Physico-chemical analysis of groundwater from Rugende II well, Rwamagana district, Rwanda

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Abstract

Ground water is vital and most appropriate fresh water resource for human consumption in both urban as well as rural areas. Some of the major quality issues faced by the ground water supply are due to domestic sewage, solid waste dump and the substandard pipe materials used in wells construction. The aim of this study was therefore to monitor the ground water quality at Rugende II well after the aesthetic complaint raised by the consumers. The Rugende II water well is a 40 meters depth well located in Rwamagana district, Rwanda. The well is sandwiched between the Rugende wetland and Rugende slums respectively at a distance of 10 m and 15 m. The quality was studied in terms of physicochemical parameters for a period of eight weeks with four samples in total, where each sample was collected at the study area every two weeks. Parameters measured included: pH, TSS, TDS, electrical conductivity, hardness, manganese, copper and iron. The results showed values that were above the prescribed limits by the World Health Organization and the Rwanda Bureau of Standards, with mean concentration for Turbidity 226.0 NTU, TSS 83.5 mg/L, water hardness 568.8 mg/L, Mn 7.50 mg/L, Fe 288.33 mg/L and pH 5.28. The other parameters were in the range of the mentioned drinking water standards: TDS 177.25 mg/L, EC 367.25 µS/cm, Cu 1.03 mg/L, $S0_4^{2-}$ 7.75 mg/L and Cl^- 118.63 mg/L. From the analysis, the Rugende II water well is not suitable for human consumption due to the values which were above the standard limits. The high iron and turbidity concentrations could be attributed to the corrosion of metal pipes used in constructing the wells.

Key words: Ground water quality, wells, physicochemical, Rwamagana

1. Introduction

Groundwater is water that is found underground in the cracks and spaces in soil, sand and rock. It is stored in-and moves slowly through layers of soil, sand and rocks called aquifers. Aquifers naturally contain gravel, sand, sandstone, or fractured rock, such as limestone (Hanrahan, 2012). The geological nature of the soil determines the chemical composition of the groundwater. Water is constantly in contact with the ground in which it stagnates or circulates, so equilibrium develops between the composition of the soil and that of the water: i.e. water that circulates in a sandy or granitic substratum is acidic and has few minerals. Water that circulates in limestone contains bicarbonates alkalinity (Adepoju-Bello et al., 2009).

Groundwater is the major source of drinking water in both urban and rural areas. Groundwater not only supplies drinking water for the global population, but also provides water for industrial and agricultural uses. It was reported that access to clean groundwater is not only a drinking water issue but also a food supply issue (FAO, 1993) and that the water demand has considerably increased given that the currently world's irrigated crops rely on groundwater for production. In general, the agriculture is by far the biggest user of water and account for about 69 percent worldwide of all water withdrawals (FAO, 2002).

Groundwater, under most conditions, is safer and more reliable for use than surface water. Part of the reason for this is that surface water is more readily exposed to pollutants from factories, for example, than groundwater is. However, this doesn't mean that groundwater is not vulnerable to contamination. Although it is not as vulnerable as surface water, contaminants can still reach wells and then households. Any chemicals that are easily soluble and penetrate the soil are prime candidates for groundwater pollutants (Stroup and Meiners, 2000; Maheshwari et al., 2010).

Consequently, prolonged discharge of industrial effluents, domestic sewage and solid waste dump affect the groundwater quality and causes various health problems. With this in mind, water related diseases are responsible for 80% of all illnesses and deaths in the developing world (UNESCO, 2006). In addition, the method and materials used in groundwater abstraction can pollute the well water and needs to be properly regulated to avoid the environmental health impact caused by the infiltration of poor quality water. For example, the mobilization of naturally occurring arsenic by drilling deep tube wells in Bangladesh was well documented (FAO, 2003).

In particular, sustainable groundwater management in developing countries is imperative to the rural, urban and agriculture uses given the high growth rate of the population that needs access to a clean and reliable water source. For instance, in Rwanda, the understanding of the groundwater availability in terms of quality and quantity was planned to be developed in Eastern Province where natural springs are lacking (MININFRA, 2010). Hence, that management not only needs a strong scientific basis but also regular monitoring of groundwater allocations, licensing, groundwater levels and quality.

Therefore, the purpose of this study was to assess the water quality of the supplied groundwater well at Rugende II, in Eastern province of Rwanda. Complaints have been raised about the quality of the supplied well water, mainly due to the observed reddish-dark colour in the water that has resulted in a temporal closure of that well few weeks before the current study.

