak River and ground water (mainly hand pumps) in river floodplain and Khagaria town using Water Quality Index as an indicator of water quality.

MATERIALS AND METHODS

Study Area

For collection of Surface Water samples, three sampling sites of Budhi Gandak stretch along Khagaria town and for collection of ground water samples, three sampling sites (GW1) in river floodplain and another three sampling sites (GW2) in the Khagaria municipal area (distance about 2 km from river sampling sites) were selected for present comparative water quality study. The main sources of ground water supply in the floodplain and municipal area are hand pumps. The details of study area have been presented in Table1.

Collection of water samples

Northern side of the river and its floodplain has more anthropogenic activities. So, water samples were collected from northern bank of the river and northern floodplain and Khagaria town area at selected sampling sites. Sterilized and clean plastic bottles of 2 liter capacity were used for the collection of water samples for physico-chemical analysis in three different seasons of the year (2013-2014) namely summer, monsoon and winter. Temperature, pH, TDS and conductivity were analyzed at the sites (on the spot), and for analysis of rest of the parameters, water samples were brought to the Environmental Biology Research Laboratory of T. M. Bhagalpur University. Water quality parameters were analyzed following Standards methods (APHA, 2005; & Trivedy and Goel, 1986).

Water Quality Index (WQI)

Water quality index (WQI) is a useful tool for quick estimation of quality of the surface as well as ground water pollution. WQI is defined as a rating reflecting the composite influence of different water quality parameters. Water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. The objective of water quality index is to turn complex water quality data into information that is easy to use. The BIS: 2004-2005 standards for drinking purposes have been considered for the calculation of WQI of surface water and ground water at selected sampling sites. The WQI of surface water and ground water has been calculated considering relative weights of 9 water quality parameters (Table 2) following the calculation method prescribed by Ramakrishnaiah *et al*., 2009 and Gebrehiwot *et al*., 2011.

Computed WQI values were classified into five categories (Table 3): Excellent, Good, Poor, Very poor and Unfit Water for drinking purposes (Ramakrishnaiah *et al*., 2009).

RESULTS AND DISCUSSION

Summer, monsoon and winter results of analysis are depicted in Tables 4-6. In the present study, temperature ranged from 19.5-28.5ºC in surface water and 19-26.1ºC in ground water samples in all the three seasons at all the three sites *i.e.* no marked difference between variations in temperature of surface water and ground water. It was maximum (28.5ºC) in surface water at site III in monsoon and minimum (19ºC) in GW1 at site I in summer. pH values showed almost similar range of variations both in surface water (7.2-7.9) and ground water (7.1-7.9). The pH of the water samples in all seasons was

Table 1: Study Area Details

Surface Water (River Water)			Ground Water (Hand Pumps)					
Sites	GPS Location	Average Depth(m)	Sites	GPS Location	Depth (m)	Sites	GPS Location	Depth (m)
Vidyadhar Ghat	25°29'41.9"N 86°27'49.9"E	7.5	GW1	25°29'57.2"N 86°27'40.2"E	30.48	GW2	25°30'01.5"N 86°27'36.0"E	33.53
Cremation Ghat	25°30'04.4"N 86°28'55.3"E	13.0	GW1	25°30'07.5"N 86°28'43.0"E	30.48	GW2	25°30'16.7"N 86°28'44.3"E	30.48
Sansarpur Ghat	25°30'19.8"N 86°30'33.2"E	10.5	GW1	25°30'43.8"1N 86°30'27.1E	39.62	GW2	25°30'44.0"N 86°30'27.1"E	33.53

*Hand pumps)) municipal arean urban areas near Khagaria; GW1 = Ground Water samples from river floodplain, GW2 = Ground Water samples from about 2km from river Water sampling sites within the WHO Standard of 6.85-8.5.

