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Urban Services Delivery in Limbo: A Provisional Assessment of Gweru's Water Supply System

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Abstract: This study sought to assess Gweru's water supply system from the source to the consumer to find out whether the water is safe for domestic purposes, mainly consumption. Water samples were taken from Gwenoro dam (raw water), Gwenoro treatment plant (treated water) as well as from GIS-generated random points of residential areas closest to Gwenoro and furthest from both the dam and the treatment plant. These were taken for laboratory testing where parameters like pH, hardness, turbidity and DO (dissolved oxygen) were tested. Questionnaires were used to solicit the views of the consumers on water quality and water service delivery from eight randomly selected residential suburbs. Interviews were also administered to Gwenoro Water Treatment Plant superintendent and deputy to get insight into the day to day challenges that they have to grapple with. Results generally show that treated water from Gwenoro treatment plant is relatively safe to drink for those who have access to it. However, some consumer points like Mkoba 13 and Mkoba 18 receive water whose DO is out of the recommended range. Suburbs which lie on higher ground like Mkoba 19 and Mkoba 14 however rarely receive water from Gwenoro with some residents of Mkoba 19 having had no water from their taps for more than three years now. The study recommends that new equipment be bought for the treatment plant so that treated water reaches all parts of the city. Newly resettled farmers in the Upper Runde Catchment must be resettled elsewhere while urban stream bank cultivation must be banned to reduce water pollution as well as possible sedimentation of Gwenoro dam.

Key words: Gwenoro dam, pH, turbidity, dissolved oxygen, water hardness, water quality, water service delivery.

1. Introduction

The quality of water supply in the SADC (southern Africa development community) region, once taken for granted, is increasing becoming the focus of concern. Both natural and anthropogenic factors now impair water quality in the region and water pollution from point and non-point sources is the principal factor that impairs water quality [1]. The main point sources are the untreated or partially treated effluents from municipal, industrial and mining wastewater discharges. Non-point sources of pollution include runoff from small-scale mining operations, urban storm water and runoff from agricultural, livestock and poultry operations.

In southern Africa, human waste in urban areas is mainly disposed of using pour flush latrines. This method generates large quantities of domestic waste water. Untreated sewage which was disposed in aquatic systems causes depletion of DO （dissolved oxygen) due to oxidation of organic matter, increases nutrients such as nitrogen and phosphorous and results in faecal contamination [2].

Existing waste water treatment facilities in many southern African countries are overloaded [2-4]. Most of them are facing serious challenges in handling the ever-increasing volumes of wastewater generated by an increasing urban population. In Zimbabwe, for example, many sewage treatment works are old, poorly maintained and constantly breaking down. In Gweru, raw sewage from suburbs like South Downs, Ivene and Lundi Park is flowing through the Runde Catchment and straight into Gwenoro dam where there is an out-dated water purifying system that Gweru city Council is failing to refurbish [5]. In early 2010, the

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EMA (Environmental Management Agency) discovered that raw sewer was escaping from a failed pipe near Athlone residential suburb and finding its way into Gweru River which is an indispensable water source for many unsuspecting rural communities in Lower Gweru communal lands downstream. According to EMA, however, it is an offence to dispose of waste or effluent into a public stream or into any other surface water or ground water, whether directly or through drainage or seepage, except under a licence [6].

Most of the water and sewage treatment equipment in Zimbabwe was bought from Western countries which have since imposed economic sanctions on the country making it impossible for municipalities to acquire new equipment or even spare parts from the same sources. Poor management and disposal of sewage may cause water-based and excreta-related infections such as cholera, dysentery, typhoid, paratyphoid fever and diarrhoea [1]. In fact, cholera accounted for more than 1,000 people in Zimbabwe in 2008 and Gweru was not spared.

