Spatial and Temporal Geostatistical Analysis of the Groundwater Quality in an Alluvial Aquifer of Karonga (Malawi)

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Introduction

Groundwater is the most revered source of cleaner and available water in rural areas of Malawi. However, urbanization has increased pressure on groundwater resource. More so, aquifer heterogeneity, differential abstraction and seasons result in spatial and temporal variations.

Objectives

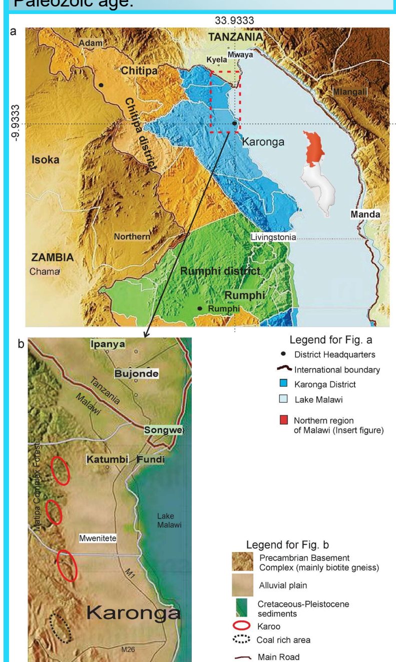
The study aimed at evaluating the seasonal disparities in groundwater hydrochemical quality for drinking and irrigation using geospatial techniques and geochemical modelling.

The Study Area

The study area is Northern Karonga.

The Entire district (within latitudes -9.9972 to -9.9108° and longitudes 33.8868 and 33.9372°) covers an area of 3,355 km² at 478 m above mean sea level with a total population of 194,572 people.

Its geomorphology consist of Karoo sediments, Cretaceous-Pleistocene Sediments and Quaternary (alluvium) formations overlaying the crystalline Basement complex of Precambrian to lower Paleozoic age.



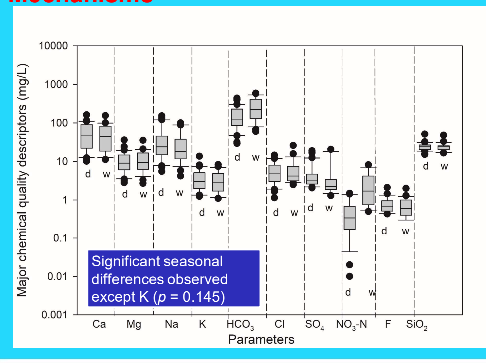
Materials and Methods

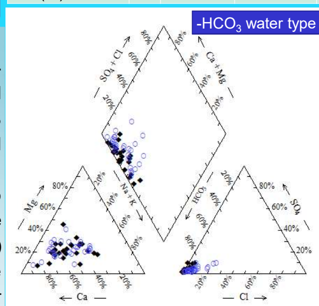
i. Field work (in situ measurements for TDS, hardness, pH, Temperature, Eh and GPS location of sampling points);
ii. Laboratory analysis of dry season samples using APHA methods (Rice et al., 2012) at State Key Laboratory of China University of Geosciences (Wuhan)
iii. Water Quality Index computation (Tiwari and Mishra, 1985)
iv. Geostatstical analysis using Kriging methods
v. PHREEQC geochemical modelling
vi. Computation of quality indices using AquaChem.
vii. Comparison with wet season published data (Mapoma et al. 2017).

Results

Hydrochemistry and Control Mechanisms

Parameter	Dry season (n=31)				Wet Season (n=25)				P-value
	N	min	max	SD	N	min	max	SD	
Eh (mV)	31	-23.1	44.7	17.883	25	-32.0	25.8	15.996	0.002
pH	30	5.7	6.9	0.326	25	6.0	7.1	0.257	0.025
Temp. (°C)	30	26.9	36.3	1.674	25	26.8	30.3	0.786	**0.726**
Turbidity (NTU)	30	0.2	42.1	10.454	13	0.0	23.0	6.169	0.124
EC (µS/cm)	30	215	1321	319	25	213	1696	476.980	0.001
TDS (mg/L)	30	106	657	158	25	105	850	231.981	< 0.05
Hardness (mg/L)	30	35.7	535	125	25	42.0	418	109.395	**0.195**
Al (µg/L)	-	-	-		14	0.3	6.6	2.099	-
As_T (µg/L)	30	0.3	8.3	1.664	25	0.4	14.5	3.366	< 0.05
Fe_T (µg/L)	24	0.1	4309	1160	25	2.2	5336	1365	**0.203**
Mn_T (µg/L)	30	0.6	507	169	25	0.1	804	211	0.053
Ion Balance	30	-4.47	5.87	2.776	25	-4.92	4.94	2.927	**0.383**
$\delta^{18}H$ (‰)	30	-36.2	-26.9	2.452	25	-35.3	-18.6	4.524	0.001
$\delta^{2}O$ (‰)	30	-5.5	-3.9	0.360	25	-5.6	-3.7	0.492	**0.983**





