



Assessing Water Quality and Its Relationship to Selected Disease Patterns in Zvishavane Town, Zimbabwe

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ABSTRACT: The research intended to establish the relationship between Zvishavane domestic water quality and selected disease patterns. Total levels of coliform, *Escherichia Coli*, chemical and other physical parameter levels in samples from selected water sources during the period March 2018 to January 2019 were evaluated. Zimbabwe National Water Authority (ZINWA) commercial laboratory methods were used to analyze thirty one randomly selected sources. This quantitative research results were compared with recommended limits from Standard Association of Zimbabwe (SAZS 560:1997) and World Health Organization (WHO). Five water sources had coliform counts ranging from < 1 to 55 cfu per 100 ml and *Escherichia Coli* from < 1 to 28 cfu per 100 ml. Chloride levels of above 200 mg/L were obtained from eight borehole water sources. Levels of selected heavy metal ions were within the SAZS 560:1997 maximum allowable limits in all water samples. Sample levels for Mg²⁺ (29 %) and total hardness (32%) were above the maximum allowable levels. Tap water samples were within recommended limits for all measured parameters. Hypertension was first among the chronic disease conditions while diarrhoea and dysentery ranked second of the outpatient general diseases attended to at the Zvishavane District Hospital during 2018. 66 neonatal death were reported during the same time period. Zvishavane domestic water require research pre-treatment methods before drinking. There is a possible link between the quality of water and the disease patterns. However these observations require further epidemiological studies to confirm the link.

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Zvishavane is a small town situated in the central part of the Midlands region of Zimbabwe. The mining town which is surrounded by largely small scale to medium gold miners is also situated in what was a very active Shabani Asbestos Mine. An estimated population of 45 230 and a total of 12 370 households are found in the small town according to the 2012 national census (Compendium of statistics 2014). There was no other census that was carried out in Zimbabwe since that time till the present time (2019). Situated in the agricultural natural region three Zvishavane is associated with warm to hot temperatures (average 27°C) and infrequent rainfall patterns Chikodzi *et al.*, (2013). The mean seasonal total infrequent rainfall for Zvishavane area is about 547 mm with a possible 745 mm and a minimum of 349 mm (Simba and Chayangira 2017). In Zimbabwe, urban councils and the Zimbabwe National Water Authority (ZINWA) are the major institutions responsible for service provision in urban areas (Zimbabwe report). Urban councils are responsible for the treatment and management of services from municipal water, sewerage and refuse removal departments while ZINWA is responsible for

provision of raw water to the urban councils. The prevailing poor state of the Zimbabwe economy has made provision of general services to the population by local authorities in particular safe drinking water difficult (World Bank, 2017). The Zimbabwe electricity supply is currently erratic affecting the drinking water pumping capacity at the water treatment and distribution stage thereby reducing normal pump flow at household level. The Zimbabwe government has stated that it is committed to the Sustainable Development Goal (SDG) number six on clean water and sanitation where it is expected that by 2030, safe affordable drinking water should be accessible to all (VNR, 2017). A base line study to assess the water quality from March 2018 to January 2019 for Zvishavane was carried out in this study.

MATERIALS AND METHODS

Two liter volume samples were collected from 30 different sampling areas (Figure 1) that were randomly selected from tap, surface and underground, around Zvishavane town as per ZINWA sampling protocol. The analysis was carried out using ZINWA

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commercial laboratory standard methods of quantification (Table 1). Samples were collected in March, May, July, September, November in 2018 and January 2019. We collected data of prevalent disease from Zvishavane District Health Information office.

RESULTS AND DISCUSSION

Escherichia coli and *Total Coliform*: Figure 2 shows that five sampling points during the period of study which reported high *E. coli* levels ranging between 4-

23 cfu per 100ml. However all sampling points (tap water or bore hole) reported *E. coli* counts of between <1 to 29 cfu from the most contaminated sources during the period of sampling. The high levels of drinking water *E. coli* and total coliform count could explain why diarrhoea and dysentery are reported (Table 2) to be second on the top ten disease attended to during 2018 at Zvishavane district hospital with acute respiratory infections coming first of the reported cases.



