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Full Length Research Paper

Physico-chemical assessment of borehole water used by schools in Greater Giyani Municipality, Mopani district, South Africa

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In the present study, the physical and chemical quality of several borehole water sources, used by rural schools in Greater Giyani Municipality, were assessed to determine their safety for human consumption. Atomic absorption spectroscopy and ion chromatography were used to determine the chemical quality of water sources. The pH of the water samples varied between 5.29 and 8.3 and tended to be lower in summer and higher in winter. The turbidity values varied between 6.17 and 44.7 NTU in some of the schools. High concentrations of magnesium and total hardness were obtained from all water sources. Calcium concentrations were high in some schools. Anions such as chloride and sulphate were within the recommended Department of Water Affairs and Forestry (DWAF) limits except for two sampling points. High concentrations of nitrates were obtained from all schools except in Nyanisi high school. There were no fluorides and phosphates from all schools. Heavy metals like arsenic, iron, cadmium and lead were within the recommended DWAF limits. The results obtained in this study indicate that the water from the studied boreholes is not suitable for human consumption based on hardness and nitrate content and may pose a serious threat to the health of the consumers and therefore calls for urgent intervention in order to reduce such chemicals and preserve the health of the children.

Key words: Physico-chemical water quality, borehole, primary schools, Giyani, South Africa.

INTRODUCTION

According to Prince (1995) and Todd and Mays (2005), water in the saturated zone, below the water table (the upper limit of the saturated zone) is called groundwater. This is the water located beneath the ground surface in soil pore spaces and in fractures of lithologic formation. Groundwater quality can be assessed by checking its total quality that is microbiological, chemical and physical quality. Chemical quality refers to the nature and concentration of dissolved substances (such as organic and inorganic chemicals including metals) (DWAF, 1998). Physical quality refers to water quality properties such as conductivity, hydrogen ion concentrations (pH), turbidity and temperature (DWAF, 2000). The presence of micro-organisms as well as dissolved substances and physical parameters should not be above specified recommended limits in order for the water to be regarded as suitable for human consumption. The nature and content of chemical substances affect life in groundwater but also affect the health of individuals consuming this water (Elleta et al., 2010).

Naturally, groundwater contains some impurities, even

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if it is unaffected by human activities. The types and concentration of natural impurities depend on the nature of geological material through which groundwater moves and the quality of recharge water (Balakrishnan et al., 2011; Ibekwe et al., 2011). As reported by Brandi et al. (2006), in Mopani District, groundwater moves through sedimentary rocks and soil and picks up a wide range of compounds such as magnesium, calcium and chlorides. However, information obtained from the local water treatment plant show that the calcium, chloride and magnesium concentrations in Khomisani Primary School were 588, 3175 and 410 mg/l, respectively (Shirinda, 2008). These are above the maximum limits as recommended by the South African Water Quality Guidelines (DWAF, 1996).

Many rural schools in Greater Giyani Municipality depend on groundwater for cooking, drinking, and general cleaning. In fact, Giyani Water Works was initially designed for section A location at Giyani in the 1960s. Boreholes are used as sources of water in most schools in Greater Giyani Municipality, but it is also known that these boreholes are located next to pit latrines. The population increase at Giyani area resulted in plant failure to treat and pump water for the bulk supply of several rural villages including Bode, Dzingidzingi, Maswanganyi and Hlaniki Village. Based on that fact, groundwater became the predominant source of water for domestic use and other purposes in these rural communities (Shirinda, 2008).