The range of variation in turbidity values was much higher in surface water (4.6-65.5 NTU) compared to ground water (1.3-16.2 NTU). High monsoon turbidity values were found both in surface water (65.5 NTU at site III) and ground water (16.2 NTU in GW1 at site III), whereas lower values were recorded in summer (4.6 NTU at site II in surface water and 1.3 NTU in GW1 at site I). Higher values of turbidity in monsoon in the present study are in agreement with the findings of Rao *et al*; 2013. Turbidity values of almost all surface water samples and 50 percent of ground water samples in all the three seasons were found above the limits (5 NTU) prescribed by BIS (10500:2004-2005). Turbidity of water is an important parameter, which influences the light penetration inside water and thus affects the aquatic life. Monsoon season shows higher turbidity values due to runoffs. It carries many particles like sand, clay, silts, agricultural runoffs etc.

TDS values were more in ground water (173-649 mg/L) than surface water (133-209 mg/L) in all the three seasons at all the three sites. The results are very similar to findings of Reddy *et al*., 2011. TDS was higher (649 mg/L) in GW2 in summer season at site III and lower (133 mg/L) in surface water in monsoon at site III. EC ranged from 260-412 mg/L in surface water and 399-1276 mg/L in ground water. EC was higher (1276 mg/L) in GW2 in summer at site III and lower (269 mg/L) in surface water in monsoon at site III. All findings were within permissible limit. From the results, it was obvious that the conductivity value increased with increasing TDS. In the present study, the conductivity values were relatively lower than the recommended values and hence the water can safely be used for domestic and agricultural purposes.

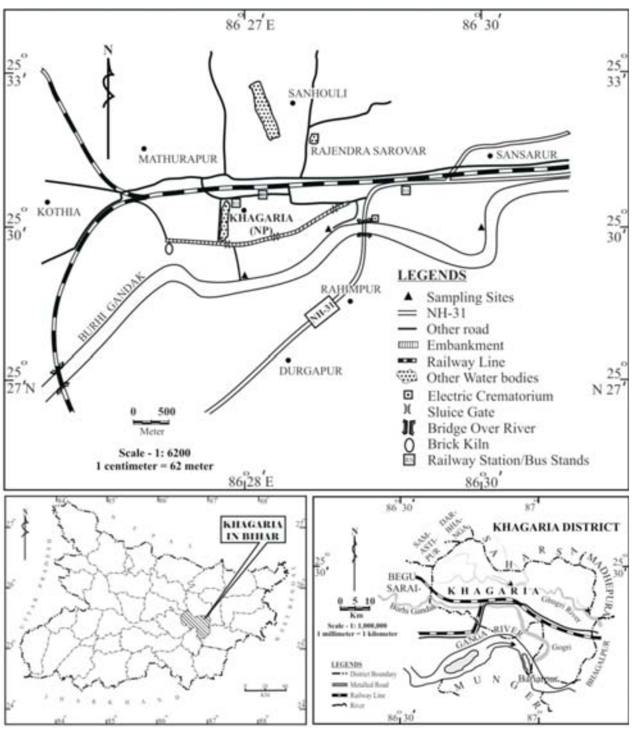

Figure 1: Location map of study area

Total Hardness (TH) values ranged from 175-360 mg/L in ground water samples and 130-194 mg/L in surface water in all the three seasons at all the three sites. It was found maximum (360 mg/L) in GW2 at site III in summer compared to surface water (130 mg/L). The results are similar to findings of Sharma *et al*., 2013. Hardness value below 300 mg/L is considered potable but beyond that limit produces gastrointestinal infection (ICMR, 1975). Khopkar (1993) classified hardness of water into 5 categories on the basis of total ion content viz. soft (0-40 mg/L), moderately hard (40-100 mg/L), hard (100-300 mg/L), very hard (300-500 mg/L) and extremely hard (500-1000mg/L). Based on these, the surface water under investigation can be placed in the hard category and the ground water in the hard to very hard category.

