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Research Article

Physicochemical Assessment and Water Quality Index of Underground and River Water in Wet Season

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Abstract

Physicochemical and water quality index (WQI) are the commonly used parameters for evaluating water contamination. Water samples were collected from the Bagmati river (Shankhamul, B-1 and Balkhu, B-2) and well water in the summer season. The physiochemical parameters such as pH, turbidity, dissolved oxygen, oxidation-reduction potential (ORP) and conductivity were measured on the spot and chemical biological parameters such as alkalinity, hardness, chemical oxygen demand (COD) and total coliform colonies were determined in the laboratory. The results showed that well water is less polluted than river water. The contaminants in the river water increased after the confluence of tributaries in the Bagmati river. Although the dissolved oxygen content was low (6.87 ppm), the observed ORP value was higher in the well water (110.1 mV) than in the river water (33.4 mV). The dissolved oxygen content was 7.11 ppm however, the oxidation-reduction potential (ORP) value was negative after the confluence of the tributaries indicating anthropogenic influence. The result is supported by a very high concentration of colonies (20000) observed in the B-2 samples. WQI revealed that the river water quality falls in the 'C' grade, indicating poor water quality. It is concluded that the groundwater and river water are polluted hence treatment is essential before using for domestic purposes.

Keywords: Bagmati river, Oxidation-reduction potential, Underground water, Water pollution, WQI

Introduction

All living organisms need water at every moment for their survival and growth. Surface and underground water are the main sources of water for daily use. Currently, anthropogenic pollutants decidedly increase contaminants in the source of water (Patil et al., 2012). The consumption of contaminated water causes waterborne diseases. About 80% of diseases in human beings are caused by water (WHO, 1999; Leevanthi, 2016). The type and quantity of contaminants in natural water vary from place to place and season to season. The types of impurities/contaminants mostly depend on their sources such as sewage and industrial waste, natural resources, the growth of bacteria, algae, viruses, and the atmosphere in the form of dissolved gases (Basavaraja et al., 2011; Leelavathi et al., 2016). The concentration of contaminants increased in the dry season but reduced in the wet season due to dilution by rain (Dahal & Joshi, 2023)

Kathmandu valley is one of the most populated cities in Nepal. The demand for freshwater has been tremendously increasing due to rapid population growth and unmanaged expansion city. Further, the Bagmati river is enormously important culturally and historically for the people in the Kathmandu valley (Milner et al., 2015). They are critical components of the hydrological cycle because they provide habitat and nourishment for organisms that rely on them. There is a lack of basic sanitation services and drinkable water for people living in the core city area (Warner, 2008). The abundantly available water sources are underground and river water for industrial, agricultural, irrigation and domestic uses. People are using underground water as one of the alternative sources to fulfil the overall demand in Kathmandu valley. The quality of underground and river water is mainly decided by the geological structure and season of the particular region however, unmanaged sewer connections are dramatically polluting sources of water (Leelavathi, 2016). The water sources of this area are being polluted at an alarming rate due to the unmanaged and uncontrolled disposal of sewage and drainage (Koju et al., 2014, Adhikari 2020). The people are disposing of sewer and solid waste directly and continuously in the rivers of Kathmandu (Mehta et al., 2017; Mishra et al., 2017). It was reported that the water quality of the Bagmati River is severely deteriorating in the present conditions due to the mixing of effluent and solid waste (Adhikari et al., 2021; Adhikari et al., 2024), which harms the river ecosystem and the health of communities relying on it. Hence determination of water quality is essential to determine the palatability of water for its use (Koju et al., 2014).

In this study, the different water quality parameters were measured at the sources and samples were collected and analyzed with physicochemical and bacteriological characteristics. The data was collected from two observation sites, before and after the confluences of five tributaries in the Bagmati river and one from a well near the Bagmati river.

