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EVALUATION OF THE DRINKING WATER SUPPLY AT FAIRVIEW HOTEL: LUSAKA

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1. Background

The Environmental Engineering section at the University of Zambia (UNZA) offers drinking water quality monitoring services to clients within and outside Lusaka. Fairview Hotel is one of its clients. The hotel usually uses groundwater for its water supply. However, the hotel can also get supplied from a Lusaka Water and Sewerage company (LWSC) connection in the event of the borehole becoming malfunction. The main source of raw water for LWSC is surface water (the Kafue River) which goes through extensive treatment processes before finally being fit for human consumption.

In water treatment, groundwater is usually of better quality because of its protected nature and therefore its treatment is usually less complex and costly. In most cases, groundwater may even be fit for direct human consumption. Where possible contamination from refuse dumping, pit-latrines, septic tanks or any known source is anticipated, treatment especially by disinfection is often necessary to render contaminated groundwater fit for drinking or just to safeguard against unknown sources of contamination.

Faecal contamination of water can easily be detected by analysing the presence of micro-organisms called ***Faecal Coliforms*(FC)**. The presence of these organisms is an obvious indicator of recent faecal contamination. The World Health Organisation (WHO) water quality standards state that there should be no FC per 100 ml of drinking water.

2. Rationale

Fairview Hotel is a regular client of the Environmental Engineering laboratory at UNZA. The laboratory has been analysing water samples from Fairview Hotel for several years. Results of theses analyses have for some time shown that water from the borehole at the hotel is potable. Unfortunately in November, 1997, analysis results of the water from the borehole at the hotel showed that the level of faecal contamination was not acceptable compared to the WHO drinking water quality standards. FC were too numerous to be counted (TNTC) for the water samples taken from the MAIN and TRAINING Kitchens. Other water samples showed thousands of faecal coliforms per 100 ml: Room 10 ⇒ 54000 FC/100 ml, overhead tank ⇒ 8100 FC/100 ml and borehole ⇒ 38600 FC/100 ml. These results clearly showed that the water was recently contaminated with faecal matter and was not fit for human consumption. It was from these results that a proposal for the evaluation of the drinking water supply at Fairview Hotel was agreed upon with the hotel management. During the time of the evaluation, the hotel management was advised to use water from the LWSC supply which is potable.

3. Objectives

The objectives were two fold:

(1) to investigate the state of the water supply at Fairview Hotel: quality of water from existing borehole and LWSC, state of the storage tanks, borehole and pipe network, and the sewerage facilities within and around the hotel.

(2) to come up with appropriate conclusions and recommendations on how to ensure potable water supply at Fairview Hotel.

4. Methodology

The existing water supply facilities at Fairview Hotel were inspected. The sewerage facilities of the hotel and surrounding areas were also inspected.

Daily water use was monitored through a LWSC water meter since during the time of the evaluation the hotel was supplied by LWSC.

Water samples were collected from the borehole for physical, chemical and bacteriological analysis. It was agreed that the borehole pump should operate as it did when it was used to supply the hotel during normal operations. This was necessary so that a real situation of the borehole pump operation was investigated. However, the borehole was only run for about 15 to 20 minutes before sampling due to the fact that it could not be connected to the power source at the same time with another pump delivering water to the overhead tanks. This short running of the borehole, before sampling, was assumed to discharge stagnant water within and outside the rising main of the borehole (the pipe through which groundwater is delivered from the ground). However, it was later made possible to connect the borehole pump separately and run it for at least 12 hours per day and the last two samples were collected.

Possible suppliers of disinfection equipment were also sort using the INTERNET system, both locally and regionally.

5. Results

5.1. Water sources

Currently, the hotel is supplied either by LWSC or from a borehole within the hotel premises. The borehole belongs to the hotel.

(a) <u>Lusaka Water and Sewerage Company supply</u>

LWSC supplies drinking water to Fairview Hotel through a two inch (2") galvanised iron pipe. There is a LWSC water meter within the premises of the hotel for monitoring water consumption. The meter is well protected and easily accessible for taking readings.

Water meter readings were monitored with the help of the maintenance superintendent at the hotel. The meter was read everyday at the same time to establish daily water consumption by the hotel. Results of the meter readings are tabulated in Table 5-1. The subsequent water consumption pattern is shown in Figure 5-1.