According to Lyle and Raymond (1998), agricultural activities (fertilizers and soil amendments), septic systems, solid waste and geology are the potential sources of groundwater pollution. When fertilizers are applied to agricultural land, a portion usually infiltrate and percolate through soil to the water table. Phosphate and nitrate fertilizers are absorbed on soil particles and constitute a pollution problem (Adhikari and Chen, 2011). In Mopani District (Greater Giyani Municipality), groundwater is extensively used as a source of water supply. There is no or very little published information on the microbiological, chemical and physical quality of groundwater in Mopani District (Maake, 2007). Studies on water quality have been done in Vhembe District, Limpopo Province, South Africa and globally. Therefore, it was important that similar studies be carried out in Greater Giyani Municipality. This research was aimed at assessing the physico-chemical quality of borehole water used in six primary schools in Greater Giyani Municipality, Mopani District of Limpopo Province in South Africa.

MATERIALS AND METHODS

Atomic absorption spectroscopy and ion chromatography are used to measure the concentrations of metals and non-metals, respectively (Muyima et al., 2004). Methods used for the measurement of anions include ion chromatography and titration method (Mande et al., 2011). Ion chromatography is precise, rapid (capable of analyzing many elements at the same time), whereas titration method is likely to have many false results when dilutions are not made properly. Titration method is time consuming. Atomic absorption spectroscopy is used to measure the concentration of metals instead of using inductively coupled plasma (ICP) which is more complicated, as it is difficult to use and requires technical expertise.

Water samples collection

Water samples were collected from six different schools in Greater Giyani Municipality based on the availability of boreholes in schools, their uses and water reservoirs such as tanks. These included Khomisani primary school, Nyanisi high school, Holapondo high school, Maswanganyi primary school, Hlaniki primary school and Macema high school. All the sampling points were selected within the chosen schools. Samples were collected for four months (June, August, September and October). The water sources that were selected are those that were used for drinking and other domestic purposes such as cooking and cleaning. According to Rice (1998), the following steps were followed: 500 ml Nalgene glass sampling bottles were used. Sampling bottles were presterilized in an autoclave before going to the field. In the field, the water was left to run for 3 to 4 min before collection. After sampling, the physical parameters were measured directly.

Determination of the physico-chemical parameters of borehole water

Assessment of physical quality

Physical parameters such as conductivity, turbidity, pH and temperature were measured in the field using cyberscan 500 conductivity meter, AQ2010 LABOTEC turbidity meter, H1 8014 HANNA instrument pH meter and Mercury thermometer, respectively. pH meter was calibrated in a buffer solution of pH of 7 and 10 before measurement. The probe was immersed in water sample and readings were taken. After taking the reading, the probe was rinsed with distilled water. The turbidity meter was calibrated using 1, 10, 100, and 1000 NTU standards provided by the manufacturer. After calibration, the readings were taken.

Chemical analysis

Sample collection

According to Fitfield and Haines (2000), the following steps were followed when sampling water for chemical analysis. Polyethylene or Teflon vessels were used, and before use, the containers were washed and stored in 10% nitric acid for two days and rinsed with double distilled water. Samples were collected once in a month (during June, August, September and October). The water was left to run for 3 to 4 min to avoid collecting water with high accumulation of metals stemming from pipes, soldering and welds. Three samples were collected in each point. The containers were completely full to avoid oxidation. Depending on the pH, the samples were stabilized with nitric acid except for the samples used for the determination of nitrate.

Assessment of chemical quality

Chemical quality was assessed by checking the concentration of metals (cations) such as arsenic, cadmium, lead, iron, magnesium and calcium and anions such as phosphates, nitrates and fluorides. Atomic absorption spectroscopy was used to measure the concentration of cations such as iron, cadmium, lead, arsenic, calcium and magnesium. Ion chromatography was used to measure the concentration of anions such as chlorides, fluorides, nitrates, sulphates and phosphates. The chemical quality of the water samples was established by carrying out an anion analysis using a

Metrohm 850 professional ion chromatograph. Heavy metals were determined by use of a Varian 220 atomic absorption spectrophotometer coupled to a GTA 110 electrothermal atomiser. The standards were prepared in accordance with Reynolds and Aldous (1970) and Wright (1998).

Statistical analysis

All the results were analyzed using the SPSS program. The significance of the differences was determined by the Chi square test, and the difference was considered significant if the p value was less than 0.05.