Materials and Methods

Water samples and data were collected from a well, underground water (G-1) and river water from two different observation sites in the Bagmati river. The first river water sample is from the Shankhamul (B-1), just before the confluence of tributaries and 2nd sample is from the Balkhu (B-2) just after the confluence of five main tributaries of the Bagmati river during the wet (summer) season. Some physicochemical parameters, temperature, turbidity, pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), conductivity, total dissolved solid (TDS) and salinity were observed and recorded in the observation sites by using a portable advanced multi-parameter analyzer (HANNA instruments, Hi-9829) (Adhikari et al., 2024). The water samples were collected in different bottles for chemical and microbiological analysis and transported to the laboratory using cooler boxes and analyzed as soon as possible using a standard method and samples were processed immediately for bacteriological analysis. The alkalinity, hardness, acidity, chloride ion, and dissolved CO_2 were determined using the titrimetric method (APHA, 2012; Rattan, 2012). Chemical oxygen demand (COD) was determined spectrophotometrically using hydrogen phthalate as standard (Bhatt et al., 2024)

The water quality index (WQI) was computed using the weighted arithmetic index of the water quality parameters. The value was calculated using eight variables. A quality rating was determined by using Equation 1.

$$Q_i = \left[\frac{(C_a - S_i)}{(C_s - S_i)}\right] x100 - - - (1)$$

Where, Q_i = quality rating for ith parameters, C_a=concentration of ith parameters in a water sample (mg/L), S_i = WHO or Nepal standard value and C_i = ideal value (0 for all parameters except DO=14.6 ppm and pH=7.0). The unit weight (W_i, Table 1) was calculated using Equations 2 and 3 (Akoteyon et al. 2011; Imneisi & Aydin, 2016).

$$W_i = \frac{k}{S_i} - - - (2)$$

$$k = \frac{1}{\sum_{i=1}^{n} 1/S_i} - - - (3)$$

Where, Wi = unit weight of ith parameters, S_i = standard value for the ith parameters n= no of parameters and k= relative constant.

From the quality rating (Qi) and unit weight (Wi), the index of i^{th} parameter I_i was calculated from Equation 4, then the WQI was calculated using Equation 5. Based on the WQI value water quality is classified into 5 categories (Table 1).

$$I_i = W_i Q_i - - - (4)$$

$$WQI = \sum_{i=1}^{n} \frac{I_i}{\sum W_i} - - - (5)$$

Table 1: Water quality classification based on the water quality index (WQI).

WQI value	Rating of water quality	Grading
0-25	Excellent water	A
26-50	Good	B
51-75	Poor	C
76-100	Very poor	D
Above 100	Unfit for drinking	E

Results and Discussion

The temperature of the river water was measured before noon and that of well water was recorded in the afternoon. The observed temperature was 24.99 and 25.29 and 28.47 °C in the B-1, B-2 and G-1 samples respectively (Figure 1a). The variation in water temperature was due to the diurnal variation of air temperature in the summer season. The turbidity was low about 130.2 FNU for well water, which was 2 to 3 times higher in the case of river water (Figure 1b).

The high turbidity of river water indicates the loading of suspended particles either soil particles from natural sources or organic matter from anthropogenic sources (Grobbelaar, 2009). pH is the negative logarithm of the hydrogen ion concentrations it ranges from 6.0 to 8.5 in surface and 6.5 to 8.5 in groundwater (Modoi et al., 2014). it is important in the disinfection, and metabolic activity of aquatic animals (Borse & Bahve, 2000), the formation of scaling, and corrosion prevention (Ahmad et al., 2020). The observed pH (7.25 to 7.67) of well and river water was slightly alkaline but within the range prescribed by WHO (WHO, 1999), the lowest pH (7.25) was observed in underground water (Figure 1c). Slightly alkaline pH indicates that river water contains carbonate and bicarbonates from the soil, limestone or waste discharge, and microbial decomposition of organic matter (Patil et al., 2012; Cuivillas et al., 2016). The conductivity measures the inorganic and organic ions in the water (Julian et al., 2018).

