SUMMARY REPORT ON THE GEOLOGICAL AND HYDROGEOLOGICAL ASPECTS OF THE LUSAKA WATER SUPPLY AND THE IMPACTS OF POLLUTION

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INTRODUCTION

The city of Lusaka is built on marble (see map on page 4), generally referred to by the local geology as the **Lusaka Dolomite**. The marble is cut by a network of fissures (called karsts) which have remained either as open hollows or been filled with soil (Plate 1A). These fissures manifest themselves on the surface as pits, sinkholes and caves. The presence of karst features in marbles (and indeed other soluble rocks like gypsum/anhydrite and rock salt) makes them very vulnerable and susceptible to a very wide range of environmental problems.

This project has been carried out from May to September 1992 in the context of the author's Ph.D studies in Engineering Geology and Hydrogeology being pursued at Aachen University of Technology in Germany.

The objective of this study is to make detailed geomorphological studies of karsts in the marble which underlie Lusaka with a view to assessing:

1. the performance of completed engineering structures (houses, roads) since karst processes and landforms often pose many problems for construction and other land usages. Every nation with karst rocks has had its share of embarrassing failures such as collapse of buildings and roads (Plate 1B), or construction of reservoirs that never held water[5]
2. the impact on the quality and quantity of groundwater and the subsequent implications on public health due to liquid and solid waste disposal practices, seepage from drainage systems, contamination of surface water by industrial liquid and solid wastes and over-pumpage from boreholes,
3. current water demands in Lusaka and comparing with present supply capabilities of the system, and in view of (2), to comment on planned expansion programmes which aim at increasing the water supply in the city by sinking more boreholes.

The methodology adopted for data acquisition comprised:

(a) visitations to, and discussions with authorities at the following Institutions and Companies; Geological Survey Department, Minex Department, Lusaka Water and Sewerage Company (LWSC), Water Affairs Department, National Council for Scientific Research (NCSR), Public Health/Food and Drugs Department at UTH, Public Health Department of the Lusaka Urban District Council, National Housing Authority (NHA), Wade Adams Piling and Foundations, UNICO, John Burrow and Partners Consulting Engineers, BCHO'D and Partners Consulting Engineers, Survey Department, Central Statistics Office (CSO), the National Archives, Ministry of Environment and Natural Resources, Ministry of Mines and Minerals Development and the International Union for the Conservation of Nature (IUCN). During this time, some geological, hydro-geological, hydrochemical and hydrobacteriological, geotechnical, survey and demographic data for Lusaka were collected,

(b) mapping of rock outcrops in the Kalingalinga quarry, United quarries, Ibex/Kabulonga Hill, Libala quarries, Crushed Stone quarries and the 'flooded' Chawama quarry to gather information on the nature of karsts and to determine in the field whether there is any structural control on their occurrence. Whether mineralogy is also an important parameter, will be determined by XRD/XRF analyses on rock samples which were collected, and

(c) sampling of boreholes belonging to Lusaka Water and Sewerage Company, and private Institutions. Physico-chemical parameters and microbial indicator organisms were analysed in the sampled water.

PROBLEM PERSPECTIVE

Although Lusaka is located on one of the higher parts of the Central African plateau, the marble surface on which it stands lacks slope to allow surface water to flow. Consequently, most of the surface water percolates into the subsurface through karst conduits to eventually form the groundwater reserves which are subsequently exploited for domestic and industrial use by the many boreholes scattered throughout the city. The pivotal aspects to this research, and which the Authorities in the Ministry of Environment and Natural Resources and other related State Agencies may need to address themselves to is the very urgent need to review and check certain human activities in the city and its environs if the quality and quantity of groundwater are to be sustained:

1. currently, about 900,000 of Lusaka's 1.2 million in-habitants live in unsewered areas serviced either by septic tanks or pit latrines, with effluent finally percolating into the aquifer(s),

2. a **big dump of toxic** waste comprising among them pesticides, herbicides, fungicides, insecticides, veterinary products discarded by the disbanded National Agricultural Marketing Board (NAMBoard) lies outside the Zambia Cooperative Federation (ZCF) premises in the Industrial area (Plate 1C). During the rainy season, percolating surface waters seep this waste to the groundwater table,

3. the car wash centres along Kafue road generate 'quantities' of waste waters everyday (Plate 1D) which finally drain into the subsurface (Plate 2A), to find their way into the aquifer(s),

4. the city centre and most processing plants in the Industrial area discharge **untreated effluent** into the unlined drains. Premium Oil Industries (Z) Limited and Unified Chemicals (Z) Limited serve as examples (Plate 2 B & C)), while effluent originating from the city centre flows in an undergound stream which surfaces across the road near ZESCO Headquarters (Plate 2D). Downstream, this stream is used as 'swimming ground' by children in the compounds through which it flows (Plate 2E). Further downstream, it merges with another river carrying sewage effluent from the Ngwerere **"treatment"** ponds. These eventually provide irrigation water for gardens (Plate 2F).