RESULTS AND DISCUSSION

Physical characteristics of borehole water used by schools in Mopani district

The results recorded during the assessment of physical parameters including pH, temperature, turbidity and electrical conductivity are shown in Table 1. The pH of water determines the solubility and biological availability of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). The pH also determines whether aquatic life can use the nutrient. Also, metals tend to be more toxic at lower pH because they are more soluble. For all the schools, the pH values ranged from 5.29 to 8.23. These values were generally higher compared to values obtained from the western coast of Africa in Lagos, Nigeria, where Adebo and Adetoyinbo (2009) described pH values mostly around 7. For the 1st sampling (June) and the 2nd sampling (August), the pH values of groundwater in all schools were within the recommended DWAF (1996) limits for human consumption of 6.0 to 9.0. During September and October, the pH values of Macema high school borehole water from storage tank 1, Macema high school borehole water from storage tank 2, Hlaniki primary school borehole water from storage tank and Nyanisi high school borehole water from storage tank were less than 6, and hence were below the recommended DWAF (1996) limit for human consumption.

In most cases, particularly in spring (September) and beginning of summer (October), the pH was less than the recommended DWAF (1996) limits for human consumption, the pH range was from 5.29 to 5.94. Contrary to a study conducted in the Province of North West South Africa, where the pH was generally higher varying from 6.5 to 9.1 (Mpenyana-Monyatsi and Momba, 2012). Similarly, a study in Pakistan found that the pH was much higher compared to those found in the present study. The pH values found in the present study tended to be higher in winter compared to spring and beginning summer and were much lower compared to those described in Nigeria where the pH varied from 6.3 to 7.1 during the dry season and 6.2 to 8.00 during the wet season (Agbaire and Oyibo, 2009).

For all the boreholes, the temperature values ranged between 18 to 29°C during winter and increased from 25°C to a maximum of 34°C during summer (Table 1). High temperatures were achieved during September and October months. Temperature is important and influences the water chemistry. For example, the rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen that cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life (Michaud, 1991). Some compounds are also more toxic to aquatic life at higher temperatures.

In the present study, high temperatures occurred during the rainy season. The temperatures observed in the present study were slightly lower compared to those described in Nigeria by Oluyemi et al. (2010) where temperature range of 26.5 to 33.0°C were described. The electrical conductivities for all the boreholes were within the recommended DWAF (1996) limits of 0 to 70 mS/m. This indicates that the water is not salty; the water is drinkable and is capable of slaking thirst. This is because conductivity is an indicator of total dissolved salts (TDS), and also establishes if the water is drinkable and capable of slaking thirst (DWAF, 2000).

The turbidity values for Macema high school borehole water from storage tank 2 and Holapondo high school borehole water from storage tank (Table 1) were within the recommended DWAF (1996) limits for human consumption of 0 to 1 NTU throughout the sampling period. During September, the turbidity of Khomisani primary school borehole water from storage tank 1, Hlaniki primary school borehole water from storage tank and Macema high school borehole water from storage tank 1 were above the recommended DWAF (1996) limits for human consumption. The turbidity values for Maswanganyi primary school borehole 1 water from storage tank 1 were above the recommended DWAF (1996) limits during June and October. The turbidity of Khomisani primary school borehole water from storage tank 1 were above the recommended DWAF (1996) limits for human consumption in all cases except where not measured. The turbidity values were between 6.17 and 20.1 NTU for Maswanganyi primary school borehole 2 water from storage tank 2 and 11.7 and 44.7 NTU for Nyanisi high school borehole water from storage tank.

The high turbidities constitute a health risk for the children consuming this water. High turbidity also indicate higher amount of total suspended solids which might include microorganisms such as bacteria or parasites as well as an increase in the concentration of minerals (Shen et al., 2008; Oluyemi et al., 2010).