Table 5-1: LWSC water supply to Fairview Hotel

Date	water meter reading (m^3)	Volume of water supplied (m^3)	Date	water meter reading (m^3)	Volume of water supplied (m^3)	Date	water meter reading (m^3)	Volume of water supplied (m^3)
09-Dec-97	188982		29-Dec-97	190991	91	18-Jan-98	193050	97
10-Dec-97	189084	102	30-Dec-97	191085	94	19-Jan-98	193158	108
11-Dec-97	189194	110	31-Dec-97	191180	95	20-Jan-98	193252	94
12-Dec-97	189291	97	01-Jan-98	191271	91	21-Jan-98	193364	112
13-Dec-97	189393	102	02-Jan-98	191371	100	22-Jan-98	193459	95
14-Dec-97	189489	96	03-Jan-98	191460	89	23-Jan-98	193560	101
15-Dec-97	189585	96	04-Jan-98	191577	117	24-Jan-98	193663	103
16-Dec-97	189676	91	05-Jan-98	191673	96	25-Jan-98	193759	96
17-Dec-97	189764	88	06-Jan-98	191778	105	26-Jan-98	193885	126
18-Dec-97	189867	103	07-Jan-98	191884	106	27-Jan-98	193977	92
19-Dec-97	189970	103	08-Jan-98	191987	103	28-Jan-98	194052	75
20-Dec-97	190060	90	09-Jan-98	192094	107	29-Jan-98	194154	102
21-Dec-97	190177	117	10-Jan-98	192199	105	30-Jan-98	194263	109
22-Dec-97	190272	95	11-Jan-98	192301	102	31-Jan-98	194355	92
23-Dec-97	190367	95	12-Jan-98	192402	101	01-Feb-98	194483	128
24-Dec-97	190468	101	13-Jan-98	192506	104	02-Feb-98	194589	106
25-Dec-97	190566	98	14-Jan-98	192614	108	03-Feb-98	194686	97
26-Dec-97	190672	106	15-Jan-98	192727	113	04-Feb-98	194794	108
27-Dec-97	190785	113	16-Jan-98	192850	123	05-Feb-98	194896	102
28-Dec-97	190900	115	17-Jan-98	192953	103	06-Feb-98		

AVERAGE CONSUMPTION PER DAY = 102 m^3 (102 000 litres)

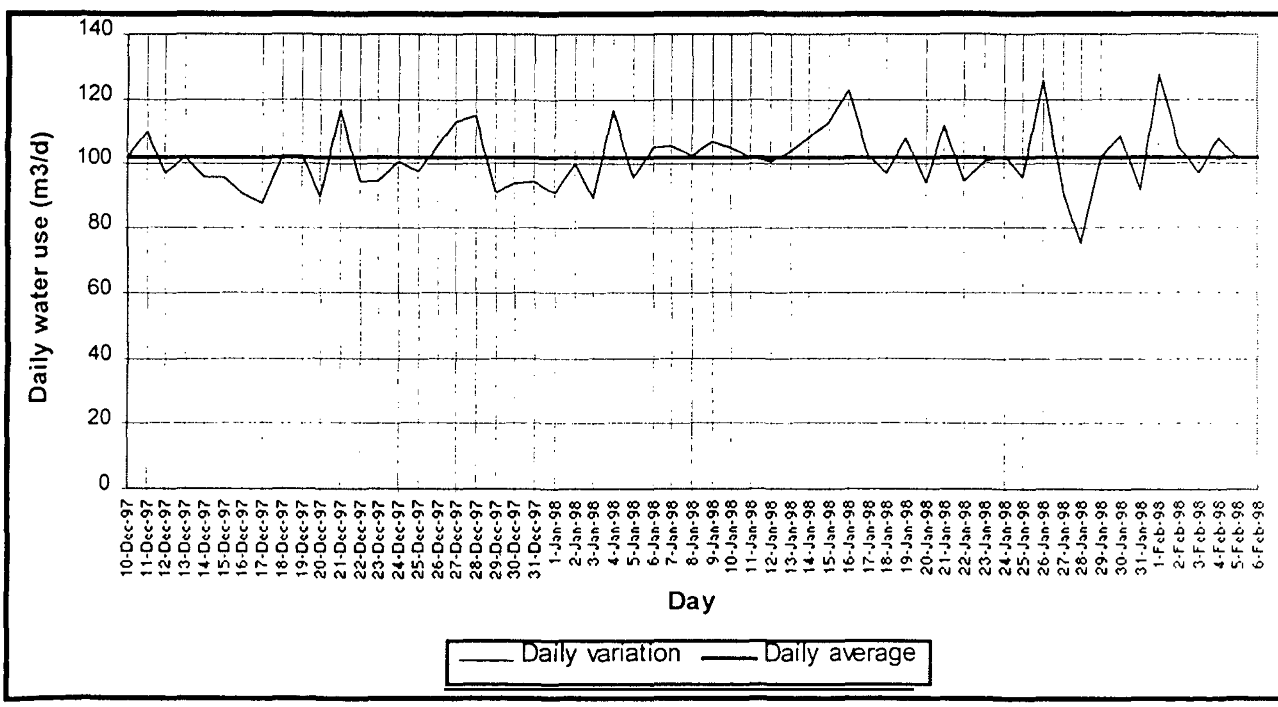


Figure 5-1: Daily LWSC water use pattern at Fairview Hotel

The daily water use shown in Table 5-1 revealed a daily average water use at the hotel of about 102 m^3 (Figure 5-1). The daily consumption variation about the average is 9.5 %.

- **Cost of LWSC water**

LWSC water tariffs are based on monthly water consumption figures. For commercial and industrial consumers, under which Fairview Hotel falls, the progressive tariffs are as tabulated in Table 5-2.

Table 5-2: Monthly LWSC water charges for Commercial & industrial consumers

Description	Cost (K)
(1) Standing charge for metered supplies	10000
(2) 0-100 000 litres per 1000 Litres	470 (590)*
(3) 100 001 - 170 000 litres per 1000 litres	750 (1100)*
(4) 170 000 litres and over per 1000 litres	1100 (1500)*

Note: ( )* water tariffs effective March 1, 1998.

The figures in Table 5-2 mean that:

◊ a standing or fixed amount of K10000.00 is a charged every month.