Although industrial sources of pollution in southern Africa are relatively minor compared with those in developed countries, the absence of adequate enforceable discharge standards and lack of monitoring makes the task of controlling industrial pollution difficult [7]. In many countries, highly toxic industrial waste and chemical liquid waste are discharged into municipal sewage systems or directly into rivers without adequate treatment. In Zimbabwe, the capital city Harare and the country's second largest urban settlement, Chitungwiza both sit on their own catchment. Their street run-off containing excess nutrients such as nitrogen and phosphorous wash into both towns main source of water, Lake Chivero and this has largely contributed to severe eutrophication levels in the lake.

While industries and domestic sewage waste are the main sources of pollution in developed countries, agriculture plays a relatively bigger role in developing countries due to clearing of land, the use of inorganic fertilizers, pesticides and irrigation. Extensive farming within the river catchment areas has resulted in gully erosion and rapid siltation of reservoirs and rivers in southern Africa [4-8]. Soil erosion leads to an increase in suspensoids which contribute to turbidity. High levels of turbidity in domestic water supply sources make water treatment difficult and expensive

In recent years deforestation has become widespread especially in Zimbabwe following the FTLRP (fast-track land reform programme). In Gweru district, for example, new farmers have been resettled in the Runde catchment upstream of Gwenoro dam where they cleared large portions of land both for settlement and farming. A new wave of urban agriculture necessitated by a nationwide economic meltdown between 2000 and 2009 has also seen residents in Lundi Park, South Downs, Ivene and South View all engaged in serious agricultural activities with some using inorganic fertilizers like ammonium nitrate. This, coupled with the dysfunctional sewage system in South Downs has led to a lot of raw sewage being directed into Runde River and into Gwenoro dam. This paper therefore assesses Gweru's potable water supply system and its resilience in the face of the country's ailing economy and dysfunctional infrastructure.

According to Ref. [9], water quality refers to the physical, chemical and biological characteristics of water. It includes a set of standards against which compliance measures can be measured. Parameters for drinking water quality fall under two categories namely chemical (or physical) and microbiological [10]. Chemical parameters include trace organic compounds, total suspended solids and turbidity while microbiological parameters include coliform bacteria *E. coli* and specific pathogenic species of bacteria-like vibrio-cholera causing cholera, viruses and protozoa parasites.

Water quality parameters and drinking water standards were designed to set a world standard for drinking water [11, 12]. The World Health

Organization also set up some guidelines for drinking water quality, which are internationally referred points for standards setting and drinking water safety. It is against these standards that national systems set their own local water quality standards. Testing water is important because when parameters are not within normal range, this can cause health problems to human beings. According to Gilbert [13] water purification is essential for filters water thus reducing the rate of morbidity and mortality emanating from contaminated water.

1.1 Rationale for Selecting pH, Hardness, Turbidity and Dissolved Oxygen

It is important to state here that these parameters were chosen mainly because of their importance in the determination of water quality but also because these are the ones the researcher had the capacity to test since the research was self-sponsored.

1.2 pH

pH refers to potential hydrogen in water. It is important to test for pH because all water treatment processes are pH dependent. pH is also important to test because a strong base and a strong acid both have equal effects. When pH is above 7, water would be alkaline (or base) and when it is below 7, it would be acidic. According to the Standards Association of Zimbabwe [14], pH has to be maintained at recommended minimum limit of 6.5 (minimum) to 8.5 (maximum) and allowable limits of 6.0 (minimum) to 9.0 (maximum).

1.3 Hardness

Water hardness refers to the amount of calcium, magnesium and other minerals in a water sample. The required standard for total hardness ($CaCO_3$) is 50 mg/L (desirable) to 100 mg/L (maximum). There is temporary and permanent hardness. Hardness forms scales, which is white staff that causes a variety of problems in pipes. If scaling occurs within the pipe the diameter of the pipe reduces, resulting in blasting or it may cause a barrier in water-boiling tins at home, steam raising plants or boilers. If scaling occurs in boilers, they may choke. Hard water can cause laundering and washing problems because magnesium and calcium ions will react with soap instead of water. Conversely, soft water can cause corrosion in pipes. Drinking water treatment plants attempt to maintain a desirable balance between hardness and softness by adding minerals to soft water and removing them from hard water with attach titration procedure based on the USEPA approved method. To remove permanent hardness, lime can be used and to remove temporary hardness, water is boiled.