Fig 1: Map showing sampled borehole distribution in Zvishavane district, Zimbabwe

Table 1: Zimbabwe National Water Authority Laboratories methods of analysis used in this study

Elements	Method code	Summary of method (s)
Mg, Ca, K, Na, Fe, Cu, Zn, Mn	CHW101	Acid digestion and AAS finish
Chloride	CHW102	Titrimetric
Sulphate	CHW103A	Turbidimetric
Nitrate	CHW104	Spectrophotometric
pH	Test Not SADCAS Accredited	pH Electrode
Total hardness	Test Not SADCAS Accredited	Calculation
Conductivity, TDS	Test Not SADCAS Accredited	Electrode
Total Alkalinity	CHW110 - Test Not SADCAS Accredited	Titrimetric
Turbidity	CHW123- Test Not SADCAS Accredited	Turbidimetric
T.V.C	M501	37°C,48hrs PCA
Coliforms	M502 Test Not SADCAS Accredited	37°C,24hrs, Brill <i>E.coli</i> /Coli agar
<i>E. coli</i>	M502 Test Not SADCAS Accredited	37°C,24hrs ,Brill <i>E.coli</i> /Coli agar

Results in Table 2 were obtained from the Zvishavane District hospital health information office indicating that diarrhoea and dysentery were second on a list of top ten conditions attended to in their outpatient department during 2018. Water with less than 1 cfu *E. coli* count is considered to be low risk for drinking (WHO, 2017) and SAZS 560:1997 guidelines state that its equivalent to zero count.

However when considering that in many cases consumers harvest tap water when available in containers at home for use when the municipal water is not available, the level of risk increases. Zvishavane

being situated in a very warm region of average temperatures above 27°C, storage conditions could encourage the less than one colony to grow may be one of the causes of high incidence of diarrhoea shown by the hospital statistics in Table 2.

Turbidity, Total Dissolved Solids and Conductivity: During the period of study only three samples reported very high turbidity, 13.9 NTU from the Clinic well source at 6.9 NTU, Masvingo road borehole and 12.94 NTU from Ngomeyebani borehole. The rest of all samples were below 5 NTU (SAZS 560:1997). However, for total dissolved solids, SAZS 560:1997

has no specified a limit but WHO recommended 1000 mg/L and 26% of the water samples readings were above that limit. All tap water sources were below the 1000 mg/L indicating that most of the possible contaminants were left at the water treatment stage. Water containing TDS level below 1000 mg/litre is usually acceptable to consumers (WHO, 2017). The palatability of drinking water has been rated by panels of tasters in previous studies in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre (WHO,

2017). Water with extremely low concentrations of TDS may lack flavour and usually corrosive to plumbing systems (WHO, 2017). Conductivity is a measure of water's capability to pass electrical flow which is directly related to the concentration of ions in the water. About 82% of all conductivity readings during the study were above the stipulated recommended limit of 700 μ S/cm but below the maximum allowable limit of 3000 μ S/cm by SAZS 560:1997. This can be expected because of the high magnesium, calcium sodium and anion levels that were recorded.

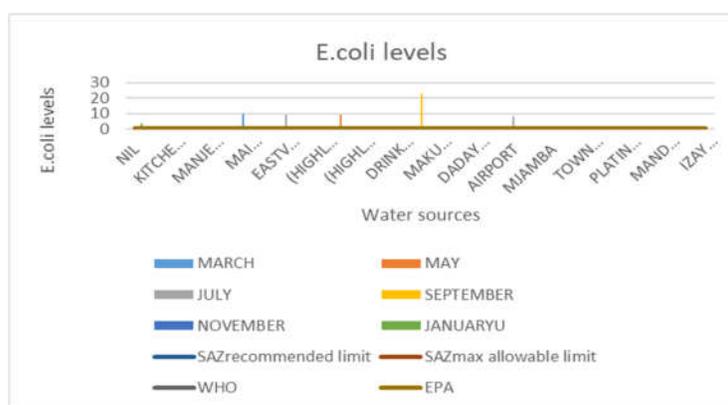


Fig 2: *Escherichia coli* counts from March 2018 to January 2019 from 19 boreholes, one water source and 11 tap water sources from Zvishavane urban and peri-urban area