The physico-chemical analysis will assist in addressing the pollution issue raised by the local populace and to determine whether the ground water requires some specific form of treatment prior to consumption.

2. Materials and Methods

Study area description

The Rugende II well water is located in Rwamagana district, eastern province of Rwanda, Nyakariro sector, in Gishore cell as shown in figure 1. The 40 m well was drilled in 2010 for domestic purposes and is positioned at S 02^0 00.276 and E 30^0 13.990, at 22 km from Rwamagana city. The well is a manually pumped system that was covered/protected to avoid potential surface contamination from the nearby human activities at Rugende wetland and slums, located respectively at 10 and 15 m distance. Much information is not available on the ground water quality in the study area, but the lack of proper waste handling system in the slum have the potential to affect the ground water quality.

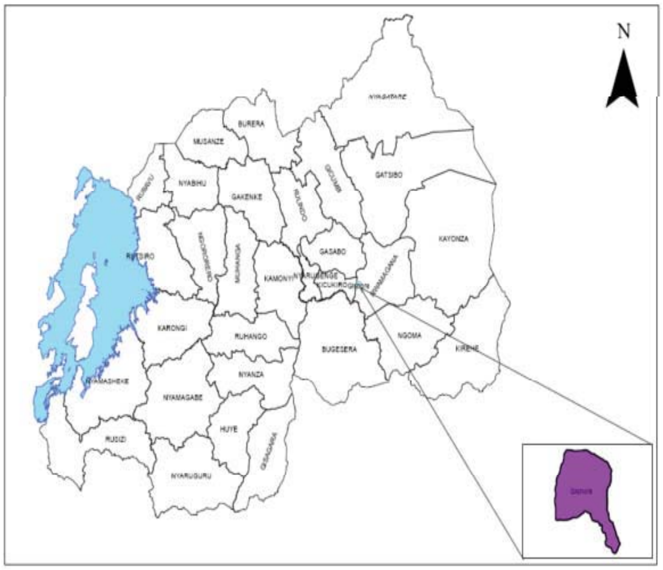

Figure 1. Location of Rugende II well water in Gishore cell, Rwamagana district, Rwanda

Sampling and analytical techniques

Sample collection: Water samples were collected for a period of eight weeks from February to March 2013 with one sample taken every two weeks; hence four samples were collected in total. Given that the Rugende well water was closed few days before our analysis, the water in dug - well was flushed out for 20 min before each sample collection to allow an ideal sample representing the well water system. The samples were collected in sterilized polyethylene bottles and kept in cool environment before the analysis.

Analytical techniques: The water samples were analysed in terms of physical properties: Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Total suspended solids (TSS) and in terms of chemical properties: pH, Total hardness, Calcium, Magnesium, Iron, Manganese, Copper, Sulfate and Chloride. The method for analysis was validated by using a standard reference wheat flour sample from National Institute of Science and Technology (NIST), USA. The analysis was carried out by using standard procedures (APHA, 1998) and the results were compared with the drinking water standards for World Health Organization (WHO, 2011) and Rwanda Bureau of Standards (RS2, 2012).

3. Results

The water quality in terms of physico-chemical characteristics for the Rugende well water is summarized in table 1. The interpretation of the results was made with the aid of RBS and WHO potable water specifications.

Table 1. Water quality parameters at Rugende II supplied ground water. Indicated values are average ± standard deviations (n = 4). Units are expressed in mg/L except where stated

Physico-Chemical Characteristics	Average	RBS[1]	WHO[2]
EC (µS/cm)	367.25 ± 74.82	1500	-
Turbidity (NTU)	226.00 ± 114.49	5	5
pH (unitless)	5.27 ± 0.54	6.5-8.5	6.5-8.5
TDS	177.25 ± 42.16	700	600-1000
TSS	83.5 0 ± 51.34	Not detectable	Not detectable
TH	568.83 ± 280.73	300	200
Calcium	442.96 ± 247.51	150	100–300
Magnesium	125.89 ± 33.49	100	-
Iron	288.33 ± 174.35	0.3	0.3
Manganese	7.49 ± 0.95	0.1	0.1
Copper	1.02 ± 0.70	1	2
Sulfate	7.75 ± 1.56	300	250
Chloride	118.62 ± 28.79	250	200-300

1. RBS: Rwanda Bureau of standards (RS2, 2012)

2. WHO: World Health Organization (WHO, 2011)

Physical characteristics

As presented in table 1, the EC ranged between 262 to 439µS/cm and was below the maximum permissible limits of 1500 µS/cm for RBS. The EC is widely used to indicate the total ionized constituents of water. The turbidity ranged between 74 to 345 NTU and has crossed the standard values of 5 NTU, in many cases turbidity is due to colloidal and extremely fine dispersions. TDS determines the amount of soluble salts in water and averaged between 119 to 219 mg/L which is within the permissible limits. Concentrations of TSS were found between 40 to140 mg/L and according to the standards, TSS concentrations should not be detected for potable water. In addition, a low intensity reddish-dark colour was noticed during the well water sampling.