1.4 Turbidity

Turbidity refers to the concentration of undissolved, suspended particles present in a liquid (water) [15, 16]. It is not a direct measure of those particles but rather a measure of how these particles scatter light. It is measured in NTU (nephelometric turbidity units). Water with cloudy or opaque appearance will have high turbidity while water which is clear or translucent will have low turbidity. High turbidity value is caused by particles such as silt, clay, microorganisms, organic matter, algae growth, phytoplankton and urban runoff. According to the guideline in Ref. [17], turbidity should be 5 NTU (desirable) to 10 NTU (maximum). Turbidity is important because water without turbidity is difficult to treat as the chemicals need some nitrates to react with.

1.5 Dissolved Oxygen

DO (dissolved oxygen) refers to the amount of dissolved oxygen in water. This is important because it supports all forms of life from flora to fauna. The shortage of dissolved oxygen in water poses a threat to higher forms of aquatic life that depend on DO in order to survive.

2. Description of the Study Area

The study area stretches from Gwenoro dam in Shurugwi district to the city of Gweru in Gweru district (Fig. 1). Gwenoro dam lies some 45 km south of Gweru city about 12 km off Gweru-Shurugwi road due south. It is surrounded by farms such as Fig tree, Gwenoro and Montgomery. It is along Runde River. The dam is in the Runde catchment which stretches south-west from Gweru to Ngundu. Runde catchment comprises areas drained by Runde, Tokwe, Mutirikwi and Chiredzi rivers which finally drain into Limpopo River. Gwenoro dam was officially opened in 1958. Its capacity is 4,200 mega litres and its depth is 78 m. The dam supplies potable water to most of Gweru's high density areas including Mkoba, Senga, Mtapa and low density areas like Lundi Park, Kopje, South View, and South Downs among others.

The city of Gweru is Zimbabwe's fourth largest urban settlement in terms of population size although it is the country's third largest city. It is located at 19°25′ and lies about 285 km south of the capital Harare. According to the 2002 national census [18], Gweru had a population of 140,806 the bulk of which was concentrated in the city's high density suburbs of Mkoba which has 19 separate residential suburbs (or villages). Other high density suburbs include Ascot, Senga Mtapa, and Nehosho among others. Examples of middle to low density suburbs in Gweru are Lundi Park, Kopje, Athlone, River Side, Daylesford, Ridgemond, South Downs and South View. Most of these suburbs receive potable water from Gwenoro dam. The other supplier dam, Whitewaters, situated about 13 km along Mvuma Road from Gweru and with a capacity of 33 mega litres supplies mainly the north-eastern part of the city which includes Hwahwa prison, Thornhill Airbase and Anderson High School among others.

Main soils in Gweru are black basaltic soils, red loams sands and gravel. The city lies on Zimbabwe's central watershed which stretches from Rusape, through Harare to Bulawayo. Gweru is at an altitude of about 1,422 m above sea level.

