Research Journal of Chemical Sciences ____ ISSN 2231-606X
Vol. **3(8),** 78-82, August **(2013)** *Res. J. Chem. Sci.*

Physico-chemical Assessment of Deep Groundwater Quality of Various Sites of Kathmandu Metropolitan City, Nepal

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Available online at: www.isca.in
Received 2nd August 2013, revised 6th August 2013, accepted 16th August 2013

Abstract

The present study was carried out to assess deep tubewell groundwater quality of Kathmandu metropolitan city. To study various water quality parameters, groundwater samples from eight major locations of the city were collected and analyzed. Samples were collected in pre-monsoon (month of April-May 2013) and preserved using suitable preservation methods. The collected groundwater samples were analyzed for the following physico-chemical parameters: temperature, colour, turbidity, pH, electric conductivity (EC), total alkalinity, phenolphthalein alkalinity, total hardness, calcium, magnesium, iron, chloride and total ammonia using the procedure outlined in the standard methods. Results showed that the water quality status was found to vary from place to place. High levels of turbidity, total alkalinity, total hardness, iron and total ammonia were found in the groundwater of many sites. The results were compared with WHO water quality guideline and National Drinking Water Quality Standard (NDWQS) of Nepal.

Keywords: Deep groundwater, physico-chemical parameters, NDWQS and WHO guideline values, Kathmandu metropolitan city

Introduction

Water is an essential component for survival of all living creatures on the earth and the supply of safe water is univocally a major concern for human consumption. The presence of elevated amounts of organic compounds, radio-nuclides, toxic heavy metals, phosphates, sulphates, nitrites and nitrates in water may cause unfavorable effects on the human health especially cancer, chronic illness and many other human body malfunctions[1]. The unsafe disposal of agricultural, industrial and municipal wastes into natural water bodies may cause serious contamination and anticipation of water transmissible diseases[2]. According to WHO, about 80% of all the diseases in human beings are caused by contaminated water[3].

Groundwater is one of the important natural resources to which majority of the world's population rely on for their daily life. In Nepal, it is the major source of drinking water in both urban and rural areas. In Kathamndu valley, nearly 50% of the total water supply from the government's authentic operator, Kathmandu Upatyaka Khanepani Limited (KUKL), during wet season and 60-70% during dry season is contributed from groundwater sources[4]. The dependency towards the use of groundwater in the valley has been increasing with the growth of population and industrial activities. The contamination of the river and surface waters by agricultural, industrial and municipal wastes has further increased dependency towards the groundwater use. Many researchers have reported the occurrence of various forms of groundwater contamination *viz*. arsenic, nitrate and ammonia in the groundwater of the valley[5,6].

Groundwater quality depends on the composition of recharging water, the mineralogy and reactivity of the geological formations in aquifers, the impact of human activities and environmental parameters that may affect the geochemical mobility of certain constituents[7]. The groundwater quality with these aspects seems to be poorly known in case of the Kathmandu metropolitan city. Obviously, water of good drinking quality is a basic requirement for human consumption since unsafe drinking water contributes to numerous health problems associated mainly with water borne diseases[1]. Once the groundwater is polluted, its quality cannot be renovated by stopping the pollutants from the source. However, it is necessary to regularly monitor the quality of groundwater. This study assesses the current status of deep tubewell groundwater quality in the valley and evaluates its suitability for drinking with respect to National Drinking Water Quality Standard (NDWQS) of Nepal and WHO guidelines[8].

Material and Methods

Study Area: Kathmandu valley is cantered on 27º 42' N, 85º 20' E covering the area of roughly 650 km^2 in the central part of Nepal. This valley is elongated east-west with an average altitude of about 1350 m above the sea level and the surrounding hills are about 2800 m above the sea level. The climate of the region is semi tropics, warm and temperate. Average precipitation in the valley is 2,000 mm/year, about 80% of which falls in the monsoon period during June and July. Surface runoff is high during the monsoon. Because the Kathmandu Valley is a closed basin with gentle slopes towards the centre, the groundwater flow is assumed slow, particularly in the deep aquifers.