5. farms in the vicinity of the city apply tonnes of chemical fertilizers, insecticides, herbicides, fungicides, veterinary products, etc which later get washed away and transported into the subsurface during the rainy season or by irrigation seepage,

6. the Hindu Crematorium some 3 km outside the city on Mumbwa Road generates partially **burned** human remains which are dumped within the premises without due regard for a highly productive Lusaka Water and Sewerage Company bore-

hole located some 30 - 40 m away (Plate 3A),

7. sewer line blockages are the order of the day, resulting in overspillage and flow of human waste on the ground surface (Plate 3 B & C),

8. there is seemingly a lack of central control on the award of Water Rights pertaining to the sinking of boreholes, with no regard for limitations on the amounts of extractable water reserves from the aquifer and the ensuing consequences as a result of over-exploitation.

THE IMPACT OF HUMAN ACTIVITIES

Karst areas are susceptible to a much greater range of environmental problems than any other terrain because of the presence of highly and well developed subterranean networks[2]. These karst features manifest themselves on the surface as pits, sinkholes, and caves (Plate 1 A & B). Unfortunately, they have been found to be suitable dumping grounds for various forms of waste in most parts of the city because it immediately disappears underground (Plate 3 D & E): naturally, "out of sight, out of mind".

Karst aquifers are among the most sensitive to disturbance and are readily contaminated[2]. Therefore, karst features provide the worst possible places to dispose of any form of waste since they are direct conduits for the infiltration of surface water into the underlying aquifer. This creates four major factors which contribute to the contamination of groundwater[2]:

(a) the rapid water infiltration through the open vertical channels (karst conduits) as have been developed in most parts of the city (Plate 1 A & B), reduces the opportunity of evaporation, a mechanism that is important in the elimination of some of the highly volatile organic compounds such as solvents and pesticides,

(b) physical filtration is ineffective as most of the marble areas are covered by thin karst soils and have large secondary voids; thus sediment and micro-organisms are readily transported into the aquifer(s),

(c) transmission of particulate matter through karst systems is greatly assisted by the turbulent regime commonly associated with conduit aquifers, and

(d) time-dependent elimination mechanism (of bacteria and viruses for example) are curtailed in effectiveness because of rapid flow through time in conduits and reduced retardation by adsorption-desorption processes.

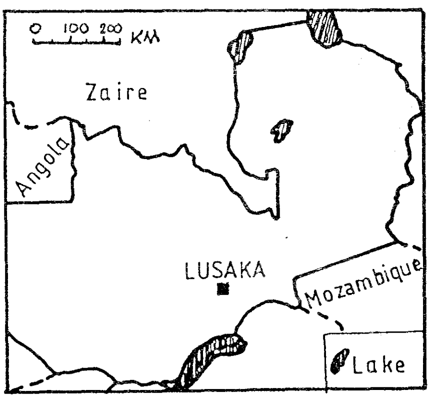
Some chemical and bacteriological analyses performed on samples from production boreholes and wells during the period of this research indicate that pollution differs considerably among individual water sources as indicated in the table below.

The Table indicates some variation of polluting constituents in individual water sources. The nature of pollutants present viewed from the location of the water sources does indicate aquifer contamination by human waste.

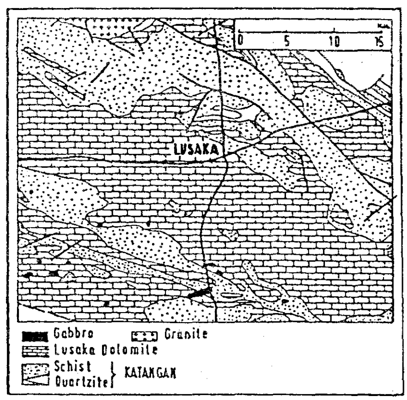
Unfortunately, all the boreholes except Shaft 5, discharge directly into the homes. This implies a lot of people sometimes consuming very unsatisfactory water with considerable degrees of contamination, resulting in outbreaks of diarrhoeal and other gastro-intestinal diseases.

Another aspect to the environmental problems in Lusaka is the seemingly lack of central control of Water Rights regarding the sinking of boreholes. Many houses in the low density areas, almost every industrial/processing plant both in the Light and Heavy Industrial areas and most office blocks in the Town and Civic centres are serviced by boreholes. A large number of houses in the high density areas are on hand-dug wells (Plate 3F).

Unfortunately, the specific yield of the Lusaka aquifer(s), which would give an indication of the amount of the available and extractable water is not known. Therefore, aquifer response due to high underground water pumpage is unpredictable. This, compounded with the drought which has ravaged the entire sub-continent, has a drastic effect of very rapidly depressing the water-table. Consequently, this causes a reduction in the bouyant force of the water, resulting in piping or consolidation of the soil. This situation creates increased probabilities of ground-collapses. Some of these may take place under engineering structures (Plate 1B), the result of which is obviously fatal. A number of structures on Kabulonga Hill may suffer such devastation within the next few years.



LOCATION OF LUSAKA



GEOLOGICAL MAP OF THE LUSAKA AREA. (After Turner, 1986).

CHEMICAL AND BACTERIOLOGICAL ANALYSES OF SOME BOREHOLES IN LUSAKA (May - September '92)

LOCALITY	**TDS**	**$NO3^{2-}$**	**$SO4^{2-}$**	**TC**	**FC**
Chainda BH	447	16.6	3.8	1	0
Chawama BH	559	8.73	ND	3	1
Chawama qrry upstrm	377	6.55	1	700	16
Chawama qrry dnstrm	362	6.57	0.6	1790	63
Chelston BH1	386	11.6	8	0	0
Chelston BH2	380	11.7	10	5	0
Chunga BH	531	3.61	ND	4	0
George T/ship W1	353	1.4	ND	960	122
George T/ship W2	444	2.24	ND	760	5
Ibex Hill BH	423	1.17	ND	3	0
Leopards Hill BH	393	0.87	ND	360	0
Malo Farm BH	382	10.9	3.6	470	31
Mass Media BH	442	15.6	11	38	0
Mulungushi BH	480	9.82	14.8	0	0
Northmead BH	500	10.1	13.6	5	0
Shaft 5 BH	428	8.73	ND	3	0
Showgrounds BH	496	11.4	10.6	1	0
Unified Chem. BH	430	11.4	ND	0	0
Walkover Farm BH	231	4.47	4	0	0

TDS, $NO3^{2-}$, & $SO4^{2-}$ measured in (mg/l); TC & FC being counts/100ml; $NO3^{2-}$ is determined as (mg/l)N; TDS = Total Dissolved Solids; TC = Total Coliforms; FC = Faecal Coliforms; BH = Borehole; Chem. = Chemicals; qrry = quarry; T/ship = Township; W1 = Well 1; ND = Not Determined; up/dnstrm = up- and down-stream, respectively.

Therefore, to resolve the problem of unchecked sinking of boreholes and ground collapses which may result from the subsequent over-abstraction of the groundwater, **it is imperative that measures aimed at better management of the water resources are urgently sought and put in place.**

CONCLUSION

Many of the city's inhabitants and members of the general public appear to be either ignorant or ill-informed of the environmental/health and engineering hazards inherent in karst areas. This may be due to the fact that the City's Local Government has not effectively addressed the issues of land use. For instance, while the harmful effects of the traditional use of sinkholes and caves as convenient dump sites, and the devastation on engineering structures which may occur as a result of over-exploitation of groundwater may be obvious to the informed mind, they are unfortunately not so to a majority of the people.

Therefore, the key elements and major steps towards addressing this problem are **education of the masses about the nature and magnitude of the problem, follwed by enforcement of corrective regulations**

Appreciation of the problem by the general public, Local Government and other relevant state agencies is likely to change behaviour patterns of part of the offending population, thereby facilitating the creation of an enabling environment for the formulation of more effective enforcement regulations and sustainance of an improved situation. Otherwise, Lusaka faces serious environmental problems arising from the impact of high and unacceptable levels of mostly man-influenced physico-chemical and bacteriological constituents in the groundwater, and sinkholes/ground collapses as a result of a depression in the water-table caused by high quantities of groundwater abstraction.