◊ the first 0-100 m^3, the second 0-70 m^3 and any amount of water in excess of 170 m^3 of LWSC water consumed are charged according charges (2), (3) and (4) in Table 5-2. respectively.

Considering the daily average consumption of 102 m^3 at Fairview Hotel, about 3060 m^3 of LWSC water is consumed per month of 30 days. Therefore, Fairview Hotel pays about K 3278500.00 (100*470+70*750+2890*1100) per month on LWSC water supply plus a standing charge of K10000.00.

New LWSC water tariffs were announced in the February 3, 1998 Daily Mail paper and are effective from March 1, 1998 (see Table 5-2, figures in brackets). The monthly standing charge will remain at K10000.00. This means that Fairview Hotel will be spending about K4471000.00 per month on LWSC water supply from March, 1998; an increase of about 35%.

(b) Fairview Hotel borehole water supply

The borehole is located within the backyard of Fairview Hotel main buildings. It is made of a 3 inch rising main, reduced to a 2 inch main after the ground level. The depth of the rising main was estimated to be about 50 metres. This depth is equivalent to the manometric head in meters of water column which the borehole pump has to overcome when operational.

- **Capacity of the borehole pump**

The current capacity (Q) of the pump [water abstraction per day (m^3/d)] was checked by volumetric measurement, using a stop watch and drum. About 217 litres were collected in 130 seconds which is equivalent to a discharge of about **144 m^3/d ($1.67 * 10^{-3}$ m^3/s).**

Since the volumetric measurements were done on the ground-level, the above capacity could be slightly less if the pump is used to directly fill overhead tanks located on top of the hotel buildings.

- **Energy costs of the borehole pump**

The cost of the energy (kWh) used by the borehole pump are calculated by multiplying the power (W) required by the number of running hours. Power is given by

$$P = (Q * H * \rho * g)/\eta_{pump}$$

in which: *Q ⇨ the discharge in m^3/second, H ⇨ manometric head in meters of water column (~50 m), ρ ⇨ density of water in kg/m^3 (1000), g ⇨ acceleration of gravity (9.81 m/s^2), η_{pump} ⇨ efficiency of the pump (an assumption of 50% is considered safe)*

From the known values of the above parameters and assuming a 24 hour operation period as being critical, the energy required is

$$E = 24 * (1.67 * 10^{-3} * 50 * 9.81 * 1000)/0.5 = 39.24 \text{ kWh}$$

Hence monthly (assuming a month of 30 days) energy consumption is about **1200 kWh**

Electricity to the borehole is supplied by ZESCO. For commercial tariffs, the current energy costs for consumers exceeding 1000 kWh is at K63.00/kWh. Therefore, about K75000.00 per month is spent on ZESCO energy supply to the borehole pump.

5.2. Water distribution system

(a) <u>Pipe network</u>

From the LWSC water meter connection, a 2 inch GI pipe delivers water to two underground water reservoirs, each with a total volume of about 25 m^3. From each of the underground reservoirs, 1.25 inch pipes deliver water, through pumping, to elevated tanks located on top of the hotel buildings. From these tanks, water flows by gravity through 0.5 inch, 1 inch or 1.25 inch pipe network to the various consuming locations within the hotel. A physical inspection of the pipe network revealed that it is in good condition. There are no visible leaks or corrosion of the pipes.

(b) Storage facilities

There are 2 underground water reservoirs and 3 elevated water tanks located on top of the hotel buildings. For the schematic layout and details of these water storage facilities, see Figure 5-2.

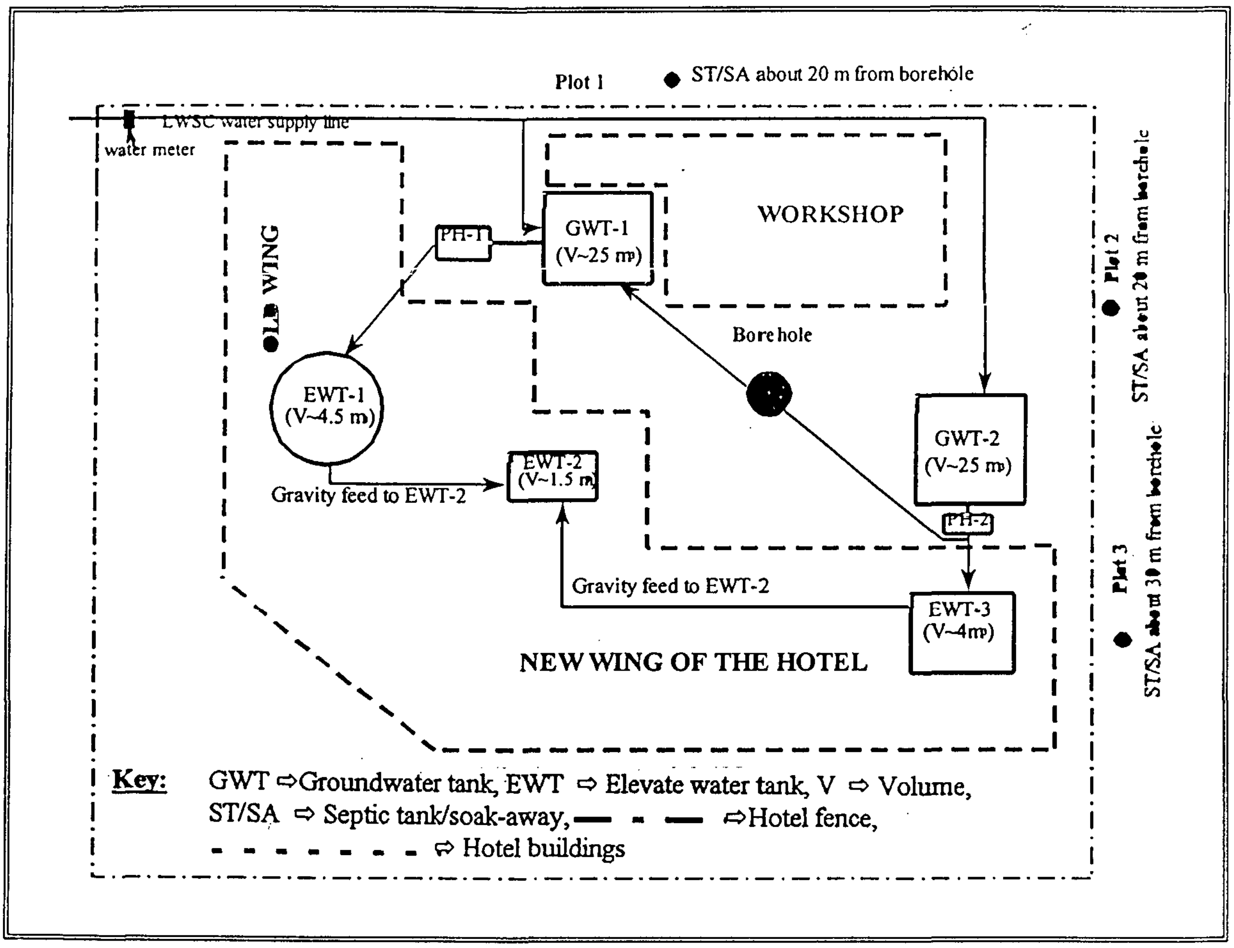


Figure 5-2: Schematic layout of the water distribution system at Fairview
(not to scale)

None of the elevated water tanks is provided with any drainage facilities for use if the need for cleaning the tanks arose. Such drainage facilities, often located at the bottom of the tanks are necessary when the tanks need to be emptied completely. If the tank outlets supplying the hotel are instead used to drain the tanks, settled matter within the tanks can be flushed into the pipe network leading to blockages. All the elevated tanks are corroded. Excessive corrosion can eventually lead to leak developments. Tanks EWT-1 and EWT-2 are not well covered. It is thus possible that birds, rats or cats can contaminate the water by either defecating in the water or getting drowned and rot in the water.

5.3. Drinking water quality

(a) LWSC water

The drinking water supplied by LWSC is usually potable. A sample collected at the time the hotel started getting LWSC water revealed zero coliform per 100 ml. However, there is usually little or no residual chlorine in the water by the time it reaches the hotel.

(b) Groundwater from the Fairview bore-hole

Table 5-3 below shows the water quality parameters analysed, the WHO guideline values (in curly brackets) and the subsequent analysis results. An overview of the significance of the water quality parameters checked is given in Appendix A.

Table 5-3: Fairview bore-hole water quality analysis results

Date	Water quality parameter, {WHO guideline}, analysis results								
	FC (#/100 ml) {<1 FC}	COD (mg/L) {<5}	TDS (mg/L) {<1000}	TSS (mg/L)	TH (mg/L) {<500}	Turbidity (NTU) {<5}	DO (mg/L)	Iron (mg/L) {<0.3}	Ammonia (mg/L)
02-12-97	2000	90	515	<1	-	-	-	-	-
12-12-97	80000	116	608	<1	612	4.9	-	0.32	-
17-12-97	1800	-	486	-	368	0.8	0.7	-	-
08-01-98	37	-	450	-	372	1	-	-	-
13-01-98	15	-	592	-	374	2	0.6	0.52	1.25
20-01-98	36	-	452	-	380	2	0.7	0.86	0.12
24-02-98	0[1]	-	472	-	378	-	-	0.024	-
27-02-98	36	-	-	-	-	-	-	-	-

NOTE: FC ⇒ faecal coliforms, COD⇒ chemical oxygen demand, TDS ⇒ total dissolved solids, TSS ⇒ total suspended solids, TH ⇒ total hardness, DO ⇒ dissolved oxygen, { } WHO guideline values.

The analysis results in the above table show that the groundwater is contaminated with faecal and organic matter. This is evident from the unacceptable levels of faecal coliforms and COD obtained. However, the number of faecal coliforms dropped with time. This trend may suggest instantaneous contamination which gets diluted with time since groundwater flows continuously. Since the first contamination was detected after the first rains, it is possible that runoff from around the borehole area contaminated the borehole. Such contamination is bound to disappear with time, but is likely to reappear when the next rain season comes.

[1] On this day there were no faecal coliforms in the water due to the small water volumes used in the analysis (0.1 & 0.01 ml). This, however, does not mean that there are no faecal coliforms in 100 ml of the water. 100 ml volumes used on 27/2/98 reconfirmed the presence of faecal coliforms, hence contamination.