Chemical characteristics of borehole water used by schools in Mopani district

The results of assessment of heavy metals including iron, lead, cadmium and arsenic are presented in Table 2. The iron concentrations during August and October in Nyanisi high school borehole water from storage tank were 0.38

Table 1. The physical properties of borehole water.

Name of sampling point	pH				Turbidity (NTU)				Electrical conductivy (mS/m)				Temperature (°C)			
	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp
Sampling period	**Jun**	**Aug**	**Sep**	**Oct**	**Jun**	**Aug**	**Sep**	**Oct**	**June**	**Aug**	**Sep**	**Oct**	**Jun**	**Aug**	**Sep**	**Oct**
Khomisani Primary School borehole water from storage tank 1.	7.43	7.46	5.69	ND	0.17	0.4	5.69	ND	5.16	5.48	1.99	ND	22.5	25	25	ND
Khomisani Primary School borehole water from storage tank 2	7.09	7.55	ND	ND	1.17	1.13	ND	ND	5.57	5.33	ND	ND	23.7	25	ND	ND
Maswanganyi Primary School borehole 1 water from storage tank 1	7.14	7.87	6.30	5.38	2.63	0.43	0.67	3.5	1.83	1.82	1.9	1.8	23.8	25	29.1	26
Maswanganyi Primary School borehole 2 water from storage tank 2	7.33	8.10	5.75	6.18	18.4	6.17	7.78	20.1	1.58	1.58	0.12	1.53	23.4	29	34	30
Holapondo High School borehole water from storage tank	7.72	8.23	6.45	6.44	0.02	0.9	0.3	0.23	1.63	1.61	1.62	1.52	22.3	27	31.8	29
Nyanisi High School borehole water from storage tank	6.61	7.80	5.72	5.94	11.7	44.7	19.5	14.4	2.41	2.43	2.32	2.28	22	27	31.8	29
Hlaniki High School borehole water from storage tank	7.43	7.55	5.29	5.84	0.5	0.73	1.53	0.5	0.96	0.94	0.93	0.94	22.6	23	29.1	22.5
Macema High School borehole water from storage tank 1	6.84	7.63	5.60	5.29	0.93	0.56	1.12	0.73	2.39	1.32	1.32	1.93	22.3	22	25.1	24
Macema High School borehole water from storage tank 2	6.60	7.92	5.42	5.70	0.63	0.63	0.73	0.63	0.00	1.34	1.22	1.28	22.7	18	21.4	22.1

ND, Analyses were not done. There was no water at the point of sampling due to technical problems. Samp, Sampling.

Table 2. The chemical properties (heavy metals) of borehole water sources used by schools in Greater Giyani Municipality.

Name of sampling point	Iron (Fe) mg/l				Lead (Pb) mg/l				Cadmium (Cd) mg/l				Arsenic (As) mg/l			
	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp
Sampling period	**Jun**	**Aug**	**Sep**	**Oct**	**Jun**	**Aug**	**Sep**	**Oct**	**Jun**	**Aug**	**Sep**	**Oct**	**Jun**	**Aug**	**Sep**	**Oct**
Khomisani Primary School borehole water from storage tank 1	<0.1	<0.1	<0.1	ND	0.04	0.06	0.05	ND	1.0	1.0	1.0	ND	<0.1	<0.1	<0.1	ND
Khomisani Primary School borehole water from storage tank 2	<0.1	<0.1	ND	ND	0.03	0.09	ND	ND	1.0	1.0	ND	ND	<0.1	<0.1	ND	ND
Maswanganyi Primary School borehole 1 water from storage tank 1	0.01	<0.1	<0.1	<0.1	0.08	0.04	0.07	0.03	0.00	1.0	0.00	1.0	<0.1	<0.1	<0.1	<0.1
Maswanganyi Primary School borehole 2 water from storage tank 2	0.01	<0.1	<0.1	<0.1	0.05	0.05	0.04	0.04	0.00	1.0	0.00	1.0	<0.1	<0.1	<0.1	<0.1
Holapondo High School borehole water from storage tank	<0.1	<0.1	<0.1	<0.1	0.02	0.05	0.07	0.04	0.00	1.0	0.00	1.0	<0.1	<0.1	<0.1	<0.1
Nyanisi High School borehole water from storage tank	<0.1	0.38	<0.1	0.22	0.06	0.05	0.02	0.08	1.0	1.0	1.0	1.0	<0.1	<0.1	<0.1	<0.1
Hlaniki High School borehole water from storage tank	<0.1	<0.1	<0.1	<0.1	0.03	0.01	0.03	0.06	0.00	0.00	1.0	1.0	<0.1	<0.1	<0.1	<0.1
Macema High School borehole water from storage tank 1	<0.1	<0.1	<0.1	<0.1	0.02	0.02	0.03	0.04	0.00	1.0	0.00	1.0	<0.1	<0.1	<0.1	<0.1
Macema High School borehole water from storage tank 2	<0.1	0.07	<0.1	<0.1	0.04	0.01	0.02	0.04	0.00	0.00	1.0	1.0	<0.1	<0.1	<0.1	<0.1

