

Figure 3: Curves showing concentration-variabilities of Chloride and Nitrates with varying levels of saturation in the aquifer different sampling locations in the project areas (The pink curve is for concentrations in the rainy season – March 2004, while the green and blue are for the two dry seasons – November 2003 and October 2004). Locations 1 – 14 are: 1) Near Salvation Army with reeds; 2) Shallow well (Islamic BH2); 3) Mutenje Bar; 4) In depression; 5) Near new Barbershop; 6) Near Lubilo School; 7) Chanda Bar; 8) Yellow House; Ekupumuleni Mini Mart; Near Dollose; Bambe Grocery; Chairman’s Place; In caverns; Mwinga’s well.

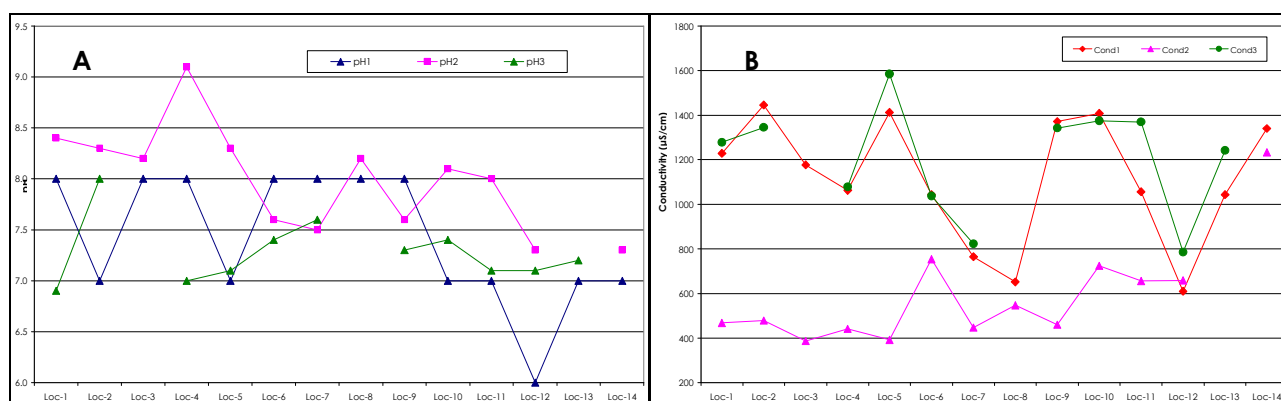


Figure 4: Variability of (A) pH and (B) Conductivity with variable levels of saturation in the aquifer. Locations 1 – 14 are: 1) Near Salvation Army with reeds; 2) Shallow well (Islamic BH2); 3) Mutenje Bar; 4) In depression; 5) Near new Barbershop; 6) Near Lubilo School; 7) Chanda Bar; 8) Yellow House; Ekupumuleni Mini Mart; Near Dollose; Bambe Grocery; Chairman's Place; In caverns; Mwinga's well.

Water with high conductivity (high TDS) also tends to have high chloride (and sulphate) concentrations as indicated in these analyses. Sulphate removal is expensive (desalination or ion exchange) and normally not considered viable.

With data acquired from this research, bulletins were issued to the National Epidemic Preparedness, Prevention Control and Management Committee (NEPPCMC) meetings in April and October 2004 outlining the type and extent of pollution of the aquifer in the project areas and the possible link to some public health problems experienced in these areas.

3.1 Safety of water for Domestic use

Decision making on the suitability of water for domestic use is largely determined by the health problems related to drinking the water. One way to determine the safety of the water for domestic use was on the basis of faecal coliform counts and their acute effects on health (Tables 4 & 5). Appendix 4 shows the arrangement for water sources and excreta disposal in the project areas.