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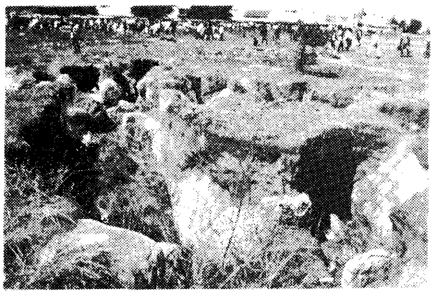
PLATE I

Kabulonga Hill area



Luburma market/near Independence Ave. fly-over bridge

Old Crushed Stone Quarry

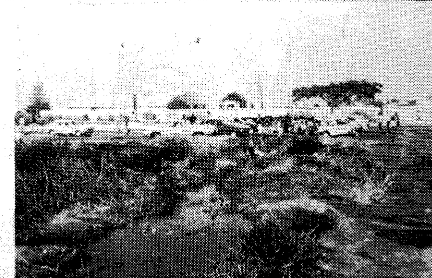
A **vertical channels/ conduits in marble**

Woodlands Extension Township

under a road in Nyumba Yanga Township

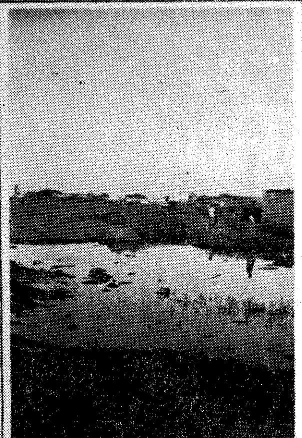
B **Ground collapse in marble**

C: Toxic Dump near ZCF shed (Industrial area)



D: **Waste waters from car wash centres along Kafue Road**

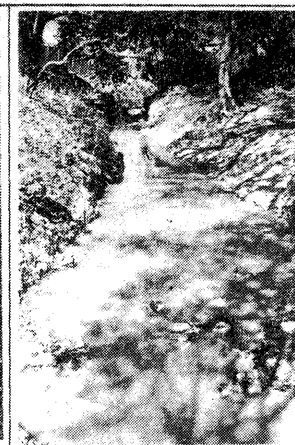
PLATE 2



A
Water pool from the car wash centres
(here river disappears underground)

B
Effluent from an oil processing plant
(Premium Oil Industries (Z) Ltd)

C
Effluent from a soap plant
(Unified Chemicals (Z) Ltd)



D
Effluent from the city centre surfacing in a stream across the Great East Road, near ZESCO HQs.

E
Downstream, (D) providing 'swimming grounds' for children

F
Sewage effluent from the Ngwerere River used to irrigate gardens

The expected value of water inflow into PA-1 shaft with the designed depth of 650m at the "Palazu-Mare" iron ore deposit with depth of layer of 500m with coefficient of filtration 37.8 m/day was reduced from 97.87 cu.m/min to 0.015 cu.m/min and the process of shaft-sinking was carried out without any complications.

At "Severnaya" mine site which is in the Northern Urals, Russia the sinking of a new ventilation shaft with depth of 780m was carried out in fissured rocks with co-efficient of filtration exceeding 21 m/day and expected value of water inflow of 2700 cu.m/h. To perform the program on pregrouting from the ground surface 12 boreholes were projected and the volume of grout amounted to 62700 cu.m. Currently these works are being completed.

In fractured rocks there were carried out the grouting operations at sinking of more than 100 mine shafts with depth of 600-1400m in Donets Coal Basin. At the expected values of water inflows from 115-580 and more cu.m/h those of residual inflows into shafts were not exceeding on average 1.5-3.5 cu.m/h, thus the percentage of sealing amounted to 99%. This can also be demonstrated with some more examples of carrying our of grouting works at sinking of ventilation shaft at N1 Zhdanovskaya-Kapitalnaya mine site with designed depth of 615m. The grouting of aquifers with water inflow of 115 cu.m/h was performed through 6 inclined boreholes. The dimensions of sealing curtains around the shaft amounted to 19.7 and 31m, the volume of grout - 5275 cu.m. The residual water inflow into the shaft was 1.4 cu.m/h. The average rates of sinking - 100m/month.

In porous rocks the worked out methodology of designing of sealing curtains and technology of grouting applying methods of hydraulic fracturing of rocks was introduced at sinking of 15 deep mine shafts in Donets Cal Basin, and also in Chechia at "Slany" coal deposit. In Donets Coal Basin at "Octyabrskaya" mine site at sinking of an air conducting shaft with depth of 1011m the values of reduced residual water inflows were from 622 to 13.2 cu.m/h - 87.9%. At shafts N4 and N7 at Stachanov mine site with depth of 1000m, the values of water inflows amounted to 9.0 and 13.3 cu.m/h respectively, and the percentage of reduction 97.4% and 95.7%. At "Slany" mine site as the result of surface pregrouting of fine-pore sandstone water inflow into