The inorganic ions having high mobility have a great influence but organic ions having less mobility have a low influence on conductivity (Gupta et al., 2009). The recorded conductivity of well water was highest (1084 µS/cm) which was lowest (322 µS/cm) for the B-1 sample and more than two times higher for the B-2 sample (745 µS/cm) (Figure 1d). The high conductivity of well water may be due to the presence of minerals from natural sources. The increase in conductivity in the B-2 sample indicated that the tributaries and local influence increased conducting species in the river. Dissolved oxygen is one of the most important parameters of the water ecosystem. The atmosphere and photosynthetic process are the main sources of dissolved oxygen. The concentration of dissolved oxygen depends on temperature, exposed surface area etc. (Yasin et al., 2015).

It is drastically reduced by the chemical or microbial decay process of organic materials, dead vegetation, and sewages (Bisht et al, 2013). Hence, dissolved oxygen (DO) is one of the important parameters which reveals the quality of water it makes water tasty. The observed DO (Figure 1e) value ranged from 6.87 to 7.11 ppm. The lack of aeration may be one of the causes of the low DO concentration of well water. Oxidation-reduction potential (ORP) is the capability of water to conduct a specific redox reaction. The redox reaction includes nitrification, denitrification, removal of phosphorus and organic matter, and production of biological malodor (Al-Samawi & Al-Hyssaini, 2016). Natural fresh water has a high and positive ORP whereas polluted water has a low and negative ORP. The observed ORP of well water was high (110.1 mV) but low (33.4 mV) in B-1 and negative (-0.4 mV) in B-2 (Figure 1f).

ORP higher than 100 mV is characterized by enough free oxygen, which is the most common condition of surface water. Denitrification occurs when the ORP values are between 50 to -50 mV by denitrifying bacteria. Based on the ORP value it is considered that reduction of nitrate occurs in the river water which releases nitrogen. The negative value of ORP and high turbidity in the B-2 indicate the presence of organic pollutants from domestic influents (Adhikari et al., 2024).

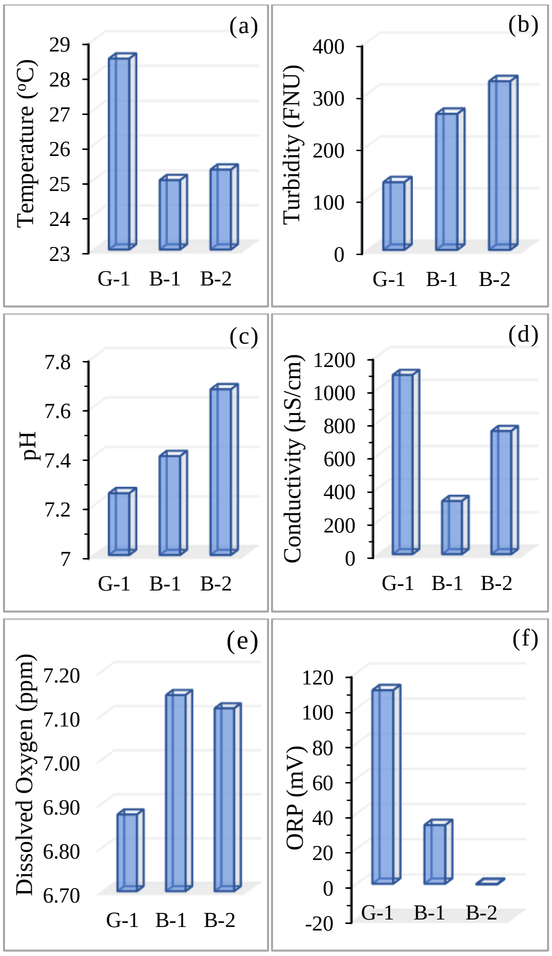

Figure 1: In-situ observed data of physicochemical parameters of the well and the Bagmati river water.