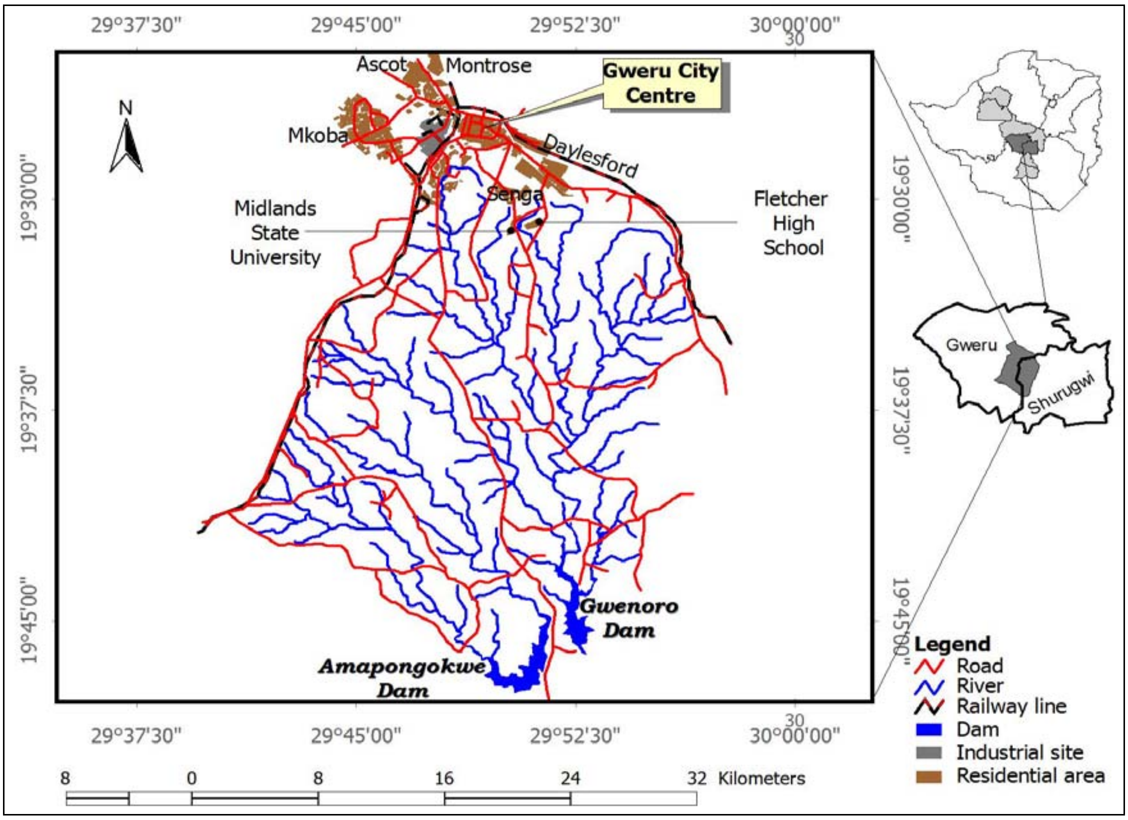

Fig. 1 Location of Gwenoro dam in relation to Gweru City.

3. Materials and Methods

Water samples were collected from Gwenoro dam, Amapongokwe dam, Gwenoro water treatment plant (treated water) as well as from GIS randomly selected consumption points which included Mtapa, Mkoba 17, Mkoba 11, Mkoba 13, Mkoba 18 and Senga high density suburbs. (Mkoba suburbs alone house over 60% of Gweru's current population estimated at about 180,000). The samples were collected on August 26, 2010. Amapongokwe dam water was only collected to compare it with Gwenoro water and find out whether it could be a better option to Gwenoro water. Although sometimes Amapongokwe water is also treated and pumped to Gweru, during the time of the research this was not being done due to inadequate treatment and pumping capacity at the plant.

120 questionnaires were randomly distributed within the six residential suburbs which constituted the subject of this study with 20 questionnaires per suburb being answered by household representatives who were at least 18 years old (national age of maturity). An additional 20 respondents were selected from Mkoba 14 and another 20 from Mkoba 19, suburbs which hardly receive piped water from the municipal water reticulation system. Thus a total of 160 questionnaires were administered. All questionnaires were answered and returned since all of them were administered as questionnaire interviews with the help of research assistants. The Water Treatment Plant superintendent and deputy at Gwenoro were also interviewed to get insight into the day to day challenges that they encounter in their duties.

