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Physicochemical characterization of city supply, underground and river water in Kathmandu, Nepal

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Abstract

Physicochemical characterization of water is imperative for evaluating the palatability of water for domestic, agricultural and industrial uses. Water samples were collected from three different sources namely city supply, underground and river in Kathmandu. The pH, hardness, alkalinity, dissolved oxygen, and conductivity were measured and compared with standard value. The results of present study showed that sample water from the city supply were relatively clean and free from contamination though the water from Tyangla Sarkari Dhara was slightly acidic. As regards to underground water samples, the values measured for all parameter were within the range of standard value. It was observed that the underground water was slightly alkaline and hard especially the Panga well water. The physicochemical parameter showed that the river water (Bishnumati and Bagmati) was highly polluted and not potable. Alkalinity and conductivity exceeded the standard value and content of dissolved oxygen was as low as 2ppm. The results indicate that the rivers of Kathmandu are highly contaminated with alkaline and conductive pollutants. Hence river water is not suit fitted for domestic, agricultural and industrial uses and also dangerous for aquatic animal.

Keywords: Conductivity, hardness, pH, physicochemical parameters, water pollution.

Introduction

Water is essential for all living organisms for their survival and growth. However, decidedly increasing population, agriculture and man-made activities, unmanaged disposal of waste are increasing harmful contaminants in the source of water[1]. People are suffering from varied of water borne diseases due to use of such a contaminated drinking water[2]. Water causes about 80% of the diseases in the human beings[3]. Hence, the availability of palatable water is an indispensable feature to improve lifespan by preventing them from waterborne diseases. The content of impurities and their concentration in natural water varies from place to place. The types of impurities/contaminants mostly depend on their sources such as sewage and industrial waste, decomposition of plants and animals, the growth of bacterial, algae, viruses, leaching of soils etc., the atmosphere in the form of dissolved gases[4,5].

Kathmandu valley is one of the most populated cities of Nepal. The water sources of this area are being polluted at alarming rate due to the unmanaged and uncontrolled disposal of industrial effluents, hospital discharge, sewage and drainage[6]. Further, the demand for fresh water has been tremendously increasing due to unplanned urbanization, rapid growth of population, use of pesticides and fertilizer in agriculture etc. Hence, there is a lack of palatable water and basic sanitation services for most of the people[7]. People are using underground water as one of the alternative sources to full fill the overall demand in Kathmandu valley. Underground water is mostly useful for domestic, agriculture, irrigation and industrial purpose[8]. The quality of underground water is decided by the chemical constituents and their concentrations present in water, which are mainly decided by the geological structure of the particular region[3].

On the other hand, rivers are of enormous importance historically, culturally and geologically for the people in Kathmandu and other places of Nepal. Historically and culturally, there is no alternative of river water for the people[9]. They also provide nourishment and habitat for water organism so they are critical components of the hydrological cycle. Although this fact is widely accepted, people are still disposing industrial waste and the municipal solid waste continuously in the surface water especially in the rivers of Kathmandu[10].

The lack of proper investigation and treatment of polluted water is creating several health related and environmental problems in Kathmandu. Water borne disease like cholera, dysentery, diarrhea, typhoid and gastrointestinal disorders are common health problems of Nepalese peoples[11]. Hence determination of water quality is essential to determine the palatability of water for its use and requirement of treatment prior to a specific use. However, it was suggested that the water quality is impossible to measure directly, but using the physicochemical parameters such as color, temperature, acidity, alkalinity, hardness, DO, sulphate, chloride, indicates the state of water quality[12].

The general objectives of present work are to collect and analyze the water samples from three different sources such as city supply, underground and river. To determine the physicochemical characteristic such as pH, alkalinity, hardness, conductivity, and dissolved oxygen of the collected water sample and evaluate water quality of different sources.

Materials and methods

Sample collection and storage: Altogether nine water samples were taken from the different locations in Kathmandu valley during the last week of Falgun (20th to 26th March, 2016). The temperature recorded during those periods was about 26 to 29 Celsius[13]. The collected water samples were stored in cool place and analyzed as soon as possible by using standard method[5]. According to the condition of location, collected water samples are categorized into three types. First, category of sample is considered as treated city supply water, which includes jar water, water supply from municipality of Tyangla, Kirtipur and tanker water. The jar water is considered as pure drinking water. People use this water directly for drinking without any treatment. The water supply from municipality is considered as clean water. People use such water directly for domestic use and by using simple treatment method, such as boiling for drinking. The tanker water is collected either from the surface water or from shallow groundwater and supplied by private company. These sources are mainly used to collect water for domestic, agricultural and industrial uses in Kathmandu valley[7].