Table 4: Faecal Coliforms as a Guideline for drinking water

FAECAL COLIFORMS RANGE (No./100 ml)	DRINKING	FOOD PREPARATION
0	No detectable chance of infection	No detectable chance of infection
0-1	Insignificant chance of infection	Insignificant chance of infection
1 – 10	Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	Clinical infections unlikely in healthy adults, but may occur in some sensitive groups
10 – 100	Clinical infections common, even with once-off consumption	Clinical infections common, even with once-off consumption
> 100	Serious health effects common in all users	Serious health effects common in all users

Source: South African Water Quality Guidelines (DWA, 1996) & Health Guidelines: Drinking Water Quality (Department of Health, 1995)

Table 5: WHO Guidelines for Drinking water

Faecal Coliforms	Action Needed
0	None
1 – 10	Action
11 – 50	Urgent Action
> 50	Very Urgent Action

On the basis of Table 4, most of the water points in the project areas pose serious effects in all user-groups. Table 5 shows no significant deviation from the classification in Table 4 in that most of the water sources may be classified as having needed VERY URGENT ACTION. Yet this ACTION may appear not to have been readily apparent at the time. As a result, there was NO prioritisation work to improve water supplies to ensure that those sources, which presented the greatest risk to public health, were improved first.

3.2 The relationship between water quality and waterborne diseases

The presence of faecal coliforms in the water, as per sampling results, shows the presence of disease-causing micro-organisms – *faecal coliforms* – which may be responsible for gastro-intestinal diseases, typically characterised by cholera, typhoid, dysentery and sometimes by fever and other secondary complications. In this regard, the dependence of residents in John Laing and Misisi compounds on groundwater (re)sources obtained from private boreholes and shallow had-dug wells may be the cause for heightened outbreaks of waterborne diseases such as cholera, typhoid and dysentery, which have also been experienced in other areas of the city with similar sanitary and water-source arrangements.

Between 1 November 2003 and 30 January 2004, 2,482 cases of cholera had been reported for Lusaka alone with 110 deaths. Annual figures for the project areas in particular, and Lusaka, in general, for the period 1996 to March 2004, are given in Table 6 from which it can be observed that John Laing shows higher disease prevalence than Misisi. This may be attributed to the more ubiquitous use of shallow-wells in the former than in the latter. And as at 7 April 2004, there were 6,487 cumulative cholera cases reported for the whole of Lusaka with 186 cumulative deaths and 62 cumulative brought-in-dead (BID) cases from eight health centres.

Table 14: Annual cholera figures for Misisi and John Laing (1996 – 2004)

YEAR	CASES OF CHOLERA		TOTAL CASES IN THE CITY OF LUSAKA
	MISISI	JOHN LAING	
1996	109	28	2,469
1997	140	26	2,492
1998	0	0	0
1999	-	-	6,485
2000	0	0	0
2001	46	30	887
2002	-	-	2
2003/2004	96	250	4,734*

*Figure for the period 28/11/03 – 03/03/04. During this period, 157 deaths were reported at the health centres and 55 bodies were brought-in-dead. **Source:** LDHMB cholera reports

3.3 Methods of water treatment at household level

Decision-making on the suitability of water for domestic use is largely determined by the health problems related to drinking the water. Because most of the water sources, particularly in the high-settlement areas, are of unsatisfactory quality, a number of methods have been employed to purify the water and make it safe for household use. Some of them may need re-emphasising and discussing.

3.3.1 Boiling

This is a simple way to kill pathogens. Some of its major disadvantages include:

- Uses a lot of fuel-wood – *about 1 Kg of wood is needed to boil one litre of water*. In a city-setting, such as Lusaka, where this wood resource is scarce, its use may be limited by its availability and cost.
- It sometimes gives an unpleasant taste to water.
- Water may be contaminated again when it cools down.
- Hot water may cause serious accidents in homes.

3.3.2 Chlorination

This process inactivates all types of microorganisms – protozoa, bacteria and viruses. However, its efficiency to inactivate microbes is affected by **pH**, **contact time** and **its reactions with water**. Microbes may be protected from chlorine if they are attached to or within particles in the water.

When added to water, chlorine has three types of reactions, which may affect its availability and efficiency as a disinfectant:

- Iron (Fe), Manganese (Mn) and hydrogen sulphide (H₂S) react irreversibly with chlorine, thereby improving water quality. As a result, chlorine is removed from the water without contributing to the disinfection process.
- Chlorine may react reversibly with organic matter and ammonia to form weak disinfectants. It has also been recognised that chlorine **may** react with organic substances in some waters to form trihalomethanes (THMs). There is some evidence that THMs may be uncommon causes of cancer (Boxes 1 & 2).