Figure-1
A map of sampling sites of Kathmandu metropolitan city

Groundwater sampling: The study was carried out in deep tubewell groundwater collected from eight major sites of Kathmandu metropolitan city (figure 1). The list of sampling sites and sources of groundwater is given in table 1. The study covered the groundwater of 9-60 m depth. The water samples were taken in pre-monsoon (month of April-May 2013). The samples were collected in sampling bottles after pumping water for five minutes before sampling to get the representative samples from each site under study. The sampling bottles were labeled with the sample code number. The collected samples were preserved immediately by acidifying with 2 ml/L concentrated nitric acid (HNO_3) as described in APHA-AWWA-WPCF[9]. All water samples were stored in sterilized bottles and delivered on the same day to laboratory. All the samples were kept at 4°C until processing and analysis.

Table-1
Description of study sites of deep tubewell groundwater from Kathmandu metropolitan city

Site code	Study Sites	Sources
S_1	Kalanki	Hand pump
S_2	Kuleshwor	Hand pump
S_3	Tahachal	Hand pump
S_4	Sitapaila	Hand pump
S_5	Bansbari	Hand pump
S_6	Sinamangal	Hand pump
S_7	Tripureshwor	Hand pump
S_8	Ratnapark	Hand pump

Water quality analysis: The collected groundwater samples were subjected to various physico-chemical analyses for evaluating the water quality status. The procedure for analysis was followed as per standard methods of analysis of water and wastewater[9]. Accordingly, nephelometric method was used for analyzing turbidity while colour was determined by visual comparison method. Temperature, pH and electrical conductivity (EC) were measured in situ at each sampling location. A glass thermometer was used for the measurement of temperature. The pH and EC were measured by Hanna HI 8314 pH meter and Hanna DiST3 Tester-HI98303 conductivity meter respectively. Total and phenolphthalein alkalinity were measured by titrimetric method using phenolphthalein and methyl orange as indicators. Total hardness was measured by complexometric titration method. The acid-treated groundwater samples were further diluted 20-time with ultrapure water for analyzing Ca using flame photometry while Mg was determined by the flame atomic absorption spectrometer (FAAS). Iron was determined by colorimetric method using 1,10-phenanthroline as chelating agent. Chloride was determined by argentometric method in a neutral or slightly alkaline solution using potassium chromate as indicator by standard silver nitrate as titer. Total ammonia was measured by colorimetric nesslerization method after distillation of samples.

SPSS 11.5 software was used for statistical analysis including Pearson correlation. Pearson correlation establishes relationship between the parameters of water quality i.e. whether a parameter increases or decreases with the increase and decrease of other parameters.

Results and Discussion

The deep tubewell groundwater is used for multipurpose by local people of Kathmandu for drinking and other domestic purposes. The values of all water quality parameters and elemental concentration of water samples collected from eight sampling sites are presented in table 2. The results are compared with WHO guideline value[8] for drinking water and National Drinking Water Quality Standard (NDWQS) of Nepal.

Results showed that the turbidity in the deep tubewell groundwater of the sampling sites was found in the range of 5 to 60 NTU. All except S_1, S_4 and S_5 sampling sites exhibited the values exceeding the maximum concentration unit as described by NDWQS for turbidity; the maximum being measured at S_2. Turbidity in natural waters is caused by clay, slit, organic matter, phytoplankton and other microscopic organisms. It is actually the expression of optical property in which the light is scattered by the particles present in the water. Any substance having particle size more than 10^{-9}m will produce a turbidity[10]. It makes the water unfit for domestic and many other uses. The colours of the groundwater samples of almost all studied sites were, however within the NDWQS guideline value. Colour in natural waters may occur due to the presence of humic acids, fulvic acids, metallic ions such as iron and manganese, suspended matter, phytoplankton, weeds and industrial wastes etc[10]. The increase in temperature decreases the potability of water due to the unpleasant taste produced by CO_2 and other gases[11]. Thus, the taste of sample differs from place to place. In the present study, temperature of the groundwater samples in situ was found between 23 to 26 °C.

Presence of organic and inorganic solutes together with the reaction of carbon dioxide brings about changes in water pH. Any alteration in water pH is accompanied by the change in other physic-chemical parameters[12]. The pH of the groundwater samples during the study was found neutral (pH range: 6.7-7.3) and also within the maximum permissible limits as described by NDWQS and WHO guidelines (table 2) for pH (6.5-8.5). The ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- , PO_4^{3-}, CO_3^{2-} and HCO_3^- constitute the ionic salinity in most fresh waters as reported in literature[13]. The EC values of all the groundwater samples under investigation were found within the permissible limit of NDWQS guideline; however, the samples of S_2, S_3 and S_7 sites slightly exceeded the WHO guideline for drinking water which may be attributed to the high salinity and mineral contents.