3.1 Procedure for Collecting Samples

An integrated method was used to collect the samples. This is whereby samples for trend observation are collected each with its own analyses. Samples were collected from source dams (Gwenoro and Amapongokwe raw) to consumer points closest to Gwenoro treatment plant (Gwenoro treated) then to those consumer points which lie furthest from the treatment plant (Mkoba 13 and Mkoba 18). Other possible consumer points like Mkoba 14 and Mkoba 19 have gone for more than four years without a reliable supply of tap water and hence no samples could be collected there. Questionnaires were however administered in these two suburbs to get the residents views concerning the city's water services delivery system. Glass bottles were auto-cleaved and sterilised before taking samples. For raw water samples from Gwenoro and Amapongokwe dams, the glass bottles were opened and rinsed three times with water to remove impurities. The samples were collected about four meters from the dam wall to avoid the effect of tryhalogenes. These samples were labelled Gwenoro raw and Amapongokwe respectively. Sample 3 (Gwenoro treated) was collected using the same procedure whereby the bottle was opened and rinsed 3 times with water to remove impurities and then the sample was collected from the filtering tank. Water from consumption points were collected (using the same procedure) on September 3, 2010 between 600 hours and 700 hours. All the samples were stored in a cool dry place before testing to maintain temperature.

3.1.1 Testing for pH

For all samples, water was de-ionized by a de-ionizer which has an anode and a cathode. OH^- ions were collected on the cathode which is negatively charged while H^+ ions were collected on the anode which is positively charged. This left the water pure or de-ionized. The pH meter was connected to electricity for current to flow with an electrode connected to it. 100 mL of de-ionized water was measured in a test tube and poured in a glass beaker. Each 100 mL was mixed with buffer tablets each with buffer pH = 4 and the other with buffer pH = 7. The mixture was stirred until the buffer dissolved. Buffer tablets maintain pH at an undiffused state or maintain pH at a neutral zone. 100 mL of water samples for Gwenoro (raw), Amapongokwe (raw), and Gwenoro treated, Mtapa, Senga Mkoba 11, Mkoba 13, Mkoba 17 and Mkoba 18 were measured. An electrode was dipped in samples of buffer 4 first and rinsed with de-ionized water to remove impurities. It was then dipped in different water samples for trend observations. After dipping the electrode in one water sample, it was rinsed with de-ionised water to remove impurities before dipping in another sample. Temperature was maintained at 25 ^{o}C and all the readings were taken from the reading screen on the pH meter.

3.1.2 Testing for Water Hardness

100 mL for each water sample was measured and 2 mL of ammonia buffer was added using bulb pipette filler. The indicator ariochrome black T was added and titrated against ethlyn diamine tetra-acetic acid (EDTA). Calcium carbonate was used to standardize EDTA. Ammonia buffer was used to raise pH to around 10, which is favoured by the reaction or because it is within the reaction level and it easily titrates against EDTA. A burette was used to pour EDTA to the sample of 100 mL.

3.1.3 Testing for Turbidity

The stored program number for turbidity was entered in the spectrophotometer DR 2010. A cuvert was used to pour the samples. The wave length dial was rotated until the small display showed. 25 mL of de-ionized water was then poured into a cell holder and the light shield was closed. Zero was pressed and the display showed zero. 25 mL of the sample was poured into another cell and the sample cell was immediately placed into the cell holder and the light shield closed. READ was pressed and the results were displayed in nephelometric turbidity units (NTU).

3.1.4 Measuring Dissolved Oxygen

Water samples were poured into the glass beakers until water reached the neck of the bottle. This was done to reduce the amount of atmospheric oxygen entering the bottle. A sample dispenser was used to reduce oxygen entering the bottle. Bulb pipette filler was used to fill the pipette. To avoid contamination, the pipette was not mixed with different chemicals. 1 mL of alkaline iodide and 1 mL of manganese chloride were used to test for DO. Manganese is an oxidising agent while alkaline iodide contains sodium hydroxide. Sodium has a higher pH which facilitates manganese reaction. Concentrated sulphuric acid was added to change the condition of samples from base to acid in order to turn the precipitate into a rectable compound. The precipitate changed to iodine colour. Iodine liberated was equal to the amount of oxygen which was trapped. To measure oxygen, the solution was mixed with sodium thiosulphate. To remove iodine, sodium thiosulphate was then added into a burette to do titration. Finally, volumetric analysis was done so as not to exceed the end point.