Table 2 Top ten general disease conditions reported at Zvishavane district hospital in the period January 2018 to December 2018

Rank	DISEASE/ CONDITION	CASES
1	Acute Respiratory Infections	27117
2	Diarrhoea and dysentery	8096
3	Skin Diseases	8050
4	Injuries	7476
5	Diseases of the eye	4055
6	Ear Condition	3929
7	Dental Conditions	2325
8	Locally monitored diseases	1356
9	Bilharzia	521
10	Abortion	348

Hardness Level: Hardness in water is caused by presence dissolved metallic ions, usually of calcium and magnesium. 80% of the nineteen boreholes reported total hardness above the recommended limit of 500 mg/L (SAZS 560:1997). The borehole water reported high levels of magnesium and calcium (Mg = 211mg/ L and Ca = 137.3 mg/L; for Drink Water road); (Mg = 186.6 mg/ L and Ca = 227.0 mg/ L; for Manjere MSU); Mg = 151.1 mg/ Land 148.8 mg/ L; for Maglass Cottages); as well as chloride levels (Table 1). It has been reported before in previous research that water hardness can also be caused by presence several other dissolved metals such as aluminium, barium, strontium, iron, zinc, and manganese (WHO, 2011). This study established that

both zinc (average 0.08 mg/L) and iron (average of 0.156 mg/L) levels were both below the SAZS 560:1997 limit of 0.1 mg/L and 0.3 mg/L respectively. Hardness is classified as soft, 0 - 17.1 mg/ L; slightly hard, 17.1 – 60 mg/ L; moderately hard, 60 – 120 mg/ L hard, 120 – 180 mg/ Land very hard, 180 & over (USGS, 2014). Figure 6 depicts the total alkalinity values obtained thought this study. The (SAZS 560:1997) guidelines does not have any limits but the study show that tap water levels were all below 200 mg/L but all boreholes were all above the 200mg/L. The values further indicate high levels of ions such as Mg^{2+} Ca^{2+} and corresponding anions that were identified in Table 3. There is evidence from epidemiological studies for a protective effect of

magnesium or hardness on cardiovascular mortality Stevanovic et al., (2017). Therefore despite the other risks such as *E. coli* contamination and elevated sodium levels in borehole water, the water may be of

benefit as source of magnesium and calcium which can protect from cardio vascular disease and are also necessary in bone and teeth development in humans.

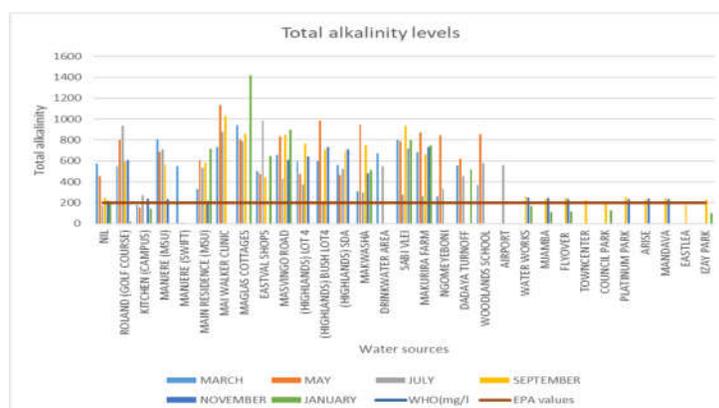


Fig 3: A summary of the levels of total alkalinity from March 2018 to January 2019

