XXXVIII IAH Congress

Groundwater Quality Sustainability

Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **284**

topic: **3**
Aquifer management

3.1
Regional groundwater systems

title: **Developing of an aquifer management strategy for the rapidly expanding City of Lusaka, Zambia**

author(s): **Roland Bäumle**
Bundesanstalt für Geowissenschaften und Rohstoffe, Germany, r.baeumle@bgr.de

Kai Hahne
Bundesanstalt für Geowissenschaften und Rohstoffe, Germany, Kai.Hahne@bgr.de

Levy Museteka
Ministry of Energy and Water Development, Department of Water Affairs, Zambia, lmuseteka@gresp.mewd.gov.zm

Andrea Nick
Bundesanstalt für Geowissenschaften und Rohstoffe, Germany, A.nick@bgr.de

keywords: aquifer management, groundwater potential, groundwater pollution, remote sensing analysis, vulnerability assessment

INTRODUCTION

Lusaka, the capital of Zambia with an estimated population of about 1.3 million in 2005, is experiencing a rapid population growth of about 3.7 percent per annum. The population density has increased from about 700 in 1969 to over 3,000 persons per sq. km in 2000 (LCC, 2008). Water is supplied by a Commercial Utility, the Lusaka Water and Sewerage Company (LWSC). According to the National Water and Sanitation Council (NWASCO, 2009), the water supply coverage (ratio of urban population with access to safe and reliable water) served by the LWSC is 68%. Total water production in 2008/2009 reached almost 260,000 m^3/d while actual daily water demand (including private and commercial abstractions) is estimated at 340,000 m^3/d. Currently, the LWSC pumps 125,000 to 140,000 m^3/d from the local groundwater systems whereas the remaining water is sourced through a pipeline system from the Kafue river situated about 40 km south of the City. The LWSC was advised to increase the water supply capacity to cope with the estimated water demand of 640,000 m^3/d by the year 2030 (KRI Int. Corp. et al., 2008).

The very productive, karstic aquifers are characterised by shallow water tables and a lack of protective cover, and therefore considered very vulnerable to pollution. The majority of Lusaka's population lives in formal and informal urban areas where the most people are using on-site sanitation facilities. One of the major factors influencing water quality therefore is the provision of safe sanitation. According to NWASCO the sanitation coverage (ratio of population with access to adequate sanitation) is only 17%. A lack of city planning and its implementation, especially in terms of new industrial and commercial areas, puts the resource further at risk. Poor drainage, inappropriate handling of industrial effluents and uncontrolled dumping of industrial and domestic waste together with unplanned developments have significantly contributed to the problem of groundwater contamination. These and many other concerns have created a huge challenge for effective groundwater resource management in Lusaka. Despite of its importance, the use of groundwater is currently not regulated. Groundwater management regulations are incorporated in the proposed Water Resources Management Bill which is yet to be enacted.

PHYSIOGRAPHY AND HYDROGEOLOGY OF THE STUDY AREA

The project area covers an area of approximately 3,000 square kilometres and extends over the City of Lusaka and adjacent areas including parts of the Mwembeshi and Chongwe Catchments. The tropical continental highland climate is characterised by a cool and hot dry season lasting from May to October and a wet season between November and April. 80% of the total annual rainfall (average of 860 mm) occurs from December to March, usually with a peak during January (average of 220 mm).

Regionally, the Lusaka rocks are part of the Zambezi Belt that, by definition, is separated by the Mwembeshi Shear Zone (MSZ), from the Lufilian Belt to the north (Porada, Berhorst, 2000). The Lusaka area is covered by strongly folded overthrusted metasedimentary rocks of Katanga (Neoproterozoic) age which have been intruded by granitic and basic bodies (Hanson et al., 1994, Johnson et al., 2007). Owing to the intense tectonical deformation of the Katanga sequence, the stratigraphic succession and its regional correlation are still not fully clarified. Based on the stratigraphical succession proposed by Simpson et al. (1963) the metasedimentary cover can be divided into three formations: the Chunga Formation comprising schist and quartzites, the Cheta Formation including schist and carbonates and the Lusaka Dolomite Formation (Figure 1).