✓ Table indicates seasonal differences for in situ measurements for Eh, pH, EC, TDS
✓ Stable isotope ($\delta^{18}O$ and $\delta^{2}H$) analysis for both seasons indicates the groundwater source is infiltrating rainwater in the uplands that migrates down gradient towards Lake Malawi.

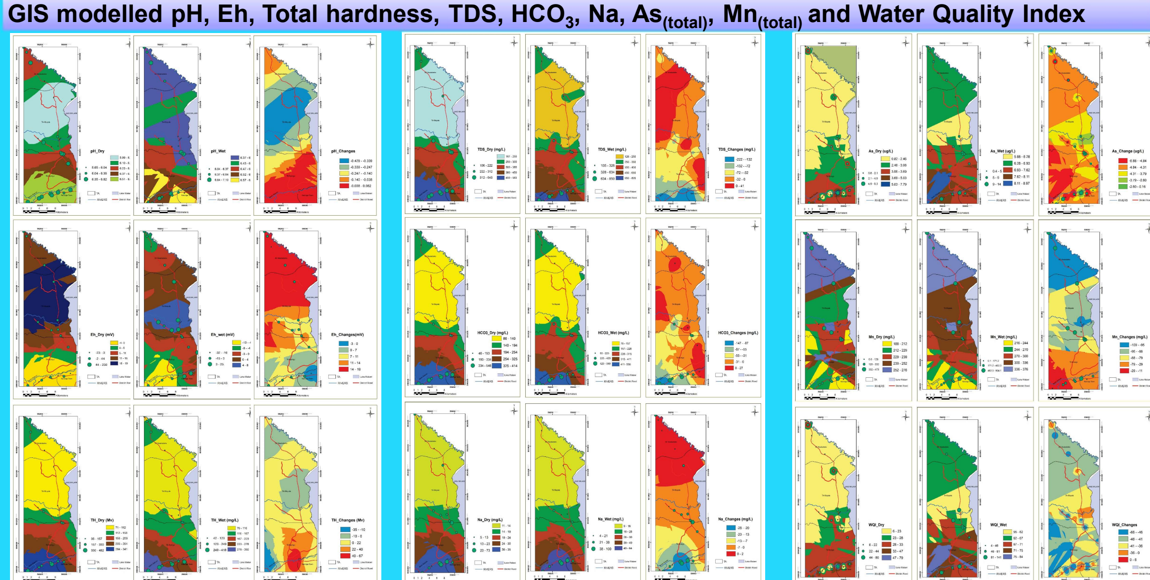
Aquachem Results:

✓ System favours cation exchange (72% of samples) as source of Na.
✓ Carbonate weathering (53%) dominates as the mechanism controlling the general chemistry
✓ Sources of Ca and Mg are likely from limestone-dolomite weathering (53%) followed by ferromagnesian mineral sources

PHREEQC Geochemical Modelling

✓ Groundwater consistent of undersaturation conditions with respect to calcite, dolomite, gypsum and halite.
✓ Thus, dissolution of these mineral phases is favoured to equilibrate the system.

GIS modelled pH, Eh, Total hardness, TDS, HCO_3, Na, $As_{(total)}$, $Mn_{(total)}$ and Water Quality Index



✓ Spatial variations are prominent for all parameters modelled.
✓ In terms of quality for drinking, dry season groundwater in the area is better than wet season.
=> Probably effect of poor oxygenation (lower Eh and elevated pH)
✓ There is evidence of seasonal changes in water quality. More prominent changes in the south of the study area.
✓ Unlike the wet season (Mapoma et al, 2017), the WQI improved in dry season with a good to excellent water for drinking and irrigation.

Conclusions and Recommendations

i. Differences in spatial and temporal hydrochemistry was observed
ii. No marked disparities in terms of geochemical controls with carbonate weathering being the dominant geochemical process.
iii. It is recommended that communities in the area follow good water use practices (GWUP) in wet season to mitigate water related health issues.
iv. The study recommends sensitization of the communities on GWUP and proper management of their groundwater.

References

Mapoma, H. W. T., Xie, X., Liu, Y., Zhu, Y., Kawaye, F. P., and Kayira, T. M. (2017). Hