UNEP/UNESCO/UN - HABITAT PROJECT DOCUMENT

Title of Sub-Programme:	*Environmental Assessment and Early Warning*
Title of Project:	***ASSESSMENT OF POLLUTION STATUS AND VULNERABILITY OF WATER SUPPLY AQUIFERS OF AFRICAN CITIES***
Project Number:	*CP/1000-02-03*
Geographical Scope:	*60 Africa*
Implementation:	*UNESCO/IHP – Division of International Hydrological Programme under the leadership of UNEP Division of Early Warning and Assessment (DEWA)*
Location:	*John Laing & Misisi Compounds, Lusaka, Zambia*
Duration of the Project:	*24 months*
Commencing:	***December 2002***
Completion:	***November 2004***

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1 INTRODUCTION

This report summarises activities executed during the period June – December 2004 for the project – *Assessment of pollution Status and Vulnerability of Water Supply Aquifers of African cities* for Misisi, John Laing and Mass Media areas in Lusaka, Zambia. The major activity executed during this period was sampling of selected water points.

2 SAMPLING CAMPAIGNS

Three sampling campaigns were planned for this project – the first at the end of dry/start of rainy season, the subsequent ones being in the middle and end of the rainy season.

However, the actual sampling campaigns were undertaken in mid-November 2003, just before the onset of the rainy season, March 2004 (during the rainy season), and October 2004 (at the peak of the dry season). This arrangement was meant to compare the variability of pollutants with varying levels of saturation in the aquifer. The two subsequent sampling campaigns targeted those points that proved qualitatively problematic during the first sampling campaign. These sample locations are shown in Figure 1.

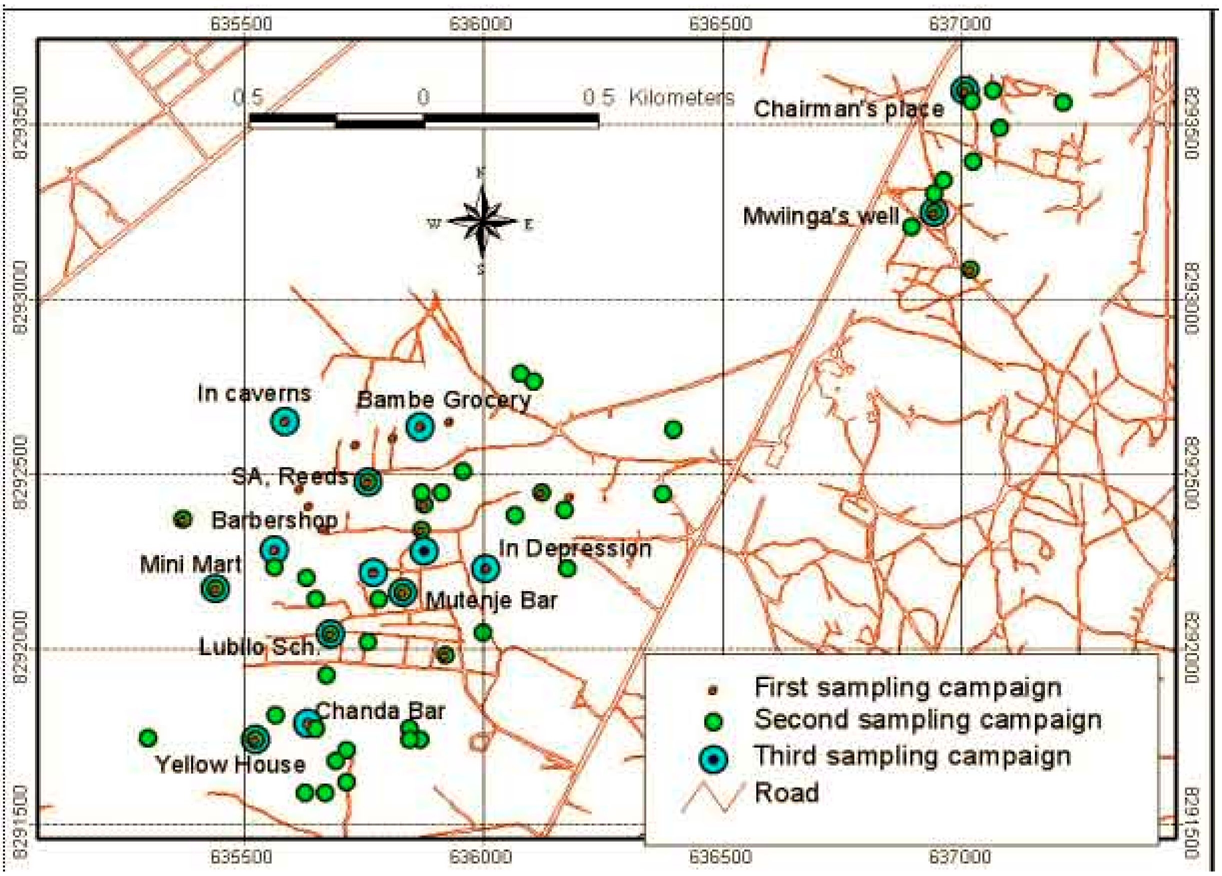

Figure 1: Locations for the three sampling campaigns in John Laing and Misisi project areas