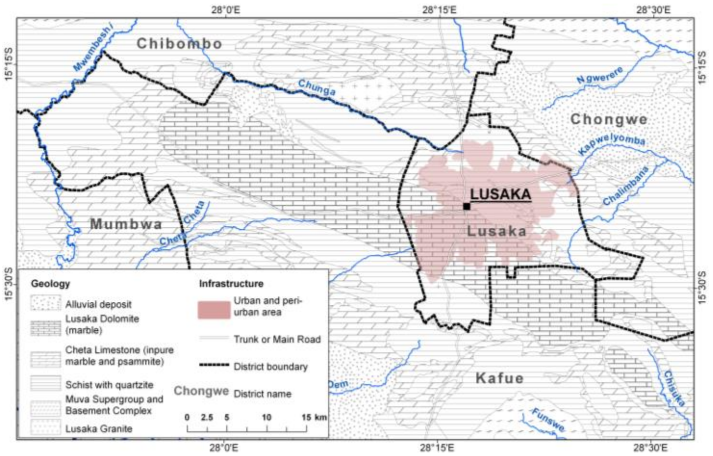

Figure 1. Geology of the study area.

The carbonate rocks cover an area of 1,600 km^2 and are known to form a terrain undergoing recent and active karstification. On the surface, an epikarstic zone has developed with an average depth of 5 m extending to a maximum depth of 25 m below the surface. The main aquifer is hosted by the marbles of the Lusaka Dolomite Formation forming an elongated about 65 kilometres long and 20 m wide plateau with its axis striking in WNW–ESE direction. Subordinate aquifers occur in the crystalline limestone and dolomite of the Cheta Formation located to the north, west and south of the Lusaka Dolomite aquifer. Minor aquifers are developed in the schists, psammites and quartzites of the Cheta and Chunga Formations and within alluvial deposits.

PRELIMINARY FINDINGS OF THE INVESTIGATION PROGRAM

First investigations carried out during the preparatory phase of the study included the development of a groundwater information system including a Geographic Information System (GIS), the establishment of a groundwater, spring and surface water monitoring network, remote sensing studies and water quality sampling campaigns. The database stores information on water points including hand dug wells, boreholes, springs and groundwater exploration drill sites comprising information of all major hydrogeological investigations carried out since the mid-1970s (Bäumle, Kang'omba, 2009).

Satellite imagery was used to identify land use distribution, directions of maximum principal stress and the main trends and types of faults (Hahne, 2010). The current land use and surface cover distribution was determined by an automated supervised classification with the method "maximum likelihood" of 80% using a Landsat ETM scene with acquisition date May 13, 2002 as the main information source. To obtain a more recent picture, the obtained major classes were then manually adjusted in a GIS on basis of four SPOT scenes with acquisition dates July 11, 2008 (western part), August 13, 2007 (north east) and July 14, 2007 (south east). Major land use and surface cover classes included water, settlement, various types of shallow or bare soil, agriculture and forest. From 2002 to recent the most striking change is a loss of forest and scrubland in favour of commercial- small scale agriculture, as well as for the production of charcoal. Also development areas grew rapidly, especially in the south of Lusaka.

Three main trends of faults could be derived from satellite imagery (Figure 2):

- A strike direction NW–SE (± 120°), parallel to the main structural trend,
- A further NW–SE direction (140°),
- A probably conjugate NE–SW direction (035°, 045°).

To a minor extent also a NE-SW trend (080°) parallel to the MSZ direction is present.