Phenolphthalein alkalinity was not detected in any of the samples analyzed. So alkalinity for the groundwater samples in Kathmandu metropolitan city is mainly for carbonates and bicarbonates[14]. The total alkalinity of the groundwater samples of all the sampling sites under investigation was found in the range of 70-600 mg/L. Among the sites, S_1 (260 mg/L), S_2 (600 mg/L), S_3 (530 mg/L), S_7 (590 mg/L) and S_8 (450 mg/L) exceeded the maximum permissible limit as recommended by WHO for total alkalinity (200 mg/L).

Deposition of calcium and magnesium salts increases hardness of water[15]. It is an important parameter in decreasing the toxic effect of poisonous element. The total hardness in groundwater samples was found in the range of 44-320 mg/L; the values are well below the maximum concentration limits as described by NDWQS. However, the values in all groundwater samples except S_4, S_5 and S_6 sites were found to exceed WHO guideline value (total hardness range: 80-120 mg/L) for drinking water. Further, it has been reported that high consumption of salts may be crucial for the development of hypertension and increases the risk for stroke, left ventricular hypertrophy, osteoporosis, renal stones and asthma[16].

Calcium is an essential nutrient for living organisms. Its' deficiency causes rickets[10]. High concentrations of calcium are not desirable in washing, laundering and bathing. Scale formation in boilers takes place by high calcium along with magnesium[17]. In the present study, calcium was found in the range of 12 to 96 mg/L and lower than the NDWQS guideline. Magnesium also occurs in all kinds of natural waters with calcium, but its concentration remains generally lower than the calcium[18]. The present study also exhibited lower concentration of Mg than Ca. The concentration of Mg was found in the range of 3.3 to 26.6 mg/L.

Iron is one of the most abundant elements of the rocks and soil, ranking fourth by weight. All kinds of waters including groundwater have appreciable quantities of iron. Although the metal has got little concern as a health hazard but is still considered as a nuisance in exceeding quantities for domestic as well as industrial uses[10]. The Fe content of the groundwater samples (S_2, 6.0 mg/L; S_3, 2.5 mg/L; S_6, 3.5 mg/L; S_7, 1.5 mg/L; S_8, 5.5 mg/L) exceeded the NDWQS as well as WHO guideline value for drinking water (0.3 mg/L). The level of Fe was found maximum in S_2 site which may be due to the inflow of surface run off from hill torrents and agricultural wastes (agricultural and rocks). Besides, the abundantly high concentrations of Fe could be the source of high dissolved iron particularly in the deep groundwater. The iron release mechanism is not understood fully, but may be due to the reducing environment, in which iron oxides generally dissolve into soluble form[19].

According to Versari *et al.*[20], chloride concentrations higher than 200 mg/L are considered to be a risk for human health and may cause unpleasant taste of water. In the present study, the chloride concentration in all the groundwater samples was found far below the NDWQS and WHO guideline values for drinking water.

Ammonia of mineral origin is rare in natural waters but its presence is quite generally a result of natural degradation processes most inevitably ammonification of organic matter. Sewage has large quantities of nitrogenous matter, thus its disposal tends to increase the ammonia content of the waters[21]. In the present study, the total ammonia content in the groundwater samples varied from 0.02 to 65 mg/L. All except S_4 and S_5 samples exceeded the WHO guideline value for total ammonia in drinking water. The groundwater samples of S_2, S_3, S_7 and S_8 sites were found to contaminate with ammonia in significantly high levels which may probably be due to sewage contamination in groundwater and other natural degradation processes. Ammonia in higher concentration is harmful to aquatic animals, biota as well as human health[10].

Correlations among the water quality parameters: Correlations among the water quality parameters were checked by Pearson correlation test and the results are shown in table 3. Consequently, pH of the groundwater was found significantly correlated with TA ($p<0.01$), Cl^- ($p<0.01$), TH ($p<0.05$) and Mg ($p<0.05$) respectively. However, a significant negative correlation was found between pH and iron ($p<0.05$). Results also showed significant correlations between EC-Cl^- ($p<0.01$), EC-TA ($p<0.05$), TA-TH ($p<0.01$), TA-Cl^- ($p<0.01$), TH-Ca ($p<0.01$), TH-Mg ($p<0.01$) TH-Cl^- ($p<0.01$) and Ca-Mg ($p<0.05$) respectively.