Hardness is the natural pollutants increased by soil and slow weathering of rocks containing calcium and magnesium. It develops scaling in pipes and water heaters and reduces the cleaning ability of water by decreasing lather formation with soap and increasing the boiling points (Ladipo et al., 2011). As expected, the total hardness of well water was the highest (91.39 ppm) and that of river water was lower by three folds (Figure 2a). It was reported that the hardness of nearly 150 ppm is generally perfect for its use. It is considered that water containing hardness less than 150 is soft and greater than 200 ppm is hard water. Soft water is corrosive and hard water develops scaling (WHO, 2009; Ahn et al., 2018). The hardness indicates the corrosive nature of water, especially the river water. The direct use of soft water is not harmful to humans however, it may cause corrosion in water pipes and tanks (WHO, 2009; Ahn et al., 2018). Khadka (1993) observed a total hardness of 80-300 ppm for the underground water in Kathmandu valley. Similarly, Adhikari (2020) observed 200 to 328 ppm hardness for underground water and 44 to 140 ppm for river water.

The alkalinity depends upon the dissolved minerals from soil, limestone, rock etc. (Milner et al., 2015). It measures the concentration of carbonate, bicarbonate, and hydroxyl ions. The alkalinity leads to the scale and sludge formation and corrosion in metals hence it is unpalatable. The observed alkalinity of well water was 170.89 ppm and 149.65 and 216.94 ppm, respectively of B-1 and B-2 samples (Figure 2b). The spatial variation of alkalinity of Bagmati river water in the winter season reported by Adhikari et al. (2024) showed that the alkalinity was 248.88, and 417.24 ppm respectively, before and after the confluence of the tributaries. The low concentration of alkalinity observed in this study may be due to the dilution of river water by rainfall in the wet season. The natural source of total hardness and alkalinity are minerals so their concentrations are usually nearly equal. The alkalinity of those samples was much higher than hardness which attributes that the alkalinity is due to the presence of contaminants rather than calcium and magnesium ions from soil and rock.

Acidity and dissolved CO_2 are related to each other. Dissolved CO_2 forms carbonic acid which makes water acidic. Carbonic acid ionizes to give bicarbonate and hydrogen ions making water acidic however, at a higher pH, bicarbonate takes hydrogen ions and water becomes alkaline. Respiration, photosynthesis, and decomposition influence the CO_2 levels. In well water, the CO_2 level is usually high because of decaying plants and the decomposition of organic substances. As expected, the acidity and dissolved carbon dioxide in well water were higher than in river water (Figure 2c & 2d). The high concentration of dissolved CO_2 and acidity reduced the pH of the well water.

Chloride is naturally present in wells and river water due to the leaching of soil and rocks in the form of calcium, magnesium, and sodium salt. Chloride ion concentration was 53.79, 39.1, 46.7 ppm in the G-1, B-1 and B-2, respectively (Figure 2e). The maximum limit of chloride in drinking water is 250 ppm commonly underground river water consists of less the 50 ppm (Hong et al., 2023). Chemical oxygen demand (COD) is the amount of oxygen needed to oxidize organic matter present in the water chemically. It indicates the level of pollution in water. The COD in well water is very low (0.03

ppm) which was more than two times higher in B-1 and three times in the B-2 samples (Figure 2f), indicating the presence of organic matter in the river water. The colony forming unit (CFU) indicates the pollution level of water. The clean unpolluted water consists of less the 100 CFU/mL whereas heavily polluted water consists of thousands of CFU/mL The CFU count of well water was 525 CFU/mL however it was 8300 and 20000 CFU/mL in B-1 and B-2 samples (Figure 2g). CFU counts and negative ORP value suggested that although other water quality parameters were within the WHO limits the river water consisted of excessive levels of bacteria, hence unfit to use for domestic uses especially downstream water. The computed water quality index (WQI) using 8 important water quality parameters (Figure 2f) shows that the well and Bagmati river water belongs to the C category. Although the water quality of B-1 and B-2 samples falls in the C category, the WQI value of B-2 (62.58) is higher than that (55.98) of B-1 (Figure 2h). As indicated by other parameters before the confluence of tributaries the Bagmati river water was comparatively less polluted. After the mixing of tributaries, the contaminants especially CFU counts increased extensively in the Bagmati river. The results attributed that the river water particularly downstream is hazardous and cannot be used for domestic purposes without treatment.