4. Results and Discussion

Treated (or purified) water is normally pumped from Gwenoro and stored in large storage tanks at Kopje hills. From there it is then distributed to different consumption points (including residential suburbs) by the gravity method. However, because of the economic hardships the country has been experiencing since 2000, Gwenoro treatment plant has been operating far below capacity due to equipment failure and power shortage. Currently no water is stored at the storage tanks anymore. In an interview, the Gwenoro Water Treatment Plant superintendent revealed that water is currently pumped directly to residents from Gwenoro water treatment plant due to serious national power shortages which lead to daily load shedding lasting 8 hours on average. Water pumping from Gwenoro is dependent on the availability of electricity. As a result, no place in Gweru boasts of 24 hours of continuous supply of water. Most of the areas which receive water normally get it between 9 pm and 5 am when there is electricity. The pumps at Gwenoro are however not powerful enough to pump water to all areas. This has resulted in high altitude suburbs like Mkoba 14 and Mkoba 19 not receiving adequate water. Questionnaire responses from Mkoba 19 residents revealed that some parts of Mkoba 19 have not received tap water in their homes for more than three years. Those who received water complained that water from their taps is sometimes muddy and visibly not ideal for human consumption.

The pH levels of raw water from Gwenoro dam, Gwenoro treated, Amapongokwe, and water from the different consumption points in Gweru suburbs (Table 1) show that there are within the recommended limits as laid down by the Standards Association of Zimbabwe (SAZ, 560) [14] which states that pH has to be maintained at recommended limits of 6.5 (minimum) to 8.5 (maximum) limit and allowable limits of 6.0 (minimum) to 9.0 (maximum).

The results obtained for total hardness from all samples generally reveal that drinking water supplied by Gweru City Council is within the required limits by World Health Organization [17] that is 50 mg/L (desirable) to 100 mg/L (maximum). Although Amapongokwe raw and Gwenoro raw are above 100 mg/L and hence hard, this situation seems taken care of at treatment as evidenced by the compliant figures at all consumer points (Table 2). However, given the archaic state of equipment at Gwenoro plant and the inherent intermittent break-down of the same, it is possible that raw water may sometimes be piped directly to residents. In responses to questionnaires consumers suspected this as the water from their taps is sometimes muddy. At the time of this research for example, Mkoba 17 residents complained of diarrhoea which they suspected was a result of dirty water from their taps. This was confirmed by Mkoba polyclinic nursing staff.

Results for turbidity show that raw water from dams is highly turbid as figures from both Gwenoro dam (15 NTU) and Amapongokwe dam (17 NTU) are way beyond the WHO drinking water quality guidelines which state that turbidity should be 5 NTU (desirable) to 10 NTU (maximum) (Table 3). However, Gwenoro treated water and water from all consumption points meet the standards for turbidity levels and are therefore safe to drink, but this is only on condition that the equipment at Gwenoro is working well and that no raw water is pumped to the city. The high turbidity levels at both Gwenoro and Amapongokwe are attributable

Table 1 pH results.

Sample number	Sample name	pH at 25 degrees Celsius
1	Gwenoro raw water	7.4
2	Gwenoro treated	7.3
3	Amapongokwe raw water	7.8
4	Mkoba 17	8.4
5	Mkoba 11	8.4
6	Mkoba 18	7.6
7	Mkoba 13	7.9
8	Mtapa	7.8
9	Senga	7.7

Table 2 Water hardness.

Sample number	Sample name	Hardness (mg/L)
1	Gwenoro raw	108
2	Gwenoro treated	80
3	Amapongokwe raw	112
4	Mkoba 17	64
5	Mkoba 11	60
6	Mkoba 18	41
7	Mkoba 13	41
8	Mtapa	60
9	Senga	60

Table 3 Turbidity.

Sample number	Sample name	Turbidity (NTU)
1	Gwenoro raw	15
2	Gwenoro treated	6.6
3	Amapongokwe raw	17
4	Mkoba 17	5.7
5	Mkoba 11	8
6	Mkoba 18	7
7	Mkoba 13	6.9
8	Mtapa	7.7
9	Senga	7.5

in part to boat-assisted fishing activities as well as farming activities in the catchment areas of both dams.

