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Some physico-chemical characteristics of ground water in Rwanda

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Abstract

The aim of this study was to assess the quality of groundwater from different regions in Rwanda.

Around 40 samples from springs, boreholes and wells were analyzed from 2004 to 2009. Apart from the in situ analysis of temperature, pH, conductivity and TDS using multimeter, conductimeter and pH-meter; nutrients (nitrogen, phosphorus compounds), fluorides and chlorides were analyzed by UV-Spectrophotometer while heavy metals (Pb, Cr, Cd, Fe, Mn, Zn and Cu) were analyzed by Atomic Absorption Spectrometer. The results were compared to the World Health Organization (WHO) standard for drinking water.

It was found that 69.4% for pH, 74.07% for conductivity, 5.5 % for the total hardness, 23.8% for TDS of the samples were above the WHO limits. The nutrients results showed that 9.09% for nitrates, 43.33% nitrites of samples exceeded the recommended. The heavy metals concentrations (Pb, Cd, Cr, Fe and Mn levels) in some of the samples were found to be above the guidelines of WHO with 8% for Fe, 39% for Cr, 69.7% for Mn, 60% for Pb, 56% for Cd and 3.3% for Cu.
These results indicated different levels of pollution in groundwater of Rwanda. A detailed study looking at different plausible pollution sources should be conducted in order to validate the results and advice on environmental protection of this precious source of drinking water.

Key words: *groundwater, heavy metals, pollution, toxicity*

1. Introduction

As the world is ushered into the modern era of civilization, water and its management will continue to be a major issue, which will definitely have profound impact on our lives and that of our planet Earth than ever before (Herschy, 1999). Water is indeed life and thus the most important natural

resource without which life would be nonexistent. Availability of safe and reliable source of water is an essential prerequisite for sustained development.

Water pollution is an old phenomenon, the rate of industrialization and consequently, urbanization has exacerbated its effect on the environment. Water pollution is of grave consequence because both terrestrial and aquatic life may be poisoned; it may cause disease due to the presence of some hazardous substances, distort the water quality, add odors, and significantly hinder economic activities.

Groundwater is one of the major sources of freshwater to human society and has been considered to be a readily source of water for domestic, agriculture and industrial use (Biswas 1997 In Rwanda, groundwater provides 10% of the overall drinking water that is distributed by the energy, water and sanitation corporation (EWSA).

Data on ground water and aquifers in Rwanda is incomplete. However information available estimates that the discharge for the available resource is 66m3/second and there are about 22,000 recognized sources which have a discharge of 9.0 m3/second (NBI, 2005 and Kabalisa, 2006). Rwanda's population is estimated to be about 8.2 million with an annual growth rate of about 3.8%. It is therefore expected to rise to about 13 million inhabitants by 2020 (Vision, 2020). Given its small land surface area at approximately 26,338 square kilometres, Rwanda is one of the most densely populated countries in Africa, with a population density estimated at 401.4 inhabitants per square meter. Thus, this demographic increase would put pressure on water resources.

Over 80% of the diseases that afflict Rwandans are waterborne. Thus, access to safe water is a precondition for improving environmental and personal health. There are no available water quality data on ground water in Rwanda. It is therefore pertinent that, somehow, water quality of a big number of usable springs, wells and boreholes that abound in Rwanda should be investigated. The main aim of this study therefore, is to assess the Rwandan ground waters which may serve as a baseline for further update.

2. Materials and methods

Around 40 samples from springs, boreholes and wells were analyzed from 2004 to 2009. Samples were collected in clean polyethylene bottles to avoid any contamination and brought to the laboratory and stored at 4°C. Nitric acid was added to the samples in which cations would be analyzed.

Sampling was done at the confluence of two rivers, three samples have been taken; one sample in each river and the third sample after the confluence at different distance to allow a complete mixture of the river water. The pH, dissolved oxygen (DO), salinity, conductivity and temperature were measured in-situ.

The alkalinity, acidity, total hardness, calcium hardness and chlorides were determined by volumetric analysis (Alexeev.V1980).