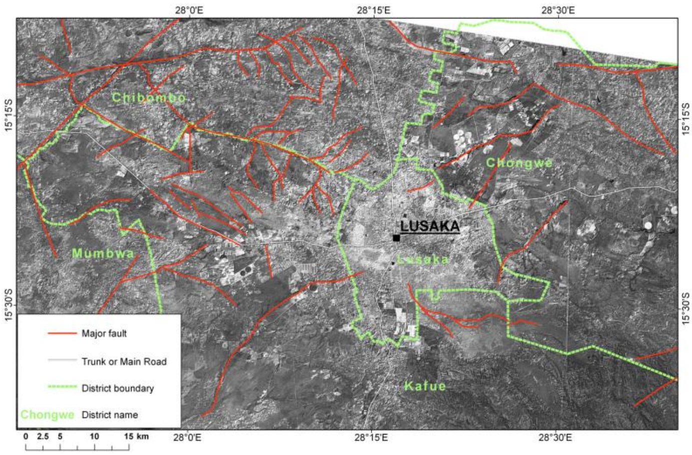

Figure 2. Examples for major faults derived from satellite images projected into Landsat ETM band 5.

Water quality sampling comprised inorganic constituents and heavy metals as well as microbiological indicators. Sampling points included perennial and seasonal springs as well as water supply wells operated by the LWSC and private wells. The water from springs and water supply wells in the limestones and dolomites corresponds to the Ca-Mg-HCO_3 type as was expected. In terms of water hardness, the water is generally hard (>250 mg/l $CaCO_3$) to very hard (>375 mg/l $CaCO_3$). Groundwater hosted by schist can be distinguished from the carbonate springs by overall lower TDS, slightly lower pH, lower HCO_3:SiO_2 ratios as well as much lower hardness and alkalinity (i.e. buffering capacity). The results could be used to identify the chemical water composition of areas that are unaffected by human pollution sources. These waters were characterised by an electrical conductivity (EC) of less than 800 µS/cm and concentrations in sodium, chloride, nitrate and sulphate below 10 mg/L. Higher levels in these parameters could consequently suggest the presence of urban pollution sources. Groundwater pollution from human activities was apparent in higher levels of EC reaching 1450 µS/cm, sodium contents up to 138 mg/l, chloride levels up to 123 mg/l, and sulphate concentrations up to 172 mg/l. Whilst these values still comply with the Zambian Drinking Water Standard (ZDWS), nitrate levels frequently exceeded the recommended standard of 10 mg/l NO_3–N. High values in EC as an indicator for anthropogenic pollution were confirmed during a recent sampling campaign in April/May 2010 (Figure 3). Especially in the unserviced areas in the southwest of the City as well as in the industrial area in the west-northwest EC values reach up to 1200 µS/cm and 2900 µS/cm respectively. Concentrations of heavy metals and iron were low throughout the study area. This could be due to the low solubility of iron and the heavy metals such as cadmium, lead and zinc at the prevailing high pH and the abundance of bicarbonate ions. The study proved that microbiological (including faecal) contamination and pollution is widespread throughout the City area confirming descriptions of numerous previous publications.

OUTLOOK

The successful development of the aquifer management strategy for Lusaka will depend on a thorough assessment of the groundwater potential, the current pollution status and potential risks, and the vulnerability of the Lusaka groundwater systems. Its successful implementation will largely rely on the institutional framework and capacities.

As large parts of the groundwater recharge areas have already been urbanised existing development can hardly be reversed. Of major importance to an improved protection of groundwater will hence be the development of suitable management concepts that take the specific situation in and around Lusaka into account.