Conclusion

The observed pH of water samples was within the permissible range recommended by WHO. Most of the natural pollutants such as hardness, acidity, dissolved CO_2, chloride ion and conductivity were higher in the groundwater than in the river water. The anthropogenic pollutants such as alkalinity, COD, turbidity, and CFU counts were in the river water than in the underground water. The WQI suggested that the water quality of well and river water is poor and falls in the C category. Though, the WQI of Bagmati river water after the confluence of tributaries falls in the same category as other samples the CFU value was very high indicating the influence of sewer pollutants. It is concluded that the groundwater is less harmful than river water but cannot be used for domestic purposes without treatment. The Bagmati river water especially downstream is hazardous for human application.

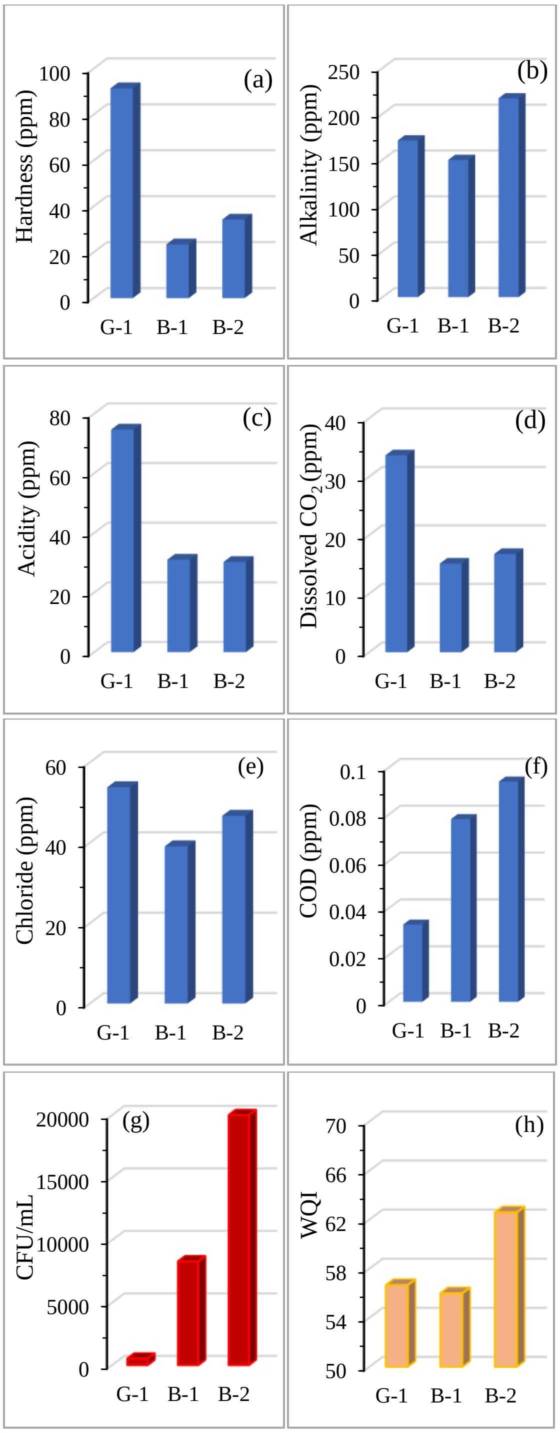

Figure 2: Physicochemical and biological parameters of the well and Bagmati river water.

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