Nitrites, sulfates, phosphates, fluorides, ammonia, copper and manganese are measured by colorimetric method using Hach Spectrophotometer model DR 2000. To assess the levels of the heavy metals, filtered sample were analysed using Atomic Absorption Spectrophotometer (AAS) model AA 10 PLUS.

3. Results and discussion

Table 1 shows physico-chemical characteristics of the analysed samples.
The temperature of majority of springs, boreholes and wells fell in range of 15.2 to 24.7°c.

Turbidity revealed that approximately 25% of these waters were above the World Health Organization (WHO) drinking water standard which is 5 NTU. 20% of the samples were up to the maximum admissible concentration of total dissolved solids as stipulated by WHO. The conductivity varies between 87.3 and 1160.33µs/cm whereas 74.07% of the entire samples were above the WHO limits for drinking water (500µS/cm). The pH revealed that 30% of the samples were in range of guideline limit for waters requiring simple physical treatment and disinfection that is (6.5 - 8.5) and 70% fell out of the range.

The total hardness was varying between 9.01 and 652.6mg/l , and 61.1% of the entire samples were below the WHO limits,33.3% fell in 100-300mg/l range stipulated by WHO while 5.5% were above the WHO limits. The nitrites and nitrates have been assessed in twenty five samples only; the nitrates had 9.09% of samples exceeding the recommended standard of 30mg/l and the nitrites had 43.33% of samples exceeding the recommended standard of 0.015mg/l. The phosphates and sulfates have been respectively assessed in 22 and 21samples; 72.7% of them exceed the WHO limits in Phosphates while all samples respect the WHO limits in sulfates.

Heavy metals assessment (table 1) showed that copper has been assessed in thirty samples and not detected in eight samples. Copper levels did not show major effect on the environment. 69.7% of the entire batch of samples was above the manganese WHO standards of 0.05mg/l. The presence of

Manganese in groundwater has been linked to the geology of the area (Mena et al., 1967). Chromium has been assessed in 23 samples where 39% were found exceeding the WHO standard of 0.05mg/l, indeed Rwakibirizi, Mpenge and Kigombe springs are highly contaminated by chromium. This may be linked to the volcanic rocks as these springs are situated in the volcanic region (Q'Flaherty, 1995). Lead has been assessed in 25 samples and the results in table1 showed that 60% of them were above the WHO (1998) limits of 0.01mg/l for drinking water. Due to high toxicity of lead, it is imperative to monitor this pollutant in the affected springs. Cadmium assessment in 25 samples showed that 56% of them had excess Cd above WHO limits. The well of Gahanga had a very high concentration in cadmium which is probably related to contamination from the landfill site situated in its vicinity. 18% of samples showed high level exceeding the WHO limits.