The second category of water is underground water. The underground water samples include the water samples from Panga well, Chardhara Panga and Tyangla well. Previously, the well water is considered as pure drinking water. Nowadays due to lack of proper management water quality is deteriorating slowly and people used to discard such water. Perhaps still some people are using such water in Kirtipur, Kathmandu.

The third category includes river water. The water samples are collected from river of Kathmandu such as Dhobi Khola, Bagmati River and Bishnumati River. The water from these rivers as culturally important. People used to take bath and wash faces in river water at different occasion. Recently, people are discharging industrial waste, household solid waste etc. directly without treatment into river hence river water is not in condition to use[7].

Measurement of different parameters of water sample: The pH was recorded directly with the pH meter (Chemiline digital meter). The pH meter was calibrated using standard buffer solutions of pH 4.2 and 9.0 before measuring pH of water sample.

The hardness of water was measured by using complexometric titration where Ethylene Diamine Tetra Acidic acid (EDTA) was used as complexing reagent and Erichrome black Tea (EBT) as indicator. Alkalinity of water was determined by the titrating sample water against a standard acid. Conductivity of water samples was recorded from the conductometer (model No: 1739). The conductometer was first calibrated and then conductivity of different water samples was measured.

Dissolved oxygen in water was determined by iodometric titration[5]. The dissolved oxygen in water oxidizes KI and equivalent amount of iodine is liberated. 0.1mL $MnSO_4$ and 1.0 mL of alkaline iodide-azide were added to 125mL of water sample. The bottle was covered and mixture was shaken in a shaker for about an hour. The brown precipitate was formed which was allowed to settle down. In clear liquid 1.0mL of concentrated sulphuric acid was added and shaken till precipitate was completely dissolved and characteristics brown color of iodine was produced. 50.0mL of above solution was transferred to a 250mL conical flask and liberated I_2 was titrated against standard hypo solution (sodium thiosulphate) with starch indicator.

Results and discussion

Samples were collected from different water sources within Kathmandu valley. Collected samples were basically classified into three groups. City supply (supposed to be treated for household use), Underground water (includes well water and spring water) and River water (surface water collected from different rivers). The city supply water includes jar water (C1), water from Tyangla Sarkari Dhara, (C2) and tanker water (C3). Underground water includes Tyangla well water (G1), Panga well water (G2) and spring water from Chardhara, Panga (G3), and river water includes water from Dhobi Khola (R1), Bishnumati River (R2) and Bagmati River (R3) in Kathmandu. As a physic chemical characterization of water, pH, conductivity, alkalinity, hardness and dissolves oxygen were measured. The results of these parameters for city supply, underground water and river water were presented in the Table-1, Table-2 and Table-3 respectively. The standard values of those parameters prescribed by World Health Organization (WHO)[2], Nepal standard (NS)[14] and Indian standard (IS)[15] were tabulated in Table-4.

Table-1: The results for city supply water samples.

Water samples	pH	Hardness (ppm)	Alkalinity (ppm)	Conductivity (μS/cm)	DO (ppm)
C1	6.5	40	100	60	9.6
C2	5.36	112	175	300	6.4
C3	6.5	176	175	270	5.2

Table-2: The results for underground water samples.

Water samples	pH	Hardness (ppm)	Alkalinity (ppm)	Conductivity (µS/cm)	DO (ppm)
G1	7.22	208	225	210	4.4
G2	7.47	328	500	1170	8.4
G3	7.83	200	175	210	5.6

Table-3: The results for river water samples.

Water samples	pH	Hardness (ppm)	Alkalinity (ppm)	Conductivity (µS/cm)	DO(ppm)
R1	7.73	44	275	450	4.4
R2	7.26	96	600	1650	2.4
R3	6.86	140	875	2100	2.0

Table-4: Standard values prescribed for water quality parameters.