The other possibility of the source of the contamination is the septic and soak away tanks located with the plots surrounding Fairview hotel (see Figure 5-2). These tanks were physically inspected. It is feasible that when there are heavy rains, as experienced this rain season, the tanks can overflow and contaminate shallow groundwater which in turn may eventually flow towards the borehole. One of the septic/soak-away tank is only about 20 m from the borehole, which is below the minimum recommendation of 30 m for the borehole-septic tank distance.

Levels of TDS, TSS, TH, and turbidity were found acceptable compared to WHO standards. If these parameters exceed the WHO standards, they negatively impair the aesthetic and palatability of the drinking water.

Levels of DO are very unacceptable, which is common for groundwater since there is little aeration underground. Low DO levels do not have a direct effect on health but indicate the presence of organic matter. However, DO levels are normally restored after abstraction and exposure to atmospheric air at the point of discharge to the storage tanks. If necessary, a baffle plate can be installed below the borehole discharge point into the storage tank. The splashing of the water on this plate provides aeration which restore DO levels.

Iron levels are higher than the minimum WHO recommendation. This is as a result of low DO levels which cannot oxide soluble iron to easily precipitated insoluble forms. However, iron gets oxidised as soon as the water restores sufficient DO levels and is precipitated within the storage tanks. Excessive iron levels cause staining of clothes and is unacceptable aesthetically. Precipitation of iron, and usually manganese, within the pipes may reduce their water carrying capacity. Ammonia is an obvious indication of organic contamination and should be completely absent in drinking water. Its presence in the borehole water reconfirms the contamination detected by the presence of faecal coliforms.

5.4. Sewerage systems

(a) <u>Within Fairview hotel premises</u>

The sewage from Fairview Hotel is collected by sewer pipes and discharged into the LWSC sewer network. The sewer network at the hotel has no visible leaks and can be considered to be in good condition. However, the 4 inch collecting main seems too small to accommodate large flows of sewage. It was reported that overflows on manholes are very common. This is a clear indication of the inadequacy of the size of the main sewer. Depending on the extent of the overflows, it is possible that they can contaminate shallow groundwater which may flow towards the borehole.

(b) <u>Surrounding areas</u>

Fairview Hotel is surrounded by three plots (see Figure 5-2). All these plots have septic and soak-away tanks located at less than 50 m from the borehole site. This means that all the sewage from these plots seeps into the surrounding grounds. These tanks can be potential sources of contaminants for the borehole depending on the soil structure which usually determines the extent of seepage.

5.5. Chlorinating practice

The water supply at Fairview does not have any chlorinating equipment. It is necessary that appropriate chlorinating equipment is used to ensure the supply of adequately disinfected water. Even when the hotel is getting treated LWSC water, this water usually has no residual chlorine. This means that even the water from LWSC requires proper safety disinfection against accidental or unknown contamination. WHO guideline values recommend that there should be between 0.2 to 0.5 mg/L residual chlorine at the end of the tap to safeguard against unforeseen contamination.

There are basically two types of chlorinators: gas chlorinators and solution feeders.

Gas chlorinators feed gaseous chlorine. They are normally complicated and require expert monitoring. They are normally installed in a separate room which should be well ventilated. Handling of chlorine gas requires special equipment and expertise. Gas chlorinators require constant power/energy supply and very good maintenance. Any breakdown would require importation of spare parts which may take long to be ordered, especially in developing countries, Zambia inclusive. Hence standby chlorinators, meaning more costs, are always inevitable. Usually these chlorinators are used in medium and large water supplies.

Solution feeders feed solutions of granular chlorine, commonly called HTH. The use of HTH, and the respective solution feeders, is normally limited to small water supplies because of the simplicity of dosing, storage and handling requirements. In medium to lager water supplies, large amounts of HTH would be required and may be laborious to handle. However, HTH is normally kept for emergency use in such water supplies in the event of gas chlorinators being out of order. For small water supplies, dripping devices are suitable as solution feeders. They can be made and maintained locally without the need for importing any spare parts. They dose directly to water tanks and cannot dose under pressure in pipes. Since it is important to provide constant flow rate of the solution, the dosing orifice is usually attached to a float so that it moves with the level of the solution. This ensures a constant head for feeding the solution. The dosing rate of solution feeders can easily be calculated from the known or estimated chlorine dose, water flow rate and the concentration of the HTH solution. If chlorine doses are estimated, measurements of residual should be followed up to monitor whether the residual chlorine is acceptable (0.2 to 0.5mg/L). If residual chlorine levels exceed 0.5m/l, water is usually characterised by irritating smells which are not pleasant to consumers.

In Zambia, gas chlorinators and chlorine (both gaseous and granular) have to be imported, from Zimbabwe and South Africa. A search on INTERNET revealed that there are suppliers of chlorinators from USA with outlets in African countries. Catalogues were requested for and are to be sent. There are also local agents of HTH within Zambia.

6. Conclusions

The following conclusions have been drawn:

(a) the water from the existing borehole at Fairview Hotel is currently not fit for direct human consumption. However, it is feasible to render the water potable by adequate Chlorination.

(b) the borehole is very susceptible to contamination either from surface runoff or septic tanks around the hotel. Contamination from surface runoff can be expected to reoccur every rain season.

(c) the borehole yield or capacity is sufficient to meet the current water demand at the hotel.

(d) the use of groundwater from the borehole is considerably cheaper than using LWSC water supply.