ND, Analyses were not done. There was no water at point of sampling due to technical problems. Samp, Sampling.

and 0.22 mg/l, respectively which are above the recommended DWAF (1996) limit of 0.1 to 0.3 mg/l for human consumption. An example of chromatogram obtained is shown in Figure 1. The iron results of the other schools including Nyanisi high school borehole water from storage tank during June and September were below the recommended DWAF (1996) levels. The concentration of lead and cadmium from all the boreholes were within the recommended concentrations of 0 to 10 mg/l and 0 to 5 mg/l, respectively. The concentrations of arsenic from all the schools were within the recommended limits of 0 to 10 mg/l. The arsenic values obtained were less than 0.1 mg/l. Unlike in many African countries where arsenic

Table 3. Chemical properties (non-heavy metals cations) of borehole water used by schools in Greater Giyani Municipality.

Sampling period	Cation								Total hardness (mg $CaCO_{3/l}$)			
	Magnesium (Mg) mg/l				Calcium (Ca) mg/l							
	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct
Name of sampling point	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp	1st Samp	2nd Samp	3rd Samp	4th Samp
Khomisani Primary School borehole water from storage tank 1	183.6	168.8	184.6	ND	135.4	162.9	190.9	ND	1094.2	1101.9	1234.4	ND
Khomisani Primary School borehole water from storage tank 2	200.0	165.5	ND	ND	106.2	164.3	ND	ND	1088.8	1091.8	ND	ND
Maswanganyi Primary School borehole 1 water from storage tank 1	57.3	154.2	130.6	157.4	6.4	11.6	9.7	6.7	251.9	664.0	562.0	664.9
Maswanganyi Primary School borehole 2 water from storage tank 2	143.4	130.6	151.8	128.1	2.8	7.4	5.2	10.8	597.5	556.3	638.1	554.5
Holapondo High School borehole water from storage tank	118.9	129.9	127.0	115.8	4.8	17.4	19.3	12.9	501.6	578.4	571.2	509.7
Nyanisi High School borehole water from storage tank	52.5	52.4	52.4	55.9	610	34.1	190.6	1060	1739.4	300.9	691.7	2877.0
Hlaniki High School borehole water from storage tank	40.4	39.9	34.2	44.0	16.2	14.5	11.8	15.2	206.8	200.5	170.3	219.1
Macema High School borehole water from storage tank 1	55.4	53.7	55.1	57.9	32.3	36.5	31.4	32.5	308.8	312.3	305.3	319.6
Macema High School borehole water from storage tank 2	153.4	39.9	51.4	115.8	30.5	34.5	32.2	29.8	707.9	250.5	292.1	551.3

ND, Not done. There was no water at point of sampling due to technical problems. Samp, sampling.

contamination of groundwater is rare, many Asian countries face the problem of arsenic in ground water like Bangladesh, Malaysia and Pakistan, and in some cases have serious health and social implications (Agbalagba et al., 2011; Ahmed et al., 2011; Shirazi et al., 2011).