Water quality parameters	Standard values prescribed by		
	NS[14]	WHO[2]	IS[15]
Conductivity	1500 µS/cm	1000 µS/cm	-
pH	6.5-8.5	6.5-8.5	6.5-8.5
Hardness	500 ppm	500 ppm	300-600 ppm
Alkalinity	-	-	200-600 ppm
Dissolved Oxygen	-	-	6 ppm

pH: The pH determines the activity of hydrogen ions [H^+]. It is represented by the negative logarithm of the hydrogen ion activity. In general, pH of surface water ranges from 6.0 to 8.5 and that of groundwater ranges from 6.5 to 8.5[16]. The water having a low pH (< 6.5) could be soft, acidic and corrosive. The pH measured for different sources of water is shown in Figure-1. The pH varied from 5.36 to 6.5, from 7.1 to 7.83 and from 7.2 to 8.1 for city supply, underground and river water, respectively. The water samples from city supply were acidic in nature and are within the range prescribed by WHO although, one of the samples from Tyangla Sarkari Dhara showed low pH (5.36). The pH is closely related with chemical constituents present in water[17]. The acidic water attributes that the dissolved carbonates were predominates in the form of HCO_3^-ion. The HCO_3^- is produce by dissolving carbon dioxide, either from aerobic degradation of organic matter or from atmosphere, into the water[18-20]. The low pH of drinking water from Tyangla Sarkari Dhara indicates the corrosive nature of water. The water having low pH may contain high levels of toxic metals, which causes premature damage of metals and development of staining to laundry and metal pipe[16]. On the other hand, the underground and river waters were alkaline in nature although the pH values were within the pH limit (6.5 to 8.5) recommended by WHO and NS for drinking water (Table-4). As reported by Cuivillas et al.[21] river water is affected by its age and the chemical discharged by communities and industries. High pH value indicates that river water contains carbonate and bicarbonates from soil, limestone[3] or waste discharge, and microbial decomposition of organic matters[1].

Total Hardness: Hardness determines the amount of calcium and magnesium present in water. It is primarily caused by leaching of soil and slowly weathering of rocks containing calcium and magnesium. Hardness is undesirable because it increases the boiling points, develops scaling in pipes and water heaters and reduces the cleaning ability of water by decreasing lather formation with soap[19]. The values of total hardness were plotted in Figure-2. The Figure shows that hardness ranged from 40 to 316, 208 to 440 and 44 to 144ppm for city supply, underground water and river water, respectively. It was reported that the hardness nearly 150ppm is generally perfect for its use. It is considered that water containing hardness less than 150 and greater than 200ppm are soft and hard water, respectively. Soft water is corrosive in nature and hard water developed scaling[22,23]. The hardness of city supply and river water except C3 showed that the value was less than 150ppm indicating the corrosive nature of water. Specially, the samples C1, R1 and R2 showed the value less than 100ppm. The direct use of such water may not influence on human body however, it may cause corrosion in water pipe and water tanks[22,23]. It was observed that the hardness of underground water was relatively high (200-440ppm) as compared to other samples. M. S. Khadka[6] observed total hardness 80-300ppm for the underground water in Kathmandu valley. Although, hardness of these water samples was within the limit of the value given by WHO (Table-4), they may develop scaling in pipes and heater.