The Heavy Metal levels: Only one sampling point (Roland Golf Club, 1.07 mg/L, July 2018) out of the combined tap water, open well and borehole sources reported above SAZS 560:1997 recommended limits of 0.1 mg/L copper, but below the maximum allowable limit of 2 mg/L. Concentrations in drinking-water range is likely to be a result of the corrosion of interior copper plumbing. Zvishavane samples sources indicated acceptable levels of copper ion in both tap, well and borehole water. The ten tap water sources reported an average of 0.156 mg/L of iron during the period of sampling with two of the points reporting levels of 0.54 mg/L (Platinum Park) and 0.80 mg/L (Arise) ranging was between 0.01-0.54 mg/L. This may be attributed to the high alkalinity value (255 and 240 mg/L respectively), steel fixtures on water pipes could be corroding into drinking water. SAZS 560:1997 guideline set the recommended iron limits at 0.3 mg/L and maximum allowable limit at 1 mg/L. The high levels of iron in samples could explain the observed typical light brown color and taste of Zvishavane drinking tap water. It has been reported that at levels above 0.3 mg/l, iron stains laundry and plumbing fixtures (WHO, 2017). The 19 borehole water samples reported a similar average of 0.156 mg/L with a range of values between 0.1-1.14 mg/L (Masvingo road). Levels of 0.62 mg/L in Nil suburb 18 and 0.61 mg/L at the East Vaal shops in May 2018 were also reported. Combined tap water and borehole water samples reported manganese levels within SAZS 560:1997 recommended limits although (17%) reported manganese levels higher than the recommended limits of 0.1 mg/L indicating that water treatment may not have in effect into the removal of the heavy metal ion from tap water. Although

manganese is an essential element for humans although previous epidemiological studies have suggested that soluble manganese is associated with adverse effects on learning in children (WHO, 2017).

Tap water samples reported low magnesium levels of 27.29 mg/L which is below the SAZS 560:1997 limit of 70 mg/L. Bore hole samples reported much higher concentrations such as 211.4 mg/L (Drink Water), 198.8 mg/L Sabi Vlei; 151.1 Maglass Cottage. Calcium levels vary from 227 mg/L (Manjere MSU borehole) to 7 mg/L Council Park tap water. There is no limit for calcium in drinking water from SAZS 560:1997. Previous research has indicated that analysis concluded that hard water could be used to prevent ischemic heart disease (IHD) or coronary heart disease, through drinking Stevanovic S., et al., (2017) although high levels of magnesium could affect the water taste particularly in the presence of sulphate and chloride which is the case for Nil, Swift, Manjere MSU residence and East Vaal shops boreholes (Table 2).

In general, Zvishavane tap water sampled sources reported low sodium ion levels and are within recommended limits by SAZS: 560:1997 but the situation was different for boreholes because 52.38% of them reported sodium ion concentration of above 120 mg/L in sampled water. High sodium levels of 258.80 mg/L from Manjere Midlands State University (MSU) borehole in July 2018; 287.70 mg/L from open well source situated a private clinic and 995.00 mg/L from East Vaal borehole situated at a popular eatery. Zvishavane district hospital statistics for chronic diseases (Table 3) indicate there is a link between the quality of water and reported disease conditions

Table 3: Top ten outpatient chronic diseases condition (Non- HIV related) reported at Zvishavane district hospital, Zimbabwe

Rank	DISEASE/ CONDITION	Registered Patients regularly attending
1	Hypertension	10560
2	Diabetes	2318
3	Asthma	1528
4	Epilepsy	928
5	Mental Sickness	770
6	Chronic Heart Failure	222
7	Rheumatoid heart disease	168
8	Conditions requiring Rehab	79
9	Other Cancers	5
10	Leprosy	12

Table 4: Average anion levels from boreholes and well sources from March 2018 to January 2019