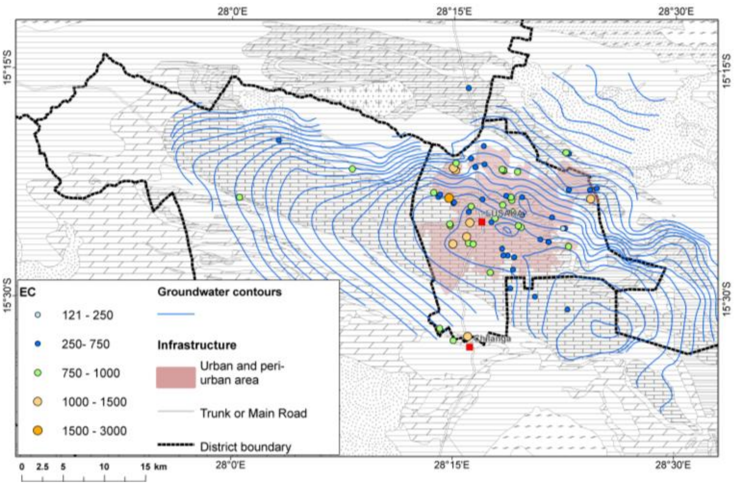

Figure 3. Distribution of electrical conductivity (in μS/cm) found in the Lusaka area during April and May 2010.

ACKNOWLEDGMENT

The authors express their gratitude to the Governments of the Republic of Zambia and the Federal Republic of Germany who financially support this program in the framework of bilateral technical cooperation agreements.

REFERENCES

Bäumle R., Kang'omba S., 2009: *Desk study and Proposed Work Program.* Report No. 2, prepared by Department of Water Affairs (DWA), Zambia & Federal Institute for Geosciences and Natural Resources (BGR), Germany; Unpubl. Report, , Lusaka, 101 p.

Hahne K., 2010: *Karstification, tectonics and land use in the Lusaka region.* Report No. 3 prepared by Department of Water Affairs (DWA), Zambia & Federal Institute for Geosciences and Natural Resources (BGR), Germany; Unpubl. Report, Lusaka, 81 p.

Hanson R.E., Wilson T.J., Munyanyiwa H., 1994: *Geologic evolution of the Neoproterozoic Zambezi Orogenic Belt in Zambia.* J. of African Earth Sciences 18/2, Elsevier Science Ltd, .pp. 135–150.

Johnson S.P., De Waele B., Evans D., Banda W., Tembo F., Milton J.A., Tani K., 2007: *Geochronology of the Zambezi Supracrustal Sequence, Southern Zambia: A Record of Neoproterozoic Divergent Processes along the Southern Margin of the Congo Craton.*-The Journal of Geology. Volume 115, pp. 355–374.

KRI International Corp., Nippon Koei Co Ltd & Japan Engineering Consultants, 2008: *The Study on Comprehensive Urban Development Plan for the City of Lusaka in the Republic of Zambia, Summary Report (Feb. 2008).* Ministry of Local Government and Housing, Lusaka City Council and Japan Int. Cooperation Agency, Lusaka, 49 p.

LCC — Lusaka City Council, 2008: *Lusaka City state of environment outlook report.* Report by the Lusaka City Council and the Environmental Council of Zambia, March 2008, Lusaka, 91 p.

Museteka L. Bäumle R., 2009: *Groundwater Chemistry of Springs and Water Supply Wells in Lusaka: Results of the sampling campaigns conducted in 2008.* Report No. 1, prepared by Department of Water Affairs (DWA), Zambia & Federal Institute for Geosciences and Natural Resources (BGR), Germany; Unpubl. Report, Lusaka, 54 p.

NWASCO — National Water and Sanitation Council, 2009: *Urban and peri-urban water supply and sanitation sector report 2008/2009.* Lusaka, 54 p.

Porada H., Berhorst V., 2000: *Towards a new understanding of the Neoproterozoic — Early Palaeozoic Lufilian and northern Zambezi Belts in Zambia and the Democratic Republic of Congo.* J. of African Earth Science 30, Elsevier Science Ltd, pp. 727–771.

Simpson J.G., Drysdall A.R., Lambert H.H.J., 1963: *The geology and groundwater resources of the Lusaka area.*– Report of the Geological Survey No. 16, Explanation of degree sheet 1528, NW. quarter; Northern Rhodesia Ministry of Labour and Mines, Government Printer, Lusaka, 59 p.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0