Box 1: Professional Water Quality Test Kit

We know that man-made chemicals, the majority of which were introduced into society after World War II, have been poisoning our surface drinking water supplies for years. Over the decades they have filtered down and contaminated our vital underground drinking sources as well. Some experts believe the toxins in our drinking water are the number one health threat causing cancer, heart disease and lead poisoning. Such chronic illnesses are brought on by the body's absorption. Water contaminants not only affect our health, but they can also corrode fixtures, stain and deteriorate clothing and household surfaces, alter the taste of food and drinking water, and slowly turn hair orange.

Chlorine

Chlorinating water is necessary for disinfecting; however, over-chlorination produces by-products known as trihalomethanes. One trihalomethane, chloroform, is a known carcinogen. <http://www.preparedness.com/watqualteski.html>

Box 2: Water District Drops Use of Chlorine

Waterworks Business

23 January 1998

The East Bay Municipal Utility District in Oakland, Calif., announced last week it will join a growing number of drinking-water providers who are no longer using elemental chlorine as a disinfectant.

Instead, the district will use chloramine (NH₂Cl), a chemical formed by the combination of ammonia (NH₃) and liquid chlorine (Cl). Chloramine offers more effective disinfection than chlorine without the high levels of potentially dangerous byproducts, such as the suspected carcinogen trihalomethane (THM), caused by the interaction of chlorine and natural organics in water.

"We made this decision primarily because of the taste of the water," said EBMUD spokesman Charles Hardy.

<http://www.clo2.com/reading/waternews/clnews.html>

.....Drinking water chlorination is a difficult regulatory area because killing waterborne pathogens has huge public health benefits to weigh against harms. But as with the thousands of other organochlorine chemicals released into the environment, from dioxins and dry cleaning solvents to pesticides, however, industry officials and regulators operate with an innocent until proven guilty prejudice. Even though virtually every organochlorine tested has been shown to have one or more toxic properties according to the American Public Health Association, regulation proceeds to various degrees with the requirement of proven harms before substantial government action to reduce exposure. The problem is that harms from long-term and/or low level exposure to environmental toxins such as disinfection by-products are very difficult or impossible to conclusively find when they exist.

http://www.greensense.com/Features/Action/cancer_on_top.htm

Since protecting public health involves establishing priorities, there is need for a comparative risk assessment to ascertain why prevention of observed waterborne diseases through the control of microbiological contaminants should take precedence over eliminating the risks posed by disinfection by-products such as THMs. In this regard, the decision to continue supplying communities at household level with chlorine should rely on informed analysis of the short-term public health benefits taking cognisance of any long-term problems and how to adequately brace for them.

Therefore, it is imperative to better understand the efficacy of chlorine as a disinfectant and the health effects of the disinfection by-products (Box 3).

Box 3: The Search for Health Effects: The Art of Risk Assessment

It hardly requires more than a few minutes of browsing EPA documents on disinfection by-products to discover a great shortage of information on health effects. This lack of information would be astonishing to anyone assuming standards for disinfection by-products were set at demonstrably safe levels. The EPA disinfection by-product rule acknowledges that risk assessment "relies on inherently difficult and preliminary empirical analysis." Animal studies are very incomplete. Not a single by-product chemical has been assessed for the range of possible effects, including cancer, reproductive toxicity, neurological damage, and immune system disruption. The animal data available for a handful of chemicals has uncertain relevance for humans. Lastly, the EPA notes that single chemical testing on animals is "insufficient" to characterize the risks from exposure to a mix of thousands of organochlorines in chlorinated drinking water. There is evidence that organochlorines can have synergistic effects in which a combination of chemicals is disproportionately more toxic in a mixture.

http://www.greensense.com/Features/Action/cancer_on_tap.htm

4 MEASURES FOR RESOURCE PROTECTION

The Lusaka aquifer is generally characterized by shallow water tables, a thin soil cover, coarse soils with low clay contents, unconfined conditions, a flat topography which generally facilitates increased recharge and has pollution sources, which are placed in aquifer recharge areas

In this context, the issue of aquifer protection in such a setting is very difficult to attain. To a great extent, the concept of aquifer protection in Lusaka is very **reactive** as it has emerged as a response to aquifer contamination resulting from contaminating human activities having already been established in areas that would, under normal circumstances, have been candidate zones for aquifer protection.