Table 1: Some physico-chemical parameters of ground water in Rwanda

Spring/Borehole/Well	District	T(ºC)	PH	COND	TURBIDITY	D.0	TDS	ALkALINITY
				(mg/l	(mg/l)	(mg/l)	(mg/l)	(mg/l)
RWAMUHINDA	HUYE	21,8	6,85	87,3		4,57		4,33
KANYINYA	HUYE	21,7	6,44	72		5,27		2,67
KABASENGO	HUYE	21,7	6,12	120		2,93		4
KANEKE	HUYE	22,7	6	146,3		4,07		4,33
RWAMUHIRE	HUYE	22	5,49	174,3		2,93		4,67
NYAMUKO	HUYE	21,8	6,15	83,3		3,13		5
KAMIRAHUYE	HUYE	24	6,02	160,7	ND		421	24
RWEZAMENYO	HUYE	24	6,03	247,8	24		212	36
NANGAMATIKU	HUYE	24	6,08	415,2	ND		301	36
NTAKANANIRA	HUYE		5,46					
KAGURU	HUYE		4,835					
BUSHENYI	HUYE		5,085					
GIKONDO I	KICUKIRO	20	7	848,3	6,5	6,2	562,6	74,6
II		21,3	5,5	453	4	3,8	288	73,3
III		19,16	7,16	769,3	7,6	6,4	510,6	125
GITICYINYONI	NYARURUGENGE	23,26	5,08	331		2,87	218,33	33,33
GATSATA	NYARURUGENGE	23,33	5,33	233,6		3,2	233	38,66
GAHANGA	KICUKIRO	22,3	6,6	256	13		114,8	
UMUSHUMBA	GASABO	22,5	6,2	1062	ND		541	
KAVURE		22,4	6,2	478	ND		248	
RWABIDOMO	NYARUGENGE	22,5	6,5	450	ND		226	
KANYINYA	NYARUGENGE	21,6	6,2	329	ND		164,7	
GITICYINYONI BOREHOLE	NYARUGENGE	21,7	6	308	ND		151,4	
NYAKARIBA	NYARUGENGE	21,6	6,1	438	ND		190	
KABAKENE	KICUKIRO	21,5	5,8	420	ND		210	
KANENGWA	KICUKIRO	21,8	6,2	518	ND		257	
CHEZ CARLOS	KICUKIRO	23,6	6,2	764	ND		386	
UNILAK BOREHOLE	GASABO	20,5	6,4	840	ND		328	
MARUMBA	NYAMAGABE	18,1	4,8	26,4	0,5			5
KIGOMBE	MUSANZE	22,36	7,66	1160,33	3,33	5,33	812,23	462
MPENGE	MUSANZE	22,23	7,16	855,33	1,66	6,06	601,06	418
MUKABERE	NYABIHU	15,2	6,89	228	6		111,7	40
HESHA	NYABIHU	15,8	7,2	329	4		162,6	42

MUKAMIRA	NYABIHU	16,3	6,92	195	10		95,6	24
NYAKAGEZI	GISAGARA	24,7	6,6	110,8	1,405		52,55	22
RWAKIBIRIZI	BUGESERA	22,4	5,43	112,4	1,09		52,7	ND

Table 1: Some physico-chemical parameters of ground water in Rwanda (continuation)

Spring/Borehole/Well	DISTRICT	COLOUR (PtCo)	S.M (mg/l)	T.H (mg/l)	Tca (mg/)	TMg (mg/l)	NH_4OH (mg/l)	Cl^-(mg/l)	F^-(mg/l)
RWAMUHINDA	HUYE			19,69	8,007	11,683	0,0467	11,36	
KANYINYA	HUYE			15,35	6,01	9,34	0,0233	15,62	
KABASENGO	HUYE			40,7	18,683	12,017	0,0233	21,3	
KANEKE	HUYE			29,697	14,341	11,17	ND	15,62	
RWAMUHIRE	HUYE			9,01	5,673	3,337	ND	13,287	
NYAMUKO	HUYE			18,027	10,677	7,35	0,0233	1,42	
KAMIRAHUYE	HUYE	4		80	64	16	ND	2,6	0,48
RWEZAMENYO	HUYE	16		40	40	0	0,17	1,14	0,16
NANGAMATIKU	HUYE	19		84	68	16	ND	3,2	0,002
NTAKANANIRA	HUYE			33			0,144		
KAGURU	HUYE			48			0,148		
BUSHENYI	HUYE			54			0,212		
GIKONDO I	KICUKIRO	33,5	6,4	250,6	239,3	11,3	0,3741	94,16	0,12
II		24,5	2,6	100	48,6	11,4	0,1032	49,16	0,076
III		35,6	5,8	105,6	195,6	10	0,4472	102,6	0,29
GITICYINYONI	NYARUGENGE	0,66	1,66	82,66	58,66	24		16,26	0,05
GATSATA	NYARUGENGE	ND	1	84	57,33	26,67		33,9	0,053
GAHANGA	KICUKIRO			71	16,03				
UMUSHUMBA MWIZA	KICUKIRO			272	109,1				
KAVURE	NYARUGENGE			145	33,04				
RWABIDOMO	NYARUGENGE			101,8	31,26				
KANYINYA	NYARUGENGE			92	21,24				
GITICYINYONI BOREHOLE	NYARUGENGE			51	27,65				
NYAKARIBA	NYARUGENGE			134	39,27				
KABAKENE	KICUKIRO			80	9,21				
KANENGWA	KICUKIRO			126	20,04				
CHEZ CARLOS	KICUKIRO			198	20,84				
UNILAK BOREHOLE	GASABO			224	116,2				
MARUMBA	NYAMAGABE			18	2,5	2,3		0,8	0,5
KIGOMBE	MUSANZE	23,66	5,3	652,6	383,6	269,3		0,23	0,47
MPENGE	MUSANZE	11	2	466,6	297,6	169		0,3	0,37
MUKABERE	NYABIHU	2		103	34	31,7		1,9	0,39
HESHA	NYABIHU	12		147	60	26		2,2	0,49
MUKAMIRA	NYABIHU	38		80	30	21		1,5	0,42
NYAKAGEZI	GISAGARA	6,5		72	46	26	0,0967	8,2	0,005
RWAKIBIRIZI	BUGESERA			32	9,6	2		1,1	0,08