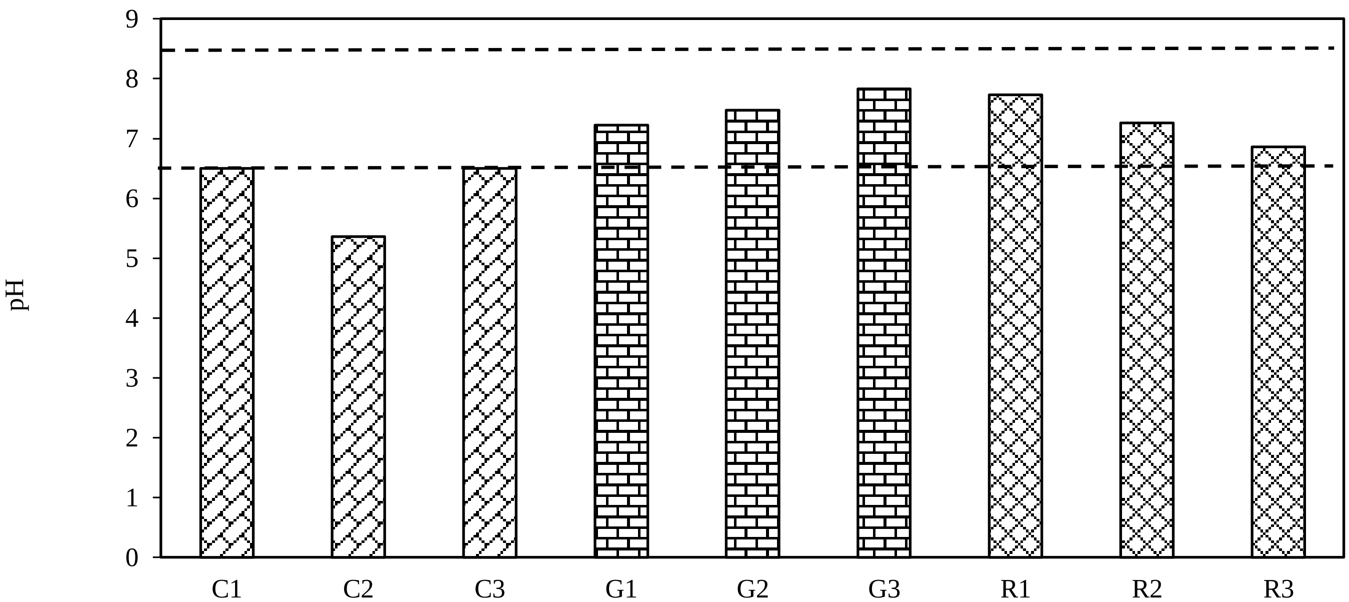

Figure-1: pH of water samples from city supply (C1-C3), underground water (G1-G3) and river water (R1-R3). Dash line indicates the range of WHO standard[2].

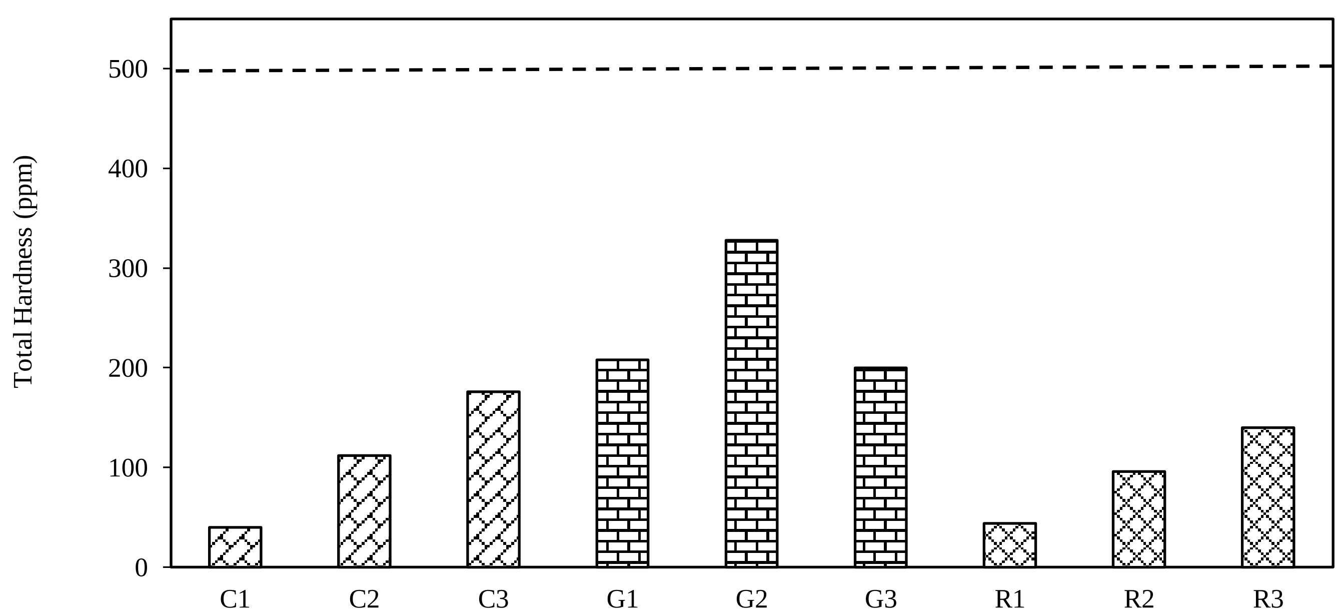

Figure-2: Total Hardness of water samples from city supply (C1-C3), underground water (G1-G3) and river water (R1-R3). The dash line indicates the WHO standard[2].