Von Hoyer et al (1978) describe how, at that time, the Lusaka City Council's prohibition on the siting of pit latrines within 800 metres of a Council borehole were impractical and could not be enforced because of the high population densities in these high-density settlements. Another ruling prohibiting the operation of gravel pits within 800 metre-radius of a Council borehole could also not be enforced as a large open laterite pit had already been excavated within 50 metres of the existing Mass Media well field.

In other words, all efforts in the protection of the aquifer must attempt to prohibit any potentially contaminating development within the cone of depression because in this zone, groundwater flow velocities towards pumped wells are highest, and have shortest travel times. Whatever the case, any groundwater protection measures to be adopted in Lusaka must accept the fact that existing infrastructure and anthropomorphic activities cannot be moved, although this does not mean that they should be ignored.

In this regard, two routes of aquifer protection in Lusaka may be envisaged – **proactive/preventive and retroactive**. Clearly, it would be preferable to adopt the former since a source that can be maintained contaminant-free would obviously be cheaper to use since treatment costs would be lower. Retroactive measures in Lusaka, on the other hand, will generally consist of reducing and/or preventing further contaminant entry into the aquifer(s), the prevention of deleterious land-uses in sensitive areas and an element of emergency clean-up.

However, the growth of high-density settlements like John Laing and Misisi Compounds, and unplanned suburbs like those being erected south of Kabwata and Chilenje (south-east of Misisi) may render certain forms of protection unworkable. Further, due to reasons of economics and inadequate public awareness, it might be very difficult, if not impossible, to force changes in land use practices in pursuit of aquifer-wide protection strategies.

It would also appear that most water well casing is not grouted. The absence of such comprehensive grouting in the vast majority of Lusaka boreholes in areas of suspected fracturing constitutes a major limitation both in terms of borehole management and pollution prevention. In

this regard, the following may constitute some of the rigorous and most immediate protection measures, such as establishment of:

- a) **Wellhead protection zones**, where *any activity*, other than water supply and maintenance works at wellheads, is prohibited.
- b) **Well field protection zones**, in which any activities likely to create pollution-risk are prohibited. This would preclude any form of construction-development unless sewered, any farming that includes pesticide or fertiliser application, and any industry.

To assess the effectiveness of the protection measures, it is **strongly** recommended that a monitoring system that has been established under this pilot project in John Laing, Misisi and the Mass Media areas is up-scaled to cover the rest of the aquifer. Water samples from supply points must be taken on a regular basis for a range of physico-chemical and microbial parameters that will give an early warning of any contaminant event likely to occur.

5 CONCLUDING REMARKS

- ⊙ Except for a few water points in the project areas, values of most physico-chemical and bacteriological parameters show a general decrease from the dry season into the wet season. This is probably resulting from dilution arising from increased saturation in the aquifer. Further, boreholes also generally record much lower values than shallow wells.
- ⊙ Available borehole drilling data indicates variations in fracturing intensities in the aquifer rock leading to differences in the development of subterranean cavities. This would appear to be responsible for the occurrence of **unconfined** (and some semi-confined) **aquifers** in parts of the city.
- ⊙ The presence of a well developed system of conduits, solution channels and subterranean cavities in the Lusaka aquifer(s) reduces and/or completely eliminates the natural attenuation of pollutants through dilution and natural filtration.
- ⊙ Regular water quality monitoring from supply points for physico-chemical and microbial parameters will give an early warning of any contaminant event likely to occur.
- ⊙ There is need to formulate adequate community-based sensitisation and educational awareness campaign programmes on, for instance, household methods of water treatment to safeguard the health status of the citizens.

The long-term deterioration of water quality, leading to progressively more costly water treatment, is the inevitable result of current ad-hoc development reminiscent of a thriving city of Lusaka located largely on a karstic aquifer. In the long-term, groundwater beneath Lusaka is likely to become unfit for human consumption even with expensive treatment. In which case, there will be need to look for new sources of water supply away from current sources or a reconsideration of whether or not a new site should be sought for the city .