Results for DO fluctuate significantly from one point of consumption to another (Table 4). Notwithstanding, they generally fall within the specified range which is 5.5 mg/L to 10 mg/L according to Ref. [14]. Mkoba 18 and Mkoba 13 figures are however below this range. This may be due to the fact that there are prolonged periods of piped water absence (sometimes several days) and hence the collected samples may have settled in pipes for quite long resulting in the available oxygen being used up by microorganisms.

4.1 Consumers Views on Water Quality and Water Delivery System

The majority (at least 60% for each suburb) of the residents in all sampled suburbs described water quality from Gwenoro Water Treatment Plant as poor (Table 5). They reported that water from their taps, if it is available, is usually muddy or has a reddish-brown colour and an unpleasant smell. Gwenoro plant superintendent conceded that these anomalies could be because of archaic pipes which were laid during the colonial period before independence in 1980 and hence were worn out and needed to be replaced. The reddish-brown colour and smell can be attributed to rusting pipes or to the iron-rich terrain under which the pipes traverse from Gwenoro to Gweru. Mkoba 14 and Mkoba 19 could not answer questions pertaining to water quality since they hardly receive any tap water but scramble on the few donor-supplied boreholes and open wells in their localities. Since these boreholes work 24 hours each day, they frequently break down exacerbating the water problem. They use any open spaces and houses under construction as toilets. These residents, however, complained that the municipality insist that they pay water service charges for a service they rarely get.

Residents voiced concern about the city's water delivery system with at least 70% of them qualifying it as poor (Table 5). This is mainly because the pumping system at Gwenoro Water Treatment Plant is dependent on the availability of electricity provided by the national grid which is unpredictable, unreliable and

Table 4 Dissolved oxygen.

Sample number	Sample name	DO (mg/L)
1	Gwenoro raw	8
2	Gwenoro treated	7
3	Amapongokwe raw	8.2
4	Mkoba 17	5.8
5	Mkoba 11	8.2
6	Mkoba 18	1.7
7	Mkoba 13	1.8
8	Mtapa	6.6
9	Senga	8.2

Table 5 Consumers views on water quality and water delivery system, *N* = 160.

Area	No. of respondents	Views on water quality						Views on water service delivery					
		Good	%	moderate	%	Poor	%	Good	%	moderate	%	Poor	%
Senga	20	0	0	7	35	13	65	0	0	6	30	14	70
Mtapa	20	0	0	8	40	12	60	0	0	6	30	14	70
Mkoba 17	20	0	0	8	40	12	60	0	0	5	25	15	75
Mkoba 11	20	0	0	8	40	12	60	0	0	6	30	14	70
Mkoba 13	20	0	0	6	30	14	70	0	0	3	15	17	85
Mkoba 18	20	0	0	5	25	15	75	0	0	2	10	18	90
Mkoba 14	-	-	-	-	-	-	-	0	0	0	0	20	100
Mkoba 19	-	-	-	-	-	-	-	0	0	0	0	20	100

grossly inadequate. Most parts of the country can go for days without power and this translates into the same number of days without water supply for city residents. All residents of Mkoba 14 (100%) and Mkoba 19 (100%) revealed that there is virtually no water service delivery in their suburbs. This was confirmed by both Gwenoro and water treatment superintendent and deputy who conceded that their pumps are not capable of pumping water to all areas of the city. High altitude and elevated areas like Mkoba 14 and Mkoba 19 therefore suffer from this technical inadequacy. They also explained that since water treatment, purification and pumping depend on electricity which itself is erratic and unreliable, they can no longer afford to first pump the water into the reservoir tanks at Kopje but instead pump whatever water they treat and purify direct to residents. This benefits mainly low-lying areas like Mkoba 17 and areas closer to the water treatment plant, for example Mkoba 11 and Senga, hence these areas have more water hours.