Conclusion

From the present study, it can be concluded that the status of deep tubewell groundwater of Kathmandu metropolitan city varies from place to place. Among the locations, the groundwater samples of Sitapaila and Bansbari show fitness for drinking purpose as the water quality parameters analyzed are within the maximum permissible limits as recommended by WHO and NDWQS guidelines. The groundwater samples from other sites could not, however meet criteria for drinking as the results of water quality variables differ in one way or the other. It is found that the groundwater in those sites contains high levels of turbidity, total alkalinity, total hardness, iron and total ammonia. The high levels of these parameters may be due to waste water of agricultural land and other domestic wastes of urban areas. Besides, cleaning kitchen utensils and bathing activities at or around the tubewells are also among the major sources responsible for groundwater quality deterioration. The high contamination levels of these parameters may create health hazards on continuous consumption. Hence, groundwater treatment should be strictly made before use for drinking purpose. Besides, interventions should be made to reduce anthropogenic discharges in or around the possible sources of contamination; otherwise, high levels of pollution will greatly influence the population and will invite socio-economic disasters. It may be suggested that the present study may be considered for future planning in using the groundwater for drinking and other purposes.

Table-2
Groundwater quality of deep tubewell of various sites of Kathmandu metropolitan city

Parameters/Sites	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	NDWQS	WHO
Turbidity/ NTU	5.0	60.0	25.0	15.0	15.0	35.0	15.0	55.0	5 (10)	-
Colour/ °Hazen	5.0	15.0	15.0	15.0	15.0	15.0	10.0	15.0	5 (15)	-
Temp/ °C	24.0	25.0	24.0	23.0	25.0	26.0	24.0	24.0	-	-
pH	7.2	6.9	7.2	7.1	6.9	6.7	7.3	6.9	6.5-8.5	6.5-8.5
EC/ μScm^{-1}	522.0	1143.0	1026.0	280.0	140.0	400.0	1100.0	945.0	1500	800-1000
T. Alkalinity/ mgL^{-1}	260.0	600.0	530.0	160.0	70.0	200.0	590.0	450.0	-	200
P. Alkalinity/ mgL^{-1}	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	-
T. Hardness/ mgL^{-1}	190.0	320.0	260.0	100.0	44.0	60.0	320.0	150.0	500	80-120
Calcium/ mgL^{-1}	52.0	84.0	68.0	24.0	12.0	16.0	96.0	48.0	200	-
Magnesium/ mgL^{-1}	14.5	26.6	21.8	9.7	3.3	4.8	19.5	14.5	-	-
Total Fe/ mgL^{-1}	0.3	6.0	2.5	0.3	0.3	3.5	1.5	5.5	0.3	0.3
Chloride/ mgL^{-1}	7.68	7.68	7.68	5.71	5.76	5.76	7.60	7.68	250	250
T. Ammonia/ mgL^{-1}	10.0	65.0	60.0	0.02	0.02	16.0	60.0	60.0	-	1.5

Table-3
Pearson Correlations among the different parameters of groundwater

	pH	EC	TA	TH	Ca	Mg	Fe	Cl^-	NH_3-N
pH	1	.178	.549(**)	.339(*)	.109	.319(*)	-.268(*)	.539(**)	-.165
EC	.178	1	.397	.211	.039	.047	-.029	.879(**)	-.091
TA	.549(**)	.397(*)	1	.711(**)	.172	.149	-.079	.598(**)	.138
TH	.319(*)	.211	.711(**)	1	.623(**)	.573(**)	.068	.318(*)	.056
Ca	.109	.039	.172	.623(**)	1	.299(*)	.058	-.057	-.097
Mg	.339(*)	.047	.149	.573(**)	.299(*)	1	.051	-.169	-.084
Fe	-.268(*)	-.029	-.079	.068	.058	.051	1	-.181	-.091
Cl^-	.539(**)	.879(**)	.598(**)	.318(*)	-.057	-.169	-.181	1	.191
NH_3-N	-.165	-.091	.138	.056	-.097	-.084	-.091	.191	1

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level, TA= Total Alkalinity; TH= Total Hardness.

Acknowledgements

The authors are thankful to Water Quality Section, KUKL, Kathmandu and Aastha Scientific Research Service Pvt. Ltd., Kathmandu for conducting part of the chemical analyses. Faculty of Science, Padma Kanya Multiple Campus, Tribhuvan University is also greatly acknowledged for providing lab facilities.

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