(e) the pipe network distributing water within the hotel is in a good state.

(f) two of the elevated water tanks on top of the hotel buildings are in a bad state.

7. Recommendations

(a) Chlorination of the borehole water

If the borehole water is to be used for supplying the hotel with drinking water, then it should be disinfected by chlorinating so that it meets the bacteriological quality standards. The use of granular chlorine(HTH) and solution feeders would be appropriate. Gas chlorinators would also be suitable but would require a lot of time and money for ordering and installing. Solution feeders can easily be fabricated locally. The use of HTH is advantageous because local suppliers are readily available unlike chlorine gas which would require importation in cylinders.

The major advantage of solution feeders would be the their easy and simple operation and maintenance. Granular chlorine (HTH) is also easier and safer to handle without demanding either separate rooms for storage or special equipment/expertise. It is therefore recommended that solution feeders be used as at now.

Chlorinating procedures and quantities of the chlorine to be dosed need to be established before the groundwater is used. The borehole pump should first discharge the water into the two groundwater reservoirs in which Chlorination should be done before pumping to the elevated tanks on top of the hotel. Chlorination should be done in each of the reservoirs. Solution feeders can be placed on top of the reservoirs.

For the details of the proposed solution feeder and estimates of chlorine dosages see Appendix B. Proposed follow-ups with regard to the Chlorination aspects and water quality monitoring are elaborated in Appendix C.

(b) Maintenance of the water systems

The elevated storage water tanks and the underground water reservoirs should be cleaned at least every 6 months. The elevated water tanks need to be painted to protect against corrosion. Tank EWT-1 (see Figure 5.2) on the old wing building need replacement because it is badly corroded. Tanks EWT-1 and EWT-2 should be properly covered to prevent contamination form birds, rats or cats.

To facilitate cleaning of the elevated water tanks, facilities for complete drainage of the tanks should be provided. These can be outlets right at the bottom of the tanks provided with gate valves. It is possible that one can get tempted to drain the tanks by isolating the inflow and allow the tank to drain into the pipe network. This is not recommended because sediments can enter the pipe network and probably block the pipes or even render the water aesthetically unpleasant. If possible bypasses should be installed to ensure continuous supply when the tanks are undergoing maintenance.

(c) Maintenance of the sewerage systems

Overflows from known manholes should be properly directed to other manholes which don't overflow. This can greatly reduce the risk of contaminating the groundwater around the borehole. The septic and soak-away tanks within the plots around the hotel area should be checked regularly to ensure that they are not overflowing and are properly maintained by owners.

The sewer systems within and around the hotel area should be inspected regularly for any leakage. Leaks should be repaired to prevent groundwater contaminated. If there are any plans to expand the hotel or other measures which may result in an increased water use at the hotel, then considerations of increasing the size of the main sewer would be imperative.

(d) The use of LWSC water

If at any time the hotel uses the LWSC water, safety disinfecting by chlorinating should continue within the underground reservoirs to guarantee acceptable bacteriological quality of the water. This is imperative because analysis results indicate that LWSC water does not have any residual chlorine vital for safety against unforeseen contamination. A chlorine dose which gives a residual chlorine between 0.2 and 0.5 mg/L would be adequate.

When using the LWSC water, water meter readings should also be taken in order to check against water quantities consumed and hence paid for.

Appendix A: Significance of analyzed drinking water quality parameters

For the quality of the borehole water the significance of the parameters analyzed are hereby discussed.

(1) **Faecal Coliforms (FC)**

Faecal coliforms consist of groups of bacteria which are not pathogenic themselves, but indicate the presence of pathogens. Another group used is the Total coliform group. However, this group contains many species and does not always indicate the presence of contamination. Although originally believed that they were all of Faecal origin, it turned out later that some members of this group were not. One particular species in the coliform group which is an obvious indicator of faecal pollution is *Escherichia coli* (*E. coli*). E. coli can be confirmed by special tests. However, it is much simpler to show the presence of a sub-group of total coliforms, the *faecal coliform* group, of which E. coli usually makes up 70%. This group indicates almost as well as E. coli itself the presence of material of definitely faecal origin, which gained access to water recently.

For the sanitary assessment of untreated surface and well water, faecal coliforms are important in addition to the total coliforms. For treated water, especially chlorinated water, it is normally sufficient to use total coliforms as indicators. Their absence shows that the treatment has destroyed also the pathogenic bacteria since the pathogens have the same or greater sensitivity to disinfectants than the coliforms.

Freedom from faecal coliforms, however, does not always indicate the absence of pathogens, such as viruses, amoebic cysts or helminth eggs. These microorganisms are more resistant to disinfectants, such as chlorine, than bacteria. A treated coliform-free water may, thus, still contain some of these parasites. In natural waters, viruses and cysts also have a longer lifetime than coliforms, especially the faecal coliforms. The latter may have died away, which erroneously indicated a safe source of drinking-water, although some pathogenic viruses or cysts may still be present.

(2) **Dissolved Oxygen (DO)**

Aerobic microorganisms need oxygen to decompose organic matter. This takes place mainly in surface water, but to a certain extent also in water percolating through the soil, which forms groundwater later on. If DO is not available, anaerobic bacteria take over, which is often not wanted because they produce odor gases like Hydrogen sulfide and other undesirable substances.