Alkalinity: Alkalinity indicates the ability of water to neutralize acids. It is mainly caused by dissolving minerals in water from soil, rock, dolomite, limestone etc.[19]. It measures the presence of carbonate, bicarbonate and hydroxyl ions. It is important because it acts as a stabilizer for pH or buffers against rapid pH changes in water. The determination of alkalinity of water is imperative because highly alkaline water is usually unpalatable. If used in boilers to generate steam, it may lead to deposition of scales and sludge, corrosion etc. Water having low alkalinity (< 150ppm) is more corrosives. Water having alkalinity greater than 150ppm may develop scaling. Total hardness and alkalinity are come from the same minerals so their concentrations are usually nearly equal. The water with alkalinity less than hardness indicates the presence of chloride, nitrate or sulfate ions[18]. The alkalinity measured in this study was plotted in Figure-3. Alkalinity of treated water (city supply) was much lower than that of underground and river waters. The alkalinity of jar water (C1) and Tyangla Sarkari Dhara (C2) was much higher than the hardness of water, which attributes the soft water. It may be because of the removal of magnesium and calcium ions during treatment. The alkalinity of underground water was much higher as compared to city supply but comparable to hardness. This result attributes the contribution of calcium and magnesium ions from soil, limestone etc. to underground water[19]. On the other hand, the river water showed great variation in alkalinity value. The alkalinity of water sample from Bishnumati and Bagmati rivers was very high which was greater than the value given by IS. The alkalinity of those samples was much higher than hardness which attributes that the alkalinity is due to presence of contaminant rather than presence of calcium and magnesium ions.

Conductivity: Conductivity measures the amount of dissolved salts present in water[24]. However, it does not indicate which ions present in water. In general conductivity (µS/cm) of unpolluted water is about two times the total hardness (ppm).The water having conductivity two times higher than the hardness indicates the presence of other ions such as sodium, chloride, nitrate or sulphate. These ions may occur naturally or effected by human activity[18]. The conductivity measured for water sample in this study was plotted in Figure-4. The conductivity of water ranged from 60 to 300 from 210 to1170 and from 350 to 2100µS/cm for city supply, underground water and river water respectively. Conductivities of city supply (C1 and C3) were nearly two times the hardness of water (ppm). However, conductivity of city supply from Tyangla Sarkari Dhara (C2) was more than two times the hardness of water, which indicates the presence of other ions as explained above. Similarly, the conductivity of Panga well water was much high and it was nearly three times the hardness of water. The conductivities of river water were very high as compared to hardness of water indicating the presence of highly conductive impurities such as sodium, sulphate, nitrate, chloride etc. introduced from human activity[18,19]. The high alkalinity of river water also revealed presence of alkaline salt. The high conductivity may influence on germination of crops and it reduces the yield hence not suitable for domestic, industrial and agricultural use[3].

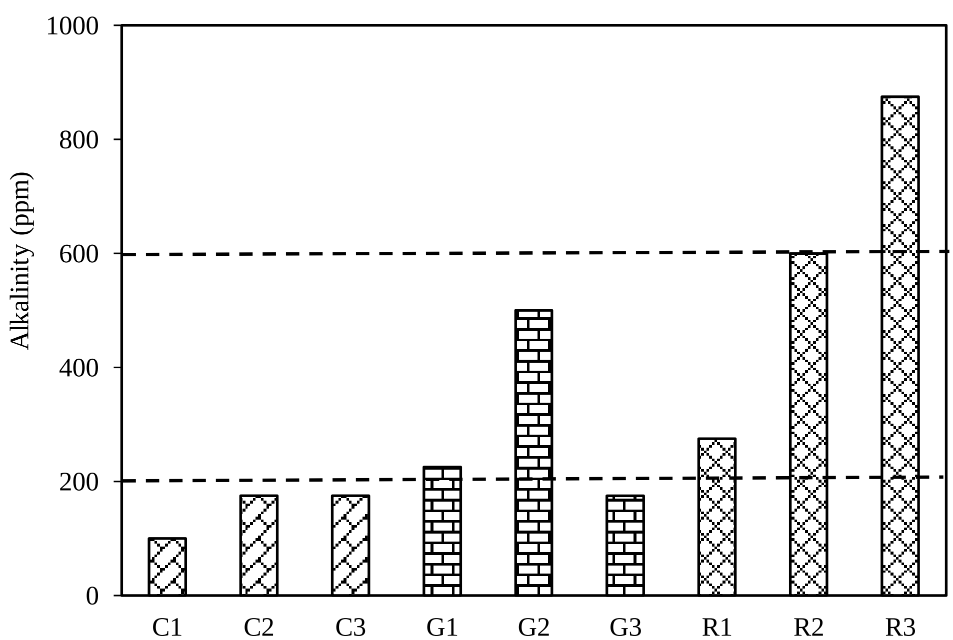

Figure-3: Alkalinity of water samples from city supply (C1-C3), underground water (G1-G3) and river water (R1-R3). The dash lines indicate the Indian standard[15] limits.