The results of assessment of heavy metal cations including those of magnesium and calcium are presented in Table 3. The concentrations of magnesium from all the schools boreholes were above the recommended DWAF (1996) limits of 0 to 30 mg/l for human use. In a study in the North West of South Africa, 45% of the boreholes did not comply with the magnesium limit (Mpenyana-Monyatsi and Momba, 2012). It is estimated that the most common source of calcium and magnesium in groundwater is through the erosion of rocks, such as limestone and dolomite, and minerals, such as calcite and magnesite (Marque et al., 2003). Magnesium gives undesirable taste to drinking water and may have a laxative effect, particularly with magnesium sulphate concentrations above 700 mg/l; although the human body tends to adapt to this laxative effect with time (Eletta et al., 2010).

The concentrations of calcium at Khomisani primary school borehole water from tank 1, Khomisani primary school borehole water from storage tank 2 and Nyanisi high school borehole water from storage tank (Table 3) were above the recommended DWAF (1996) limits of 0 to 32 mg/l for human consumption. The concentrations of calcium at Macema high school borehole water from storage tank 1 and Macema high school borehole water from storage tank 2 were above the recommended DWAF (1996) limits for human consumption during the second sampling (August). Receiving high concentrations of calcium may adversely affect the absorption of other essential minerals in the body and receiving higher amounts of calcium over a long period of time raises the risk of kidney stones in some people (Chandrajith et al., 2011). In the study by Mpenyana-Monyatsi and Momba (2012), 43% of borehole water tested did not comply with the calcium limit in the North West Province of South Africa. The concentrations of calcium at Maswanganyi primary school borehole 1 water from storage tank 1, Maswanganyi primary school borehole 2 water from storage tank 2, Hlaniki high school borehole water from storage tank and Holapondo high school borehole water from storage tank were within the recommended DWAF (1996) limits for human consumption.

The total hardness concentrations for all the school boreholes (Table 3) were above the South African DWAF (1996) recommended limits of 50 to 100 mg $CaCO_3$/l. This indicates the hardness of borehole water in Greater Giyani Municipality. Hardness seems to be a major problem with ground water. Similar results were found in Cameroon where Ako et al. (2011) found that groundwater contents of Ca^{2+}, Mg^{2+} and HCO_3^- and total hardness (TH) all exceeded World Health Organization (WHO) standards. Similarly, Raval and Malik (2010) found similar results in Gujarat, India. The results of assessment of anions including chloride, nitrate, sulphate, fluoride and phosphate are presented in Table 4. Figure 1 shows an example of 50 ppm chromato-

Table 4. The chemical properties (anions) of borehole water sources used by schools in Greater Giyani Municipality.