Table 1: Some physico-chemical parameters of ground water in Rwanda (continuation)

Spring/Borehole/Well		NO_2^- (mg/l)	NO_3^- (mg/l)	SO_4^{2-} (mg/l)	PO_4^{3-} (mg/l)	Cu (mg/l)	Mn (mg/l)
RWAMUHINDA	HUYE	0	6,5179	1	0,00619	0,02	0,06
KANYINYA	HUYE	0,013	4,2783	1	0,00155	0,02	0,08
KABASENGO	HUYE	0,0066	6,2245	1	0,00039	0,02	0,16
KANEKE	HUYE	0,0077	10,5277	1,33	0,00696	ND	0,14
RWAMUHIRE	HUYE	0,019	10,5397	2,67	0,00696	ND	0,13
NYAMUKO	HUYE	0,0077	4,052	2	0,00541	ND	0,09
KAMIRAHUYE	HUYE	0,001	11,5	6	0,48		
RWEZAMENYO	HUYE	0,003	2,6	13	0,14		
NANGAMATIKU	HUYE	0,201	13,7	4	0,16		
NTAKANANIRA	HUYE	0,077	18,65				0,02
KAGURU	HUYE	0,076	56,15				0,048
BUSHENYI	HUYE	0,069	57,9				0,275
GIKONDO I	KICUKIRO	0,0198	20,68	36,3	0,61	ND	0,136
II		0,0243	9,53	16,6	0,54	ND	0,504
III		0,0777	7,53	30,6	0,35	ND	1,32
GITICYINYONI	NYARUGENGE	0,0152	56,16		0,18	0,06	0,064
GATSATA	NYARUGENGE	0,022	23,9		0,383	0,01	0,603
GAHANGA	KICUKIRO					ND	2,135
UMUSHUMBA MWIZA	KICUKIRO					0,01	0,025
KAVURE	NYARUGENGE					0,02	0,45
RWABIDOMO	NYARUGENGE					0,01	0,034
KANYINYA	NYARUGENGE					0,05	0,138
GITICYINYONI BOREHOLE	NYARUGENGE					0,02	0,052
NYAKARIBA	NYARUGENGE					0,04	0,027
KABAKENE	KICUKIRO					0,03	0,383
KANENGWA	KICUKIRO					0,01	0,008
CHEZ CARLOS	KICUKIRO					0,01	0,228
UNILAK BOREHOLE	GASABO					ND	0,661
MARUMBA	NYAMAGABE	0,004	5	0,6	0,16	0,02	0,95
KIGOMBE	MUSANZE	0,263	35,05	6	0,58	<0.01	0,081
MPENGE	MUSANZE	0,017	17,06	3	0,6	<0.01	0,059
MUKABERE	NYABIHU	0,007	0,4	11	0,91	<0.04	0,027
HESHA	NYABIHU	0,006	0,3	17	0,71	0,01	0,01
MUKAMIRA	NYABIHU	0,04	0,3	11	0,75	0,01	0,04
NYAKAGEZI	GISAGARA	0,0049	14,96	9	0,135	0,01	0,053
RWAKIBIRIZI	BUGESERA	ND	1,3	4	0,31	0,01	ND