Bicarbonate (HCO_3^-) was maximum (110 mg/L) in GW2 at site III in monsoon and minimum (30 mg/L) in surface water at site III in summer. The range of variation in bicarbonate values was relatively higher in ground water (70-110 mg/L) compared to surface water (30-54 mg/L).

Present findings showed that all water samples have low phosphorus concentration. PO_4-P varied from 0.053-0.095 mg/L in surface water and 0.056-0.093 mg/L in ground water. Phosphate occurrence in the present study is in low quantity as many aquatic plants absorb and store phosphorous many times their actual immediate needs. Phosphate is non-poisonous at the present concentration and thus poses no threat to aquatic lives and health of human beings.

NO_3-N values ranged from 0.041-0.059 mg/L in surface water and 0.042-0.052 mg/L in ground water. It was higher (0.059 mg/L) at site I in winter in surface water, moderate in ground water (0.042-0.052 mg/L) and lower (0.041 mg/L) at site III in summer in surface water. Since this parameter is not present at

Table 2: Relative Weights of Physico-Chemical Parameters used in Assessment of Water Quality of Surface Water (Budhi Gandak River) and Ground water (Hand pumps)

Parameters	BIS (2004-05) (Si)	Weight (Wi)	Relative Weight (Wi)
pH	6.5-8.5	4	0.148148148
TDS	500-2000	4	0.148148148
EC	1000-2000*	2	0.074074074
TH	300-600	2	0.074074074
HCO_3^-	244-732	3	0.111111111
NO_3-N	45	5	0.185185185
PO_4-P	0.1-1	2	0.074074074
Cl^-	250-1000	3	0.111111111
Turbidity (NTU)	5	2	0.074074074
		$\sum wi = 27$	

a higher level in any of the selected sites, it does not pose a threat to the health of human beings.

The chloride content was found maximum (134.9 mg/L) in GW2 at site III in winter and minimum (3.99 mg/L) in surface water at site III in monsoon. It varied from 3.99-10.99 mg/L in surface water and 9.49-134.9 mg/L in ground water. Chloride contents obtained in the present study both in surface water and ground water were found within the permissible limit similar to the findings of Dash, 2013. The Surface and ground water chloride values in the present study suggest lesser degree of organic pollution and thus may be considered suitable for domestic and commercial purposes.

Assembling different parameters into one single number leads an easy interpretation of index, thus providing an important tool for management purposes (Bordalo *et al.*, 2001). Water Quality Index (WQI) offers an important tool for understanding of the interaction of ground water and surface water, in terms of their quality for any intended use as well as in the pollution abatement programs and in water quality management. Water Quality Index of both surface waters and ground waters investigated in the present study is established from important physico-chemical parameters analysed in different seasons. The seasonal values of various physico-chemical parameters and calculated Water Quality Index are depicted in Tables 4-6. WQI values in surface water in summer, monsoon and winter were found to be in the range of 40.09-52.09, 99.13-126.76, 70.15-103.67 and in ground water in the range of 42.92-73.79, 47.23-77.15, 43.24-73.66 respectively. The Water Quality Index obtained for the surface water in different seasons of study period indicate good to excellent category (40.09–90.27) at all the three sites in summer and at site I and II in winter and in poor category (103.67-127.76) at sites II and III in monsoon. Season wise WQI values calculated for ground waters indicate excellent to good quality of ground waters.

Correlation coefficient of WQI with various physico-chemical

Table 3: WQI based water quality classification (Ramakrishnaiah *et al.*, 2009)

WQI Value	Water Quality Category
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable for drinking

Table 4: Physico-chemical Characteristics and WQI of Surface Water (River Budhi Gandak) & Ground Water (Hand pumps) in Summer Season (October 2013- June 2014)