Name of sampling point	Chloride (cl) mg/l				Nitrate (No_3) mg/l				Sulphate (So_4) mg/l				Flouride (F) mg/l				Phosphate (Po_4)			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Sampling period	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct	Jun	Aug	Sep	Oct
Khomisani Primary School borehole water from storage tank 1	830.88	876.90	814.05	ND	46.99	30.39	32.58	ND	29.79	31.23	-	ND	-	-	-	ND	-	-	-	-
Khomisani Primary School borehole water from storage tank 2	816.56	896.44	ND	ND	34.75	25.05	ND	ND	29.77	31.71	ND	ND	-	-	ND	ND	-	-	-	-
Maswanganyi Primary School borehole 1 water from storage tank 1	49.93	56.11	46.61	52.5	45.06	40.42	40.62	57.33	12.50	12.86	12.21	14.48	-	-	-	-	-	-	-	-
Maswanganyi Primary School borehole 2 water from storage tank 2	48.55	48.76	43.94	45.90	34.22	35.27	35.87	36.85	12.39	19.98	20.64	18.68	-	-	-	-	-	-	-	-
Holapondo High School borehole water from storage tank	36.66	37.12	27.14	35.95	7.13	7.45	7.78	10.49	9.98	10.78	23.17	8.91	-	-	-	-	-	-	-	-
Nyanisi High School borehole water from storage tank	67.75	64.86	65.06	69.70	0.84	0.09	0.85	0.76	638.46	644.84	599.56	664.29	-	-	-	-	-	-	-	-
Hlaniki High School borehole water from storage tank	29.14	30.84	29.08	37.14	17.21	16.22	19.98	25.00	28.50	24.77	23.17	27.77	-	-	-	-	-	-	-	-
Macema High School borehole water from storage tank 1	57.02	53.47	49.81	60.44	20.35	20.42	26.08	32.86	20.08	24.65	18.71	25.40	-	-	-	-	-	-	-	-
Macema High School borehole water from storage tank 2	59.84	56.99	53.71	65.22	26.44	22.90	29.75	35.32	20.93	20.74	19.71	22.45	-	-	-	-	-	-	-	-

ND, Not done. There was no water at point of sampling due to technical problems. -, Element was not detected. The concentrations of the elements were below the detection limit of the instrument used (0.3 µg/l).

grams (calibration curves) for chloride nitrate, sulphate, fluoride and phosphate. The concentrations of chloride from all schools were within the recommended DWAF (1996) limits of 0 to 100 mg/l, except for Khomisani primary school borehole water from storage tanks 1 and 2 which were higher than the recommended limits. How-ever, the nitrate concentrations from all the schools borehole water (Table 4) were above the recommended DWAF (1996) limits of 0 to 6 mg/l for human consumption, except for Nyanisi high school borehole water from storage tank which were within the recommended limits.

The sulphate concentrations from the water from all the schools boreholes were within the recommended DWAF (1996) limits of 0 to 200 mg/l for human consumption, except for Nyanisi high school borehole water from storage tank in which the concentrations were higher than the recommended DWAF (1996) limits. There were no fluorides and phosphates from all the schools borehole water. Analysis were done twice but the concentrations were below the detection limits of the instrument used (ion chromatography).

According to South African Water Quality Guidelines set by DWAF in 1996, the results obtained in this study exceeded the limits for nitrates and hardness in all the schools borehole water. The limits for chloride in Khomisani primary school borehole water from storage tanks 1 and 2 as well as those of sulphates in Nyanisi high school borehole water from storage tank exceeded the guidelines. High concentrations of such elements make water unsuitable for domestic purposes (that is, drinking, cooking and cleaning). Consumption of drinking water high in nitrates causes methemoglobinemia in infants (Fewtrell, 2004). High concentration of chloride causes salty taste in water while high concentrations of sulphate may result in diarrhoea.

The water from Khomisani primary school borehole from storage tank 1, Khomisani primary school borehole from storage tank 2, Maswanganyi primary school borehole 1 from storage tank 1 (except for June sampling), Maswanganyi primary