Table 1: Some physico-chemical parameters of ground water in Rwanda (continuation)

Spring/Borehole/Well	DISTRICT	Cr(mg/l)	Pb(mg/l)	Cd(mg/l)	Zn(mg/l)	Fe (mg/l)
RWAMUHINDA	HUYE	0,62	ND	ND		0,42
KANYINYA	HUYE	0,55	ND	ND		0,95
KABASENGO	HUYE	0,72	ND	ND		0,65
KANEKE	HUYE	0,67	ND	ND		0,47
RWAMUHIRE	HUYE	0,82	ND	ND		0,52
NYAMUKO	HUYE	0,7	ND	ND		0,65
KAMIRAHUYE	HUYE					
RWEZAMENYO	HUYE					
NANGAMATIKU	HUYE					
NTAKANANIRA	HUYE					0,305
KAGURU	HUYE					0,24
BUSHENYI	HUYE					0,21
GIKONDO I		ND	ND	ND	ND	0,03
II		ND	ND	ND	ND	0,05
III		ND	ND	ND	ND	0,12
GITICYINYONI	NYARUGENGE		0,006	0,02	0,076	0,593
GATSATA	NYARUGENGE		0,04	ND	0,08	0,603
GAHANGA	KICUKIRO	0,012	0,055	39	ND	0,18
UMUSHUMBA MWIZA	KICUKIRO	0,043	0,24	0,03	0,026	0,02
KAVURE	NYARUGENGE	0,033	0,131	0,049	0,05	0,02
RWABIDOMO	NYARUGENGE	0,05	0,511	0,023	0,12	ND
KANYINYA	NYARUGENGE	0,039	0,039	0,029	0,7	0,02
GITICYINYONI BOREHOLE	NYARUGENGE	0,05	0,186	0,236	0,16	0,01
NYAKARIBA	NYARUGENGE	0,001	0,208	0,034	0,24	0,02
KABAKENE	KICUKIRO	ND	0,175	0,042	0,03	0,31
KANENGWA	KICUKIRO	ND	0,15	0,046	0,05	ND
CHEZ CARLOS	KICUKIRO	0,028	0,193	0,049	0,03	0,2
UNILAK BOREHOLE	GASABO	ND	0,28	0,055	0,01	ND
MARUMBA	NYAMAGABE				0,2	0,13
KIGOMBE	MUSANZE	5,4	<0.5	<0.1	<0.01	0,18
MPENGE	MUSANZE	6,37	<0.5	<0.1	<0.01	0,04
MUKABERE	NYABIHU				0.01-2	ND
HESHA	NYABIHU				0.01-2	0,06
MUKAMIRA	NYABIHU				0.01-2	0,28
NYAKAGEZI	GISAGARA				ND	0,035
RWAKIBIRIZI	BUGESERA	2,06	0,24	0,01	0,13	0,05

4. Conclusion

Groundwater from different region in Rwanda was assessed using around 40 water samples from spring, wells and boreholes. It was found that 69.4% for pH, 74.07% for conductivity, 5.5 % for the total hardness, and 23.8% for TDS of the samples were above the WHO drinking water limits. The nutrients results showed that 9.09% for nitrates, 43.33% nitrites of samples exceeded the recommended standards. The heavy metals (Pb, Cd, Cr, Fe and Mn levels) indicated in some of the samples concentrations above the guidelines of WHO with 8% for Fe, 39% for Cr, 69.7% for Mn, 60% for Pb, 56% for Cd and 3.3% for Cu.

A detailed monitoring study looking at different plausible pollution sources should be conducted in order to construct a solid database on groundwater quality in Rwanda.

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