Dissolved Oxygen (DO): Dissolved oxygen is one of the most important parameters of water ecosystem. The atmosphere and photosynthetic process are the main sources of dissolved oxygen in water. The concentration of dissolved oxygen depends on temperature, exposed surface area etc.[25]. On the other hand, dissolved oxygen is drastically reduced by decay of organic materials, untreated sewage or dead vegetation either by chemical process or microbial action[26]. Hence, dissolved oxygen (DO) is one of the important parameters which reveals the quality of water. A high DO concentration makes water tasty however it enhances the rate of corrosion in water pipes. The observed DO (Figure-5) value ranged from 4.8 to 9.6 for city supply. The value of DO indicates that the quality of city supply water is comparably good among the observed sources. The highest value of DO concentration revealed that jar water is palatable for drinking. Similarly, DO value ranged from 3.6 to 8.4ppm in underground water. The DO value of river water was very low specially, in the case of Bishnumati and Bagmati rivers. The DO values for these water samples were nearly equal to 2ppm. It was reported that dissolved oxygen is highly reduced by decay of organic material, sewage, dead vegetation by microorganisms and chemicals. The results attribute that river water may contaminated extremely with microorganisms, chemicals, organic materials etc.

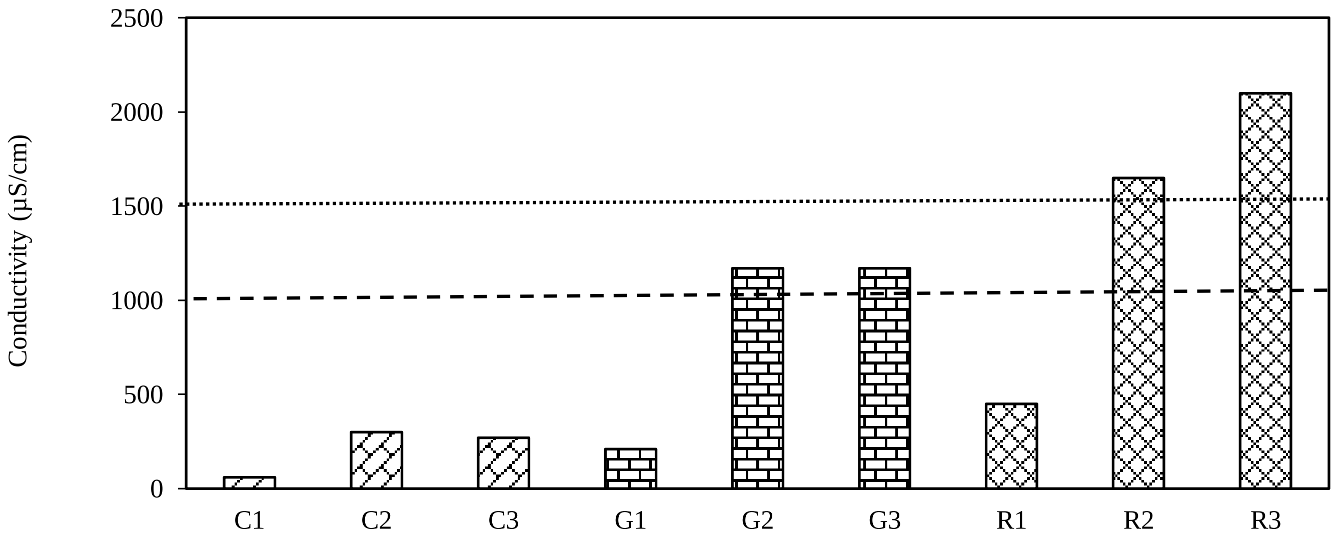

Figure-4: Conductivity of water samples from city supply (C1-C3), underground water (G1-G3) and river water (R1-R3). The dash line indicates WHO[2] limit and dotted line indicates Nepal standard[14].