Rainwater is always saturated with DO, but while water is percolating through the soil, aerobic processes consume DO. This means groundwater is normally not saturated. The deeper the groundwater, the less is its DO content, which can even reach zero in deep groundwater. Such waters need aeration to restore DO levels. Although DO is important, there is no direct significance for public health. It is not healthier to drink water rich in oxygen, nor does it directly affect the taste of water. But, the absence or low levels of DO in surface waters (< 30% saturation) is an indicator of pollution and usually also of contamination. Water in a distribution network should contain at least 3 - 4 mg/l DO for corrosion control and the prevention of odor problems.

(3) **Chemical Oxygen Demand (COD)**

The COD test is used to measure the organic content of natural waters, municipal wastewater and industrial wastes. Functionally, the oxygen equivalent of the organic matter is measured using a strong oxidizing agent (potassium dichromate) in an acidic medium. The test is performed at elevated temperatures, using a catalyst (silver sulfate) to help the oxidation of certain resistant classes of organic compounds.

(4) **Iron (Fe)**

Whereas the trivalent Fe^{3+} [Fe(III) or ferric] ions are insoluble, and may be found in surface waters as colloidal oxides, the divalent Fe^{2+} [Fe(II) or ferrous] ions are much more soluble and can be present in groundwater. Iron (II) in water does not cause color or turbidity as long as they are in the divalent state. This, however, is possibly only in waters free from DO. Hence Fe(II) only occurs in deep groundwater, which has lost all of its DO. Only under these conditions can some iron and manganese in the soil be dissolved. Iron has no direct effect on health but is an acceptable because it impairs the aesthetic quality of water and stains clothing.

(5) Total hardness (TH)

Multivalent cations, particularly magnesium and calcium, are often present at significant concentrations in natural (ground-)waters. These ions are easily precipitated and particularly react with soap to form a difficult-to-remove scum. The presence of these metal ions may also result in scaling in hot water pipes and water heaters, in industrial and domestic water supplies. For most practical purposes, *total hardness* (TH) of a water can be represented as the sum of the calcium (*calcium hardness*, CaH) and magnesium (*magnesium hardness*, MgH) concentrations, given in equivalent per cubic meter or expressed as mg/l $CaCO_3$. In literature dealing with water quality, the qualitative classification of total hardness reported to be from very soft to extremely hard is often used to describe the relative hardness of a water. Groundwater extracted from boreholes in and around Lusaka, is usually classified as very to extremely hard water.

(6) Ammonia (NH_3)

Ammonia is basically an indicator of pollution and possible contamination. Although NH_3 in higher concentrations is toxic, this is not the case with the small concentrations normally found in waters.

(7) Turbidity

Turbidity is an indicator for the clarity of a water and is caused by colloidal and suspended matter. These particles cause light to be scattered and partially absorbed rather than transmitted straight through water. Turbidity is measured by using a turbidimeter and is expressed in Nephelometric Turbidity Units (NTU). The significance of turbidity is that the Colloidal and suspended solids causing turbidity make water aesthetically unpleasant. The solids may also shelter pathogens reducing the effectiveness of Chlorination.

(8) Total Suspended solids (TSS)

Any particle passing the 1.2 m membrane filter is considered dissolved, and any particle retained is considered suspended. The significance of suspended solids is that they can be accompanied by a great number of pathogenic microorganisms and stimulate their growth by providing food for them. Inorganic suspended solids as such are not a health hazard, if they are clays, iron oxides, etc. All colloids, even clay particles, may have microorganisms encapsulated, which are thus protected from the effect of disinfection by chlorine. Viruses are known to become easily attached to suspended solids on or in their surface, hence associated with them.

(9) Total Dissolved solids (TDS)

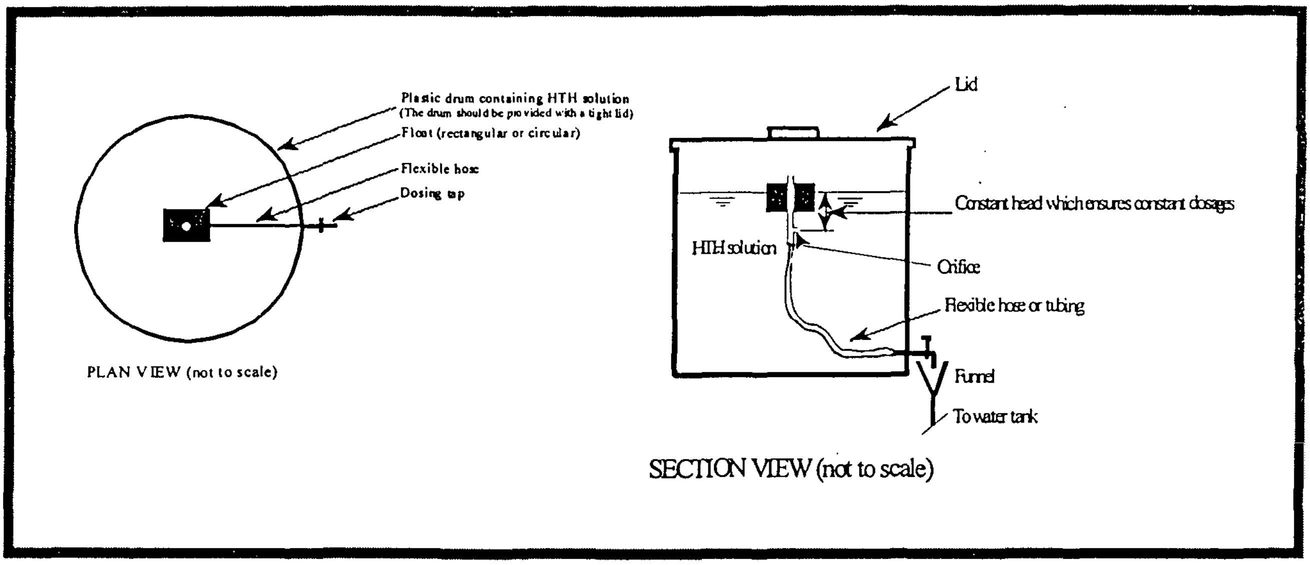
Total dissolved solids is a measure of the total ions in water. The origin of TDS are the various components of the soil. These are basically minerals and therefore TDS is often referred to as the 'mineral content' of a water.