The following parameters were identified for analysis in the first sampling campaign - *pH, conductivity, chloride, sulphate, nitrite and nitrate, total coliforms and faecal coliforms.* The selection of these parameters was because they portray information on the potability of the water as shown in Table 1. The values of these parameters in domestic water must conform to the WHO Guidelines for Drinking water as given in Table 2.

Table 1: Water quality substances of key relevance for domestic use

KEY SUBSTANCES	RELEVANCE TO DOMESTIC USERS
	Microbiological quality
Faecal coliforms	Indicates recent faecal pollution and the potential risk of contracting infectious diseases
Total Coliforms	Indicates the general hygienic quality of the water
	Physical quality
Conductivity / Total Dissolved Salts	Affects the taste and 'freshness' of the water
pH	Affects the taste and corrosivity of the water
	Chemical quality
Chloride	May impart a salty taste to the water
Nitrate and nitrite	May be toxic to infants
Sulphate	Excessive amounts cause diarrhoea

Table 2: WHO guidelines for drinking water

PARAMETER	GUIDELINE VALUE
Chloride	250 mg l^{-1}
pH	6.5 – 8.5
Nitrate	10 mg l^{-1}
Sulphate	400 mg l^{-1}
Total Dissolved Solids (TDS)	1,000 mg l^{-1}
Total Coliforms	10 Counts / 100 ml
Faecal Coliforms	0 Counts / 100 ml

3 ANALYTICAL RESULTS

A summary of results for the locations that were subjected to all the three sampling campaigns are given in Table 3.

Table 3: A summary of results for locations that were subjected to at least two sampling campaigns in John Laing and Misisi project areas (The first and third sampling campaigns were done during the dry season, while the second was made during the rainy season)

Location	Cond1	Cond2	Cond3	pH1	pH2	pH3	N1	N2	N3	Cl-1	Cl-2	Cl-3	TC1	TC2	TC3	FC1	FC2	FC3
Near Salvation Army with reeds	1228	468	1,278	8	8.4	6.9	17	28.7	21.4	84	55	95	1500	285	400	500	240	275
Shallow well (IslamicBH2)	1446	478	1345	7	8.3	8	12	7	19.1	6	75	110	500	35	460	650	20	300
Muterje Bar	1177	387	-	8	8.2	-	19	2.9	-	81	33	-	66	100	-	66	60	-
In depression	1063	442	1079	8	9.1	7	16	2.1	23.9	80	61	85	800	150	21600	4200	90	11400
Near New Barbershop	1413	392	1585	7	8.3	7.1	39	7.5	23	157	21	121	550	88	450	500	30	420
Tafimbwa Lubilo School	1044	754	1038	8	7.6	7.4	19	6.2	27.9	70	80	72	500	120	355	510	95	290
Chanda Bar	765	447	823	8	7.5	7.6	12	6.8	24.7	39	37	45	560	50	310	550	25	100
Yellow House	652	547	-	8	8.2	-	11	11.6	-	44	55	-	160	65	-	160	30	-
EKupumuleni Mini Mart	1371	460	1342	8	7.6	7.3	18	10.3	18.3	110	42	108	900	92	13300	4500	40	9900
Near Dolose	1408	724	1375	7	8.1	7.4	25	4.51	23.1	100	119	93	700	18000	625	500	12000	500
Bambe Grocery	1056	656	1369	7	8	7.1	40	6.2	19.7	103	115	105	890	14000	500	500	11000	385
Chairman's place	610	659	786	6	7.3	7.1	16	20	22	28	52	31	5000	5300	9000	500	3000	3200
In caverns	1043	-	1242	7	-	7.2	39	-	20	92	-	85	-	-	300	-	-	210
Mwiinga's well	1340	1233	-	7	7.3	-	15	2.92	-	107	83	-	-	8000	-	-	6000	-

Cond ≡ conductivity (in $\mu S\ cm^{-1}$); N ≡ Nitrate (in mg l^{-1}); Cl ≡ Chloride (in mg l^{-1}); TC, FC ≡ Total and Faecal Coliforms, respectively (both in counts per 100 ml)