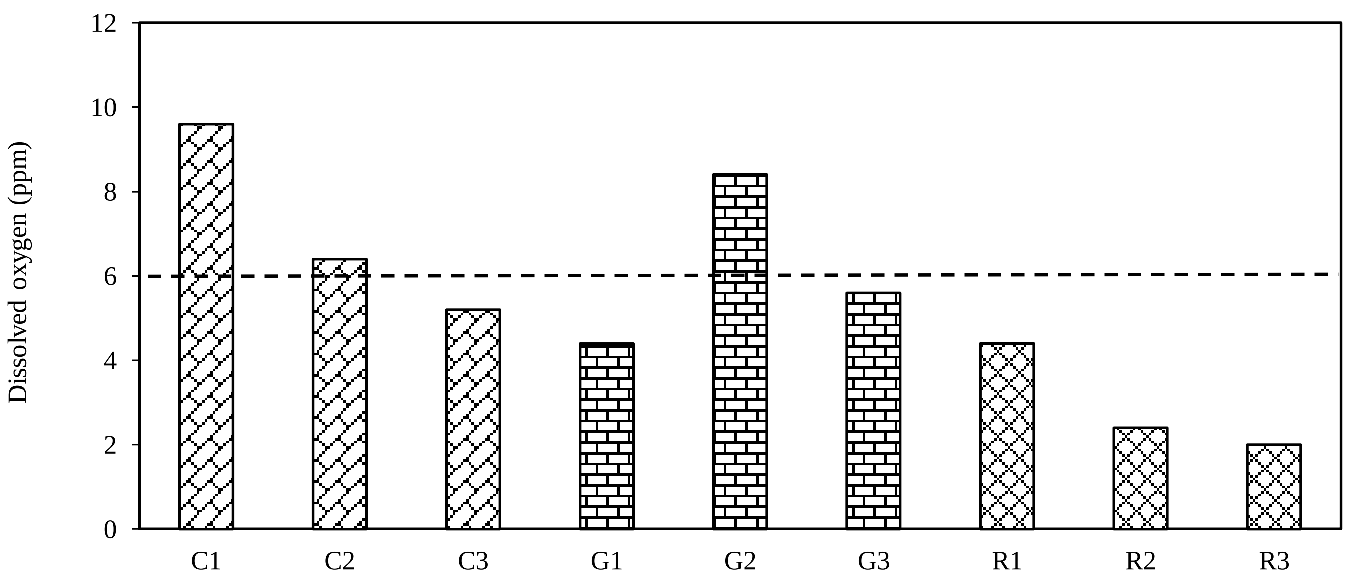

Figure-5: Dissolved oxygen of water samples from city supply (C1-C3), underground water (G1-G3) and river water (R1-R3). The dash line indicates the Indian standard[15].

The correlation between different parameters: Correlation between two parameters gives a strong indication for their variation. For the further discussion the correlation between different parameters were plotted in Figure-6. The alkalinity showed poor correlation with pH and hardness but it showed excellent positive correlation with conductivity. Alkalinity of few samples was more than two times higher than hardness. It attributes that presence of carbonate, bicarbonate ions influence the hardness of water but alkalinity is influenced by hydroxide, sodium, chloride and sulphate ions in additions to carbonate and bicarbonate ions. High conductive and excellent correlation between alkalinity and conductivity also support these results. Similarly, DO showed good correlation with alkalinity with negative slope. The correlation between DO and conductive also shows similar behavior. These results attribute that the pollutants present in water were responsible for higher conductivity. Further the medium negative correlation between DO and conductivity indicates that the highly conductive pollutants are responsible for reduction of DO in water especially in the case of river water.