In surface water, TDS is generally low. It is rarely more than several hundreds mg/l. In groundwater, the range may be much wider. It depends on the solubility of the materials in the ground with which water gets in contact with and can be as low as 50 mg/l, but it may also exceed 1000 mg/l, the upper WHO limit. If this is the case, the water will have a salty, brackish or bitter taste. These waters are common in arid areas and may also occur near the coastal sea due to the intrusion of salt water.

Appendix B: Proposed HTH solution feeder and dosages

(a) HTH Solution feeder

The figure below shows the schematic design of the HTH solution feeder.



The drum which holds HTH solution should be made of plastic because the solution is corrosive to metallic containers.

(b) Estimation of HTH solution dosages (D_{sol})

In drinking water, chlorine dosages are determined from chlorine demand tests if the quality of the water to be treated is known to be steady. However, for groundwater consumed directly, the quality is likely to be inconsistent, like the case with Fairview hotel borehole water. For such cases, an initial estimate of the chlorine dosage may be made after which residual chlorine levels have to be monitored to ensure that they remain within acceptable limits. Recommended residual chlorine levels fall within 0.2 to 0.5 mg/L. An initial dosage of at least 1 mg/L may usually be sufficient most cases. This dose is subject to adjustment depending on the level of residual chlorine after a contact time of 15-20 minutes.

(c) Calculation of HTH solution flow rate (Q_{sol})

Q_{sol} is calculated from the water flow rate(**Q L/h**), concentration of HTH solution (**C_{sol} mg/L**) and the chlorine dose (**D_{cl} = mg/L**) using the following relationship:

$$Q_{sol} = (Q * D_{cl}) / C_{sol} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Water flow rate (Q)

From the daily consumption figures at Fairview, an average water flow rate of 100 m^3/day can be assumed. However, the critical case is when consumption is more than the average value (e.g. Feb. 1, 1998. See table 5-1). Therefore, assuming a safety factor of 1.5 would be acceptable. This means the water flow becomes 150 m^3/day (6250 l/h). Assuming that this will be divided equally to the two underground tanks, each tank will receive 3125 l/h.

Amount of HTH to be used per day and concentration of the HTH solution

Taking water flow rate150m^3/day and the assumed chlorine dose of 1 mg/l, about 200 g of HTH should be used per day (taking into account the fact that HTH is 70% Free Available Chlorine which is the effective component).

Sufficient HTH solution should be prepared to last not less than a day. A 210 liters plastic drum is recommended which should stock HTH solution enough for two days. Assuming the drum is filled with 200 liters of water and 200 g HTH is added, the resulting chlorine concentration is 0.7 g/l (0.7*200 g / 200 l).

HTH solution flow rate (Q_{sol})

From relationship (1) and the known values of **Q**, $\mathbf{C_{sol}}$, and $\mathbf{D_{cl}}$ the flow rate of the HTH solution to each underground tank is:

$$\mathbf{Q_{sol} = (3125*1*10^{-3}) / 0.7 = 4.5\ l/h}$$

The above flow rate can easily be set using volumetric measurement methods: measuring cylinder and stop-watch.

NOTE

The calculations above are estimates and can only be confirmed by physical monitoring of residual chlorine. It is very likely the dosages can vary depending on the chlorine demand of the water and the residual chlorine. Residual chlorine can easily be monitored using simple potable equipment. If residual chlorine is found to be outside the recommended range of 0.2 to 0.5 mg/l, then the HTH dosages can be readjusted. If the raw water quality is known to be steady, the best way to estimate chlorine dosages is by carrying out chlorine demand tests.

HTH solutions should be dosed at the point where there is good mixing. For the underground tanks at Fairview Hotel, this can be at the point where the borehole pump discharges into the tanks.

Appendix C: Proposed Follow-ups

The following follow-ups are proposed:

(1) Technical assistance in fabricating and installing the Chlorination facilities. This will involve advising on appropriate materials and location of the chlorine feeders.

(2) Advice on commissioning procedures of the borehole use.

(3) Monitoring of the water quality during the first few days of using the borehole.

(4) Technical assistance in monitoring the Chlorination practice until the operators are well trained with respect to the procedures to be established. For any problems that may arise regarding the Chlorination procedures, the hotel management may request for assistance.