Chemical characteristics

The average pH value of the well water samples was acidic and varied from 4.88 to 6.03 and was not in the standard pH scale for potable water. The total hardness ranged from 232.27 to 824.13 mg/L and was above the permissible limits of RBS and WHO. The total hardness concentration depends on calcium and magnesium concentrations where the corresponding calcium and magnesium concentrations were also found above the standards and ranged from 142.47 to 667.13 mg/L for calcium and from 89.9 to 157.0 for magnesium.

The analysis of metals revealed high concentrations of iron and manganese above the standard limits in the range of 149.40 to 536.60 mg/L for iron and from 6.18 to 8.25 mg/L for manganese. On the other side, the copper concentration ranged from 0.38 to 1.94 mg/L which is within the WHO prescribed limits.

In addition, sulfate and chloride ions concentrations where measured and found in the RBS and WHO standard limits. Sulfate ion ranged from 5.55 to 9.18 mg/L while chloride content varied from 94.0 to 160.0 mg/L and both concentrations were not of health concern. In most cases, the high chloride concentration may indicate the ground water contamination with animal or human waste.

4. Discussion

This study has shown excessive concentrations of different physical and chemical contents in the well water samples. The physical characteristics such as turbidity and TSS in addition to the chemical components of pH, total hardness, calcium, magnesium, iron and manganese contributed to the non-potability of the Rugende well water.

The physical properties of water are of paramount importance in water quality monitoring. For instance, the current study followed the water consumer's complaints due to the colour of the well water. The observed reddish- dark colour could be associated to the measured high iron and manganese content where when exposed to the air the ferrous iron oxidizes to ferric iron giving a reddish-brown colour (Zhang, 1996) and manganese turns to dark brown and change from colourless dissolved forms to coloured solid forms (WHO, 2011).

However, it is difficult to draw conclusions on the origin of the observed high iron and manganese due to the lack of background information on the ground water quality in the region. Hence, two possible origins were discussed: (i) the Rugende II well water initially contained the high iron and manganese concentrations from the soil and the local activities, (ii) the high iron and manganese resulted from the corrosion of the pipe materials used in well water construction.

The observed total hardness of 568.83 mg/L had previously been observed in ground water (Hiremath et al., 2011) and suggests that the ground water body is fairly hard. Hardness is not suitable for drinking and other uses, as hard water may cause severe health troubles like cardiovascular disorder and kidney problems (Meena et al., 2012). Similarly, the measured pH was acidic and this is probably due to the soil type, presence of chemicals and application of acidic fertilizers (Thomas et al., 2011).

Therefore, the observed acidity and the moderate total hardness of the water could have exerted an intense chemical aggressiveness to the well pipes and filters leading to increased level of iron and the leaching of manganese from the soil to the well. This event could also explain the high turbidity and the corresponding total suspended solids observed in the well water. Usually, TSS concentrations are not detected in ground water, except in region where the ground water table is highly affected by human activities (Bundela, 2012). As a result, the high TSS concentration detected in the sampled water might have originated from the pipe corrosion and the reduced filtration performance of the system.

Besides, manganese is known to occur naturally in groundwater sources with iron particularly in anaerobic or low oxidation conditions (WHO, 2006). Thus, the reported manganese could have originated from the water-clay soil interaction. In general, manganese in ground water can go beyond 10 mg/L (Todd, 1980) which is in the range of the observed 8.00 mg/L for the Rugende sampled water.

The water hardness in terms of calcium concentration was previously reported to affect the corrosion rate of some metals (WHO, 2011). Similarly, the aging of the distribution materials is also one of the principal factors influencing the corrosion and the iron leaching in water (Health Canada, 2009). However, for this study, the Rugende well water has been in service for less than four years. Consequently, the corrosion of the well pipes was probably accelerated by the substandard materials used during the well construction. In addition, the observed wide standard deviation in iron and other parameters suggests that the well water casing was getting corroded along the time. It was previously mentioned that the change in water colour may reflect the degradation of the source water, corrosion problems in distribution systems and alteration in performance of adsorptive filters (McNeill, 2001). Equally, the chemical aggressiveness of some groundwater may affect the reliability of water well casings and pumps leading to adverse high levels of iron in the water supply (WHO, 1997; Health Canada, 2009).