	COORDINATES		Source Identity	Average Anion Concentration in mg/L		
	X	Y		SO ₄ ²⁻	NO ₃ ⁻	Cl ⁻
1	-20.354537	30.0674	NIL	21.7	82.2	119.9
2	-20.351180	30.055283	ROLLAND SPORTS CLUB	45.5	26.6	118.5
3	-20.339177	30.034765	MANJERE (MSU)	29.4	99.8	311.5
4	-20.317609	30.059197	CLINIC Well source	32.4	45.4	200.2
5	-20.339379	30.035268	SWIFT	161.9	70.2	169.5
6	-20.314268	30.063296	MAGLASS COTTAGES	31.5	33.3	341.7
7	-20.310747	30.064713	EASTVAAL SHOPS	31.2	27.9	301.7
8	-20.286294	30.077036	MASVINGO ROAD	17.4	24.9	20.1
9	-20.291615	30.05817	CHURCH	31.4	24.7	117.2
10	-20.318453	30.060484	DRINKWATER ROAD	41.3	31.3	194.5
11	-20.371388	30.119327	SABI VLEI	103.7	35.9	76.1
12	-20.343557	30.101563	FARM	15.7	41.5	78.8
13	-20.242808	29.994494	NGOMEYEBANI	94.3	26.1	73.0
14	-20.340584	29.979097	DADAYA TURN OFF	2.7	14.4	71.5
15	-20.292273	30.146003	SCHOOL	11.5	11.4	125.0
16	-20.318809	29.914190	AIRPORT	34.4	14.0	98.0
17	-20.299067	30.055362	MAKWASHA	79.2	44.2	510.8
18	-20.294323	30.065882	HIGHLANDS LOT 4	24.9	19.0	306.2
19	-20.289527	30.062305	HIGHLANDS LOT 4 BUSH	20.1	14.7	336.2
SAZS 560:1997 recommended limit				10	200	200
SAZS 560:1997 Allowable limit				50	500	500

Supply of safer tap water by Zvishavane town council municipality is erratic forcing consumers to rely on borehole water sources. If the Zimbabwe National Census Statistics of 2012 (much higher now, population growth rate was estimated to be 1%) of 45 230 people in Zvishavane town are considered, then the condition of hypertension is claiming 23.3% of the population.

Maximum permissible limits for nitrate in drinking water is 50 mg/l (WHO, 2003; SAZS 560:1997). Although there was a huge variation in nitrate concentration from one sampling episode to another, the averages indicated in Table 4 still generally depict the relative differences from one source to another. The Zvishavane tap water sources all reported nitrate levels within recommended limits by SAZS: 560:1997 (average of 2.32 mg/L September 2018; 2.24mg/L November 2018 and 0.04 mg/L January 2019). However, high nitrate values were reported at 26.31% of the borehole water samples (Nil; Manjere swift borehole, Makwasha, Sabi Vlei, and Ngomeyebani) during the sampling period (Table 4). Nil borehole supports 100+ households composed of laid off

workers of the previously Shabani asbestos mine making a poor community. The rest of the boreholes had nitrate levels below 50 mg/L.

Makwasha borehole is used by two communities of Makwasha and Mandava high density suburbs supplying approximately 50 households with drinking water. Reports from verbal interviews at Swift borehole state that the borehole was sunk on an area which used to a cattle pan, thereby explaining the possible source of nitrate as Considering that there were 66 neonatal deaths in 2018 at the hospital (Zimbabwe Health Information System, 2018), there is need for an epidemiological study to establish if there is a link between any deaths that the hospital experienced and water quality that was used for drinking by the pregnant mothers. Reports from previous research indicated that maternal drinking water nitrate intake during pregnancy could cause a range of pregnancy outcomes, including spontaneous abortion, foetal deaths, prematurity, intrauterine growth retardation, low birth weight, congenital malformations, and neonatal deaths Ward et al., (2018). Levels above 50 mg/L of NO₃⁻ in water

exposed infants to have been reported before to cause methaemoglobinaemia (leading to blue baby syndrome), thyroid effects and gastric cancer in adults Ward et al., (2018). Only one borehole reported above the recommended limit 258.8 mg/L during the month of July at Manjere MSU borehole (Table 4). Most water sources had chloride levels were within the SAZS 560:1997 recommended limits of 200 mg/L with 24.6% of samples above this limit and 0.04% reporting above the maximum allowable limits of 500 mg/L.

Conclusion: There is a possible link between the quality of water and the reported disease patterns. The findings of the study recommend that due to the high incidence of hypertension reported by the district hospital, observations require epidemiological studies to investigate if high sodium ion levels in some borehole water samples are linked to any hypertension cases. Zvishavane drinking water needs further treatment before drinking especially the open well source.

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