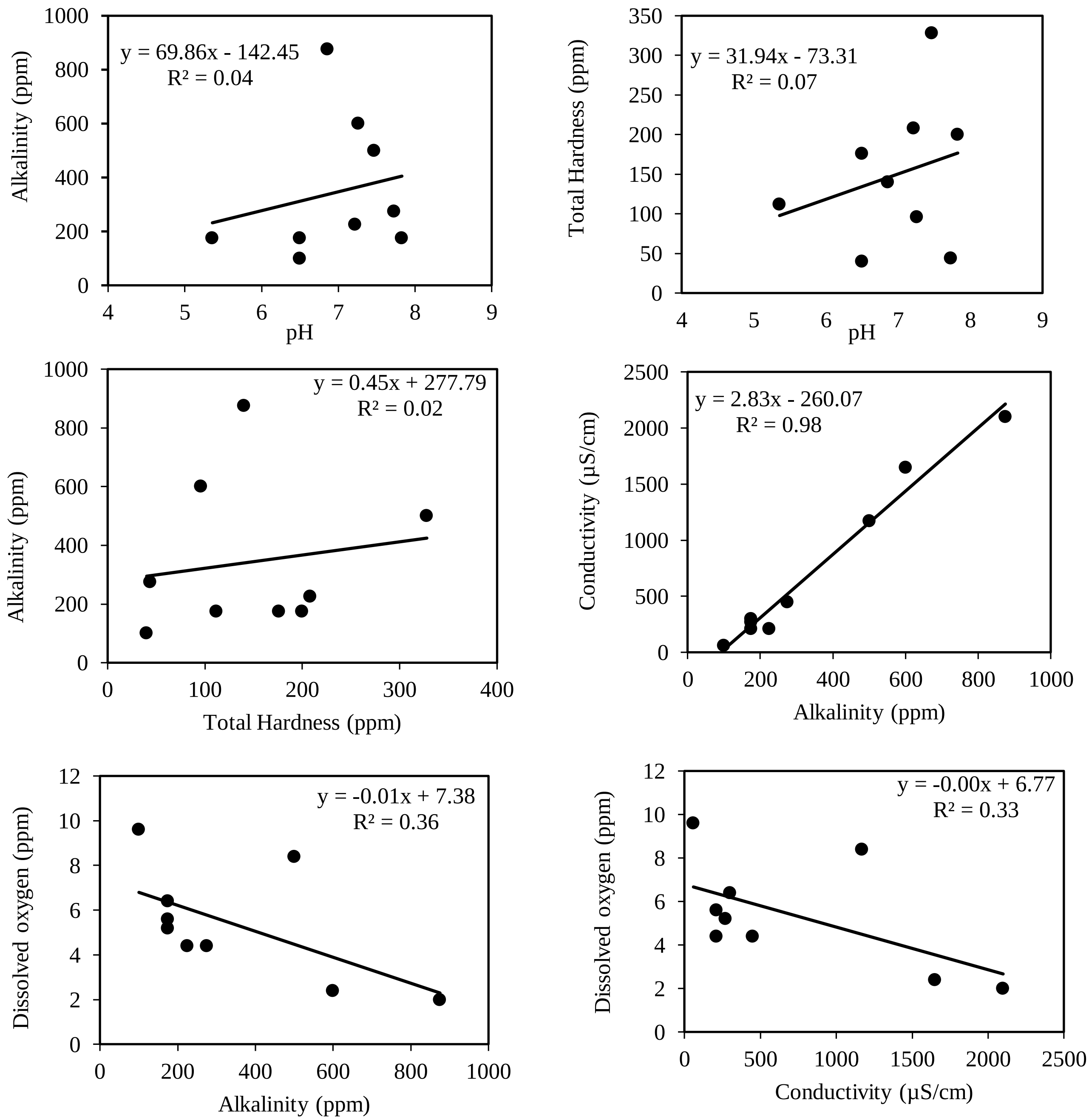

Figure-6: Correlation between different water quality parameters.

Conclusion

The chemical parameters such as hardness, alkalinity, dissolved oxygen, pH and conductivity were determined in water from different sources from different places. According to water sources the samples were divided into three groups such as city supply, underground water and river water. The observed pH of water samples was within the permissible range recommended by WHO except that obtained for Tyangla city supply water, which was pH 5.36. Hardness of groundwater was comparatively higher than that of city supply and river water indicating the contribution of calcium and magnesium ions from limestone, rocks and soil in underground water. The alkalinity of underground water and city supply was high but comparable to hardness of those samples. However, the alkalinity of river water showed great variation. The alkalinity of water samples from Bagmati and Bishnumati rivers was higher than the value recommended by WHO. The high value of alkalinity reflects that there are influenced of anthropogenic pollutant such as domestic waste, industrial effluents, drainage disposal etc. in river water. The conductivity of water from city supply and underground water was reasonable however that of river water and Panga well water was very high. The significant positive correlation between conductive and alkalinity is the indication the presence of alkaline pollutants which contributed to conductivity. This result also revealed the presence of contaminants in water. The dissolved oxygen observed for the city supply showed that the water was potable. The value of DO observed in the case of river water attributes that the polluted river water is not potable and not suitable even for the survival of aquatic animals.

From the results it is concluded that the water from city supply is potable and suitable for domestic use. The water from underground water is moderate and not harmful hence useful for domestic, agricultural and industrial uses. However, the river water is highly polluted hence, the use of river water as such is very dangerous and harmful not only to human being but also to domestic and aquatic animals, agriculture and industry.

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