5. Conclusion

The study revealed that water from Gweru's major potable water supplier dam, Gwenoro is generally safe to drink judging from the results of the four parameters selected for the study. However, although both turbidity and hardness at consumer points fall within the recommended ranges, raw water at Gwenoro is too hard and too turbid to be safe for both human consumption and equipment sustainability. This is of concern given the archaic nature of the water treatment plant's equipment which periodically breaks down and is hardly maintained because of the economic hardships obtaining in the country. As a result, in times of crises, raw water is pumped directly to consumers and these are times when consumers are exposed to possible infections and diseases from untreated water. Consumer points or suburbs which sometimes do not receive water, for example, Mkoba 13 and Mkoba 18 have samples whose dissolved oxygen fall way below both international and national standards. This is unhealthy as it threatens life given that dissolved oxygen supports all forms of life from flora to fauna. It also makes the achievement of the Millennium Development Goals by 2015 unrealistic for Zimbabwe and Gweru in particular, especially goal number six which endeavours to combat all forms of diseases by then.

In light of the findings from this study, it is recommended that:

Newly resettled farmers in the upper catchment of Gwenoro dam (along Runde River) should be relocated by government to areas away from the dam's catchment to avoid possible chances of eutrophication from nitrates.

Stream bank urban farming in suburbs like Lundi Park, Ivene, South Downs and South View which sit on the Runde Catchment should be banned to reduce both sedimentation and soil poisoning from chemicals. The City Council can achieve this with the help of the EMA (Environmental Management Agency).

The dysfunctional South Downs sewer treatment pump which pours raw sewage into Gwenoro dam via Runde River should be repaired as a matter of urgency by the City Council to reduce dam water pollution which may increase costs of water purification at the plant. Heavily polluted water is expensive to treat and purify.

The City Council must also form a partnership with reputable and qualified engineers in order to renovate the water treatment plant equipment which is always failing. In this regard government should avail some of the money from the diamond fields of Marange to urban councils so that they address this very important human service of safe and clean water provision to their residents. All urban areas in Zimbabwe currently have water and sanitation problems.

The ZESA (Zimbabwe Electricity Authority) must also solve electricity problems to enable the City Council to pump adequate water for all citizens including high-altitude suburbs like Mkoba villages 14 and 19 which have not received a reliable supply of treated water for more than three years now.

References

[1] Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa, SARDC, Harare, 2002.

[2] Water in Southern Africa, SARDC, Harare, 1994.

[3] M. Chenje, L. Sola, D. Paleczny, The State of Zimbabwe's Environment, Government of Zimbabwe, Harare, 1998.

[4] M. Chenje, P. Johnson, State of The Environment in Southern Africa, SARDC, Harare, 1996.

[5] The Times, Gweru Water Contaminated With Raw Sewer, Community Newspapers Group, Gweru, Nov. 12-18, 2010.

[6] Statutory Instrument 6 of 2007: Environmental Management (Effluent and Solid Waste Disposal) Regulations, Environmental Management Agency, Government Printers, Gweru, 2007.

[7] N. Moyo, S. Mtetwa, Water quality management and pollution control, in: Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa, Harare, 2002, pp. 135-176.

[8] J.R. Whitlow, An assessment of cultivated lands in Zimbabwe, 1963-1977, The Zimbabwe Science News 13 (12) (1979) 286-290.

[9] Guideline on Potable Water and Sustainable Resource Management, WHO, Geneva, 2006.

[10] S. Lerson, P. Carpel, International Public Health, Aspen Publications, New York, 2001.

[11] Guidelines for Drinking Water Quality, WHO, Geneva, 2002.

[12] Acceptable Water Parameters, WHO, Geneva, 2007.

[13] M. Gilbert, Introduction to Environmental Engineering, Prentice Hall, London, 1998.

[14] Standards Association of Zimbabwe Water for Domestic Supplies, Longman, Harare, 1997.

[15] Centre for Affordable Water and Sanitation Technology Safe Water System, Cleveland Clinic, New York, 1998.

[16] Safe Drinking Water: A Statistical Review, United Nations Children's Fund, New York, 2004.

[17] World Health Organization Drinking Water Guidelines, WHO, Geneva, 1998.

[18] Central Statistical Office Census Provincial Profile: Midlands, CSO, Harare, 2002.