Parameters	Site I			Site II			Site III		
	Surface Water	GW1	GW2	Surface Water	GW1	GW2	Surface Water	GW1	GW2
Temp. (°C)	22	19	20	23	20	21	24	22	23
pH	7.8	7.6	7.5	7.8	7.7	7.3	7.9	7.4	7.1
TDS	165	396	430	170	205	460	152	309	649
EC	324	777	844	334	399	902	299	602	1276
TH	144	242	240	186	250	265	130	190	360
HCO_3^-	40	81	75	48	71	90	30	77	90.7
PO_4-P	0.053	0.068	0.063	0.069	0.064	0.064	0.064	0.093	0.054
NO_3-N	0.042	0.048	0.043	0.042	0.044	0.046	0.041	0.046	0.046
Cl^-	10.99	60.95	56.89	6.99	22.99	67.18	8.99	9.64	124.9
Turbidity(NTU)	7.9	3.5	1.8	4.6	3.6	12.3	14.8	11.4	6.9
WQI	42.35	53.29	51.23	40.09	42.92	69.57	52.09	58.87	73.79
WQI class	Excellent	Good	Good	Excellent	Excellent	Good	Good	Good	Good

All parameters are in mg/L except pH and Temperature & Turbidity. TDS = Total Dissolved Solids, EC = Electrical Conductivity, TH = Total Hardness, HCO_3^- = Bicarbonate, PO_4-P = Phosphate, NO_3-N = Nitrate, Cl^- = Chloride, WQI = Water Quality Index

Table 5: Physico-chemical Characteristics and WQI of Surface Water (River Budhi Gandak) & Ground Water (Hand pumps) in Monsoon Season (October 2013-June 2014)

Parameters	Site I			Site II			Site III		
	Surface Water	GW1	GW2	Surface Water	GW1	GW2	Surface Water	GW1	GW2
Temp. (°C)	28.2	24.0	25.2	28.3	24.2	25.5	28.5	24.5	26.1
pH	7.2	7.4	7.3	7.3	7.5	7.3	7.3	7.6	7.3
TDS	148	345	370	140	443	455	133	173	513
EC	295	674	727	276	863	896	260	340	1008
TH	154	240	250	138	230	240	136	180	290
HCO_3^-	42	90	86	44	82	80	36	104	110
PO_4-P	0.058	0.057	0.062	0.093	0.079	0.078	0.082	0.084	0.059
NO_3-N	0.043	0.045	0.045	0.043	0.048	0.045	0.045	0.045	0.045
Cl^-	6.99	66.97	61.98	5.99	54.98	65.9	3.99	23.99	128.9
Turbidity (NTU)	47.1	1.3	8.6	59.2	3.6	4.5	65.5	16.2	13.2
WQI	99.13	47.23	59.20	119.08	55.59	57.74	126.76	61.31	77.15
Wqi Class	Good	Excellent	Good	Poor	Good	Good	Poor	Good	Good

All parameters are in mg/L except pH and Temperature & Turbidity. TDS = Total Dissolved Solids, EC = Electrical Conductivity, TH = Total Hardness, HCO_3^- = Bicarbonate, PO_4-P = Phosphate, NO_3-N = Nitrate, Cl^- = Chloride, WQI = Water Quality Index

Table 6: Physico-chemical Characteristics and WQI OF Surface Water (River Budhi Gandak) & Ground Water (Hand pumps) in Winter Season (October 2013-June 2014)

Parameters	Site I Surface Water	GW1	GW2	Site II Surface Water	GW1	GW2	Site III Surface Water	GW1	GW2
Temp. (°C)	19.5	20	21	19.6	23	24	19.6	21	22
pH	7.2	7.9	7.8	7.2	7.6	7.5	7.3	7.5	7.7
TDS	209	265	312	201	290	421	194	325	635
EC	412	521	615	396	567	824	381	637	1273
TH	182	205	220	194	265	255	175	175	245
HCO_3^-	54	70	83	53	83	88	51	98	99
PO_4-P	0.095	0.063	0.056	0.065	0.074	0.070	0.073	0.083	0.056
NO_3-N	0.059	0.052	0.044	0.053	0.044	0.044	0.056	0.043	0.042
Cl^-	7.89	59.48	84.48	9.99	21.49	71.4	7.49	9.49	134.9
Turbidity (NTU)	23.4	1.5	1.5	38.1	14.7	15.8	47.3	4.8	5.9
WQI	70.75	43.24	46.70	90.27	64.52	73.66	103.67	49.85	71.05
Wqi Class	Good	Excellent	Excellent	Good	Good	Good	Poor	Excellent	Good