Furthermore, the existence of high iron and manganese for Rugende groundwater need to be complemented with the background data for the groundwater quality in the region. In this case, the only reported background information for Rugende well is that the water was colourless for the past three years.

5. Conclusions

Analysis of the well water at Rugende II has shown severe deviations from the drinking water quality standards and the water is unfit for drinking purpose. The measured acidic pH coupled to the observed moderate total hardness could have induced the well pipes corrosion leading to high iron, the leaching of manganese and the resulting high TSS concentrations, event that was probably speed up by the poor quality of the well pipes. The effective selection of the groundwater well location and the well pipe materials could minimise similar pollution in the future. The current results can be used for the selection of proper treatment and usage of Rugende well water.

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References

Adepoju-Bello, A.A., Ojomolade, O.O., Ayoola, G.A. and Coker, H.A.B., (2009). Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. The Nig. J. Pharmacy., 42, 57-60.

APHA, AWWA, WEF, 1998. Standard methods for the examination of water and wastewater, 20 edn. American Public Health Association, Washington, D.C.

Bundela, P.S., Sharma, A., Pandey, A.K., Pandey, P. and Awasthi, A.K., (2012). Physicochemical analysis of ground water near municipal solid waste dumping sites in Jabalpur. IJPAES., 2, 217-222.

FAO., 1993. The state of food and agriculture. Food and Agriculture Organisation, Rome, 3 pp.

FAO., 2002. Crops and drops, making the best use of water for agriculture. Food and Agriculture Organisation, Rome, 10 pp.

FAO., 2003. Groundwater management, the search for practical approaches. Food and Agriculture Organisation, Rome, 2 pp.

Hanrahan, G., 2012. Key concepts in environmental chemistry. Waltham, MA, Academic Press, 110 pp.

Health Canada., 2009. Guidance on Controlling Corrosion in Drinking Water Distribution Systems. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. Catalogue No. H128-1/09-595E.

Hiremath, S.C., Yadawe, M.S., Pujeri, U.S., Hiremath, D.M. and Pujar, A.S., (2011). Physico-Chemical Analysis of Ground Water in Municipal Area of Bijapur (Karnataka). Curr. World Environ., 6, 265-269.

Maheshwari, R., Singh, U., Gupta, N., Rani, B. and Chauhan, A.K., (2010).Groundwater Contamination: Environmental Management for Sustainable Future. Asian J. exp. Biol. Sci., 2, 235-242.

Mcneiill, L. S. and Edwards, M., (2001). Iron pipe corrosion in distribution systems. American Water Works Association., 93, 88-100.

Meena, K. S., Gunsaria, R. K., Meena, K., Kumar, N. and Meena. P. L., (2012). The problem of hardness in ground water of Deolitehsil (tonk district) Rajasthan. J. Curr. Chem. Pharm. Sc., 2, 50-54

MININFRA, 2010. National Policy and Strategy for Water Supply and Sanitation Services. MININFRA., Kigali, 17pp.

RS2., 2012. Potable water specification, 2nd ed, Rwanda Bureau of Standard, Kigali.

Stroup, R. and Meiners, R. E. (2000). Cutting green tape: toxic pollutants, environmental regulation, and the law. New Brunswick [N.J.], Transaction Publishers. pp 288.

Thomas, D.R., Sunil, B. and Latha, C., (2011). Physico- Chemical Analysis of Well Water at Eloor Industrial Area- Seasonal Study. Curr World Environ., 6, 259-264.

Todd, D.K. 1980. Groundwater Hydrology. 2nd ed, John Wiley, New York, 535 pp.

UNESCO, 2006. Water-related diseases. Water e-Newsletter No. 161

WHO., 1997. Guidelines for drinking water quality, Volume 3: Surveillance and control of community supplies. World Health Organization, Geneva.

WHO., 2006. Guidelines for drinking water quality, Volume 1: First addendum to third edition. World Health Organization, Geneva.

WHO., 2011. Guidelines for drinking water quality, 4th ed: Water quality standards. World Health Organization, Geneva.

Zhang, Y. H. 1996. The Challenge of Removing Iron from Groundwater. Water Technology., 19, 81-84.