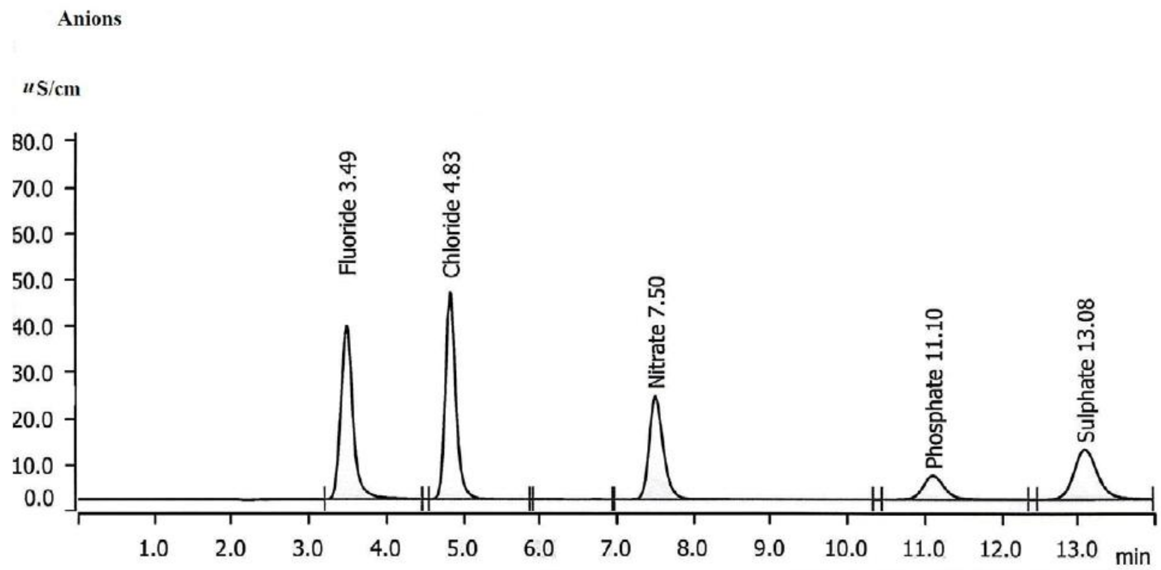

Figure 1. An example of 50 ppm chromatogram.

school borehole 2 from storage tank 2, Holapondo high school borehole water from storage tank, Nyanisi high school borehole water from storage tank and Macema high school borehole water from storage tank 1 had a total hardness >300 mg $CaCO_3$/l and can be described as very hard water. The water in Maswanganyi primary school borehole 1 from storage tank 1 during 1st sampling, Macema high school borehole from storage tank 2 during 2nd and 3rd sampling and Hlaniki primary school borehole from storage tank throughout the sampling had hardness between 200 to 300 mg $CaCO_3$/l and can be described as hard water according to DWAF (1996). According to DWAF (1996), hard water forms scale on heat exchange surfaces such as cooking utensils, hot water pipes, kettles and geysers.

Hard water increases the amount of soap required to produce lather when bathing and household cleaning. High amount of soap is thus required for classroom cleaning and this might negatively affect the economy of the school.

The combined geology of Greater Giyani Municipality as reported by Brandi et al. (2006) and very hard water (that is, high concentrations of magnesium and calcium found in the area of study) could explain that geology of the catchment might be the source of groundwater pollution. High concentration of magnesium and calcium and low concentrations of iron indicate that the geology of Mopani District (Greater Giyani Municipality) is overlain by sedimentary and mafic to altramafic rocks (Abiye, 2011). In the area of study, the mafic rocks are dominated by high concentration of magnesium, meaning that the iron concentrations have been replaced by magnesium (Bashir et al., 2009). High concentrations of calcium indicate that the area is overlain by sedimentary rocks (Adelekan, 2010).

Conclusion

According to the results obtained, it can be concluded that the borehole water used by children at Khomisani primary school, Nyanisi high school, Holapondo high school, Maswanganyi primary school, Hlaniki primary school and Macema high school is of poor physico-chemical quality. The results obtained exceeded DWAF (1996) recommended limits for iron, magnesium, calcium and hardness. Although the present study indicated poor water quality from the boreholes, the origin of contamination could not be identified. Therefore, there is need for further investigation to establish the actual source of chemical contamination. A short term solution could be to initiate the use of methodologies that further remove these salts from the water such as ultra filtration or reverse osmosis before distribution through the school taps. There is also need to carry out a comprehensive social study to determine the number of people suffering from diseases or illness related to the water quality problems identified in the area of study. This will provide information on the actual health problems on the ground contributed to by the use of untreated groundwater in schools. This will lead to recommendation of realistic remediation methods for each specific health problem.

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