All parameters are in mg/L except pH and Temperature & Turbidity. TDS = Total Dissolved Solids, EC = Electrical Conductivity, TH = Total Hardness, HCO_3^- = Bicarbonate, PO_4-P = Phosphate, NO_3-N = Nitrate, Cl^- = Chloride, WQI = Water Quality Index

Table 7: Correlation between Water Quality Index (WQI) and physico-chemical parameters of Surface Water (Budhi Gandak River) & Ground Water (Hand pumps) in Summer, Monsoon & Winter seasons (October 2013-June 2014)

	Temp.(°C)	pH	TDS	EC	TH	HCO_3^-	PO_4-P	NO^3-N	Cl^-	Turbidity (NTU)
SUMMER WQI	0.098309	-0.88262	0.851525†	0.85105†	0.67185#	0.690632#	0.004685	0.609068	0.777275#	0.385311
MONSOON WQI	0.958478†	-0.50398	-0.68736	-0.68577	-0.76235	-0.81568	0.3867	-0.55685	-0.59537	0.981871†
WINTER WQI	-0.18213	-0.75315	-0.19484	-0.1887	-0.17244	-0.56952	0.119224	0.459717	-0.31237	0.935443†

Significant at *0.1% level, †1% level, #5% level. TDS = Total Dissolved Solids, EC = Electrical Conductivity, TH = Total Hardness, HCO_3^- = Bicarbonate, PO_4-P = Phosphate, NO_3-N = Nitrate, Cl^- = Chloride, WQI = Water Quality Index

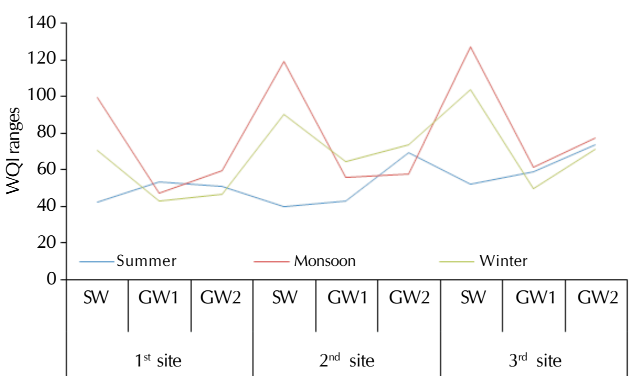

Figure 2: Seasonal results of WQI in Surface Water and Ground Water

parameters in summer, monsoon, and winter seasons is depicted in Table 7. Summer WQI was in positive correlation with temperature, TDS, conductivity, TH, HCO_3^-, NO_3-N and, Cl^- and in negative correlation with pH, the values being significant at 1% and 5% probability. WQI was positively correlated with turbidity both in monsoon and winter seasons.

In general, the physico-chemical variations observed in the present study and discussed above also support the rating of water quality of surface water and ground water ascertained by WQI calculation. The water quality rating in the present study clearly shows that the status of surface water and ground water under investigation is of moderate quality and is suitable for human uses except surface water in monsoon season. There is need to take extensive water quality monitoring studies and to find the remedial measures to protect important natural water sources in the study area. The present study suggests that the application of Water Quality Index technique for overall assessment of water quality of water bodies is a useful tool. The present study will help the local stakeholders and end users about ensuring the quality of surface and ground water mainly for drinking purpose. It is recommended that the Water Quality Index be assessed on regular basis to judge the quality of both surface and ground water.

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