From Table 3, it can be seen that the most important water quality problem in the project areas of John Laing and Misisi is that of faecal pollution together with the associated disease-causing organisms. This is particularly serious during the rainy season, when faecal contamination is *flushed* into the groundwater system. This is shown by plots of faecal and total coliform counts at different sampling points in the project areas (Figure 2), where it can be seen that both parameters heighten with increasing levels of saturation, thereby making the aquifer very vulnerable to pollution. Minor spikes during the dry season in both cases are probably a result of local through-flow since these locations are in an abandoned quarry, which places these locations at a lower elevation than the surrounding area, thus receiving recharge from most of the surrounding area.

The rest of the results for all the sampling campaigns are given in Appendices 1, 2 and 3. From these results, it can be observed that water quality from boreholes is bacteriologically **much better** than that from shallow wells. As the population density of micro-organisms is known to be dependent on the supply of nutrients and removal of harmful metabolic products (Matthess, 1982), the relatively low microbe populations in boreholes in comparison to shallow wells in the project areas may be attributed to decreasing oxygen availability at greater depths. However, this may also depend upon groundwater flow processes, which will be dealt with by a postgraduate student, who has just commenced his PhD programme dealing with:

The development of a model for groundwater monitoring in the urban and rural areas of Zambia as a tool for resource assessment and evaluation

Further, except for a few locations, there is generally a reduction in the values of most parameters from the dry season into the wet season, probably resulting from dilution due to increased saturation in the aquifer, with boreholes also generally recording much lower values than shallow wells.

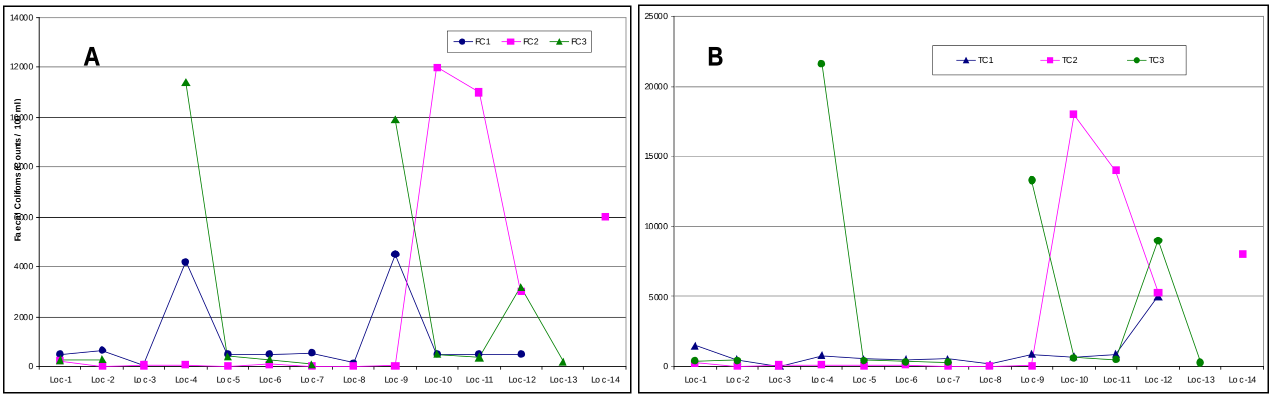

Figure 2: Variability of coliform contamination with varying levels of saturation in the aquifer (the pink being the curve for the rainy season – March 2004, while the blue and green are for the dry season – November 2003 & October 2004). *Locations 1 – 14 are: 1) Near Salvation Army with reeds; 2) Shallow 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.*

The mode of chemical loading to the aquifer appears to operate *inversely* to bacteriological burden. Conductivity, for instance, which is indicative of elevated salt concentrations (TDS, Sulphate and Chloride), and nitrate generally show elevated levels in groundwater during the dry season (Figure 3). This appears to be the trend for almost all chemical elements, which can be explained as being caused the lowering of the feed rates (due to reduced flows) and the rise in mineralisation.

For the physical parameters – *pH and conductivity* – (Figure 4), the water appears to become more alkaline during the rainy season, probably indicating the predominance of the HCO_3^- radical (and some CO_3^{2-}) in solution. In other words, this *alkalinisation* processes may result from the exposure of carbonate rocks to a lot of water, thereby raising the pH-levels during the rainy season. And conductivity (arising from high concentrations of chloride, nitrate and sulphate), on the other hand, appears to decrease during the rainy season – also probably as a result of high flows, which keep the system *flushed* and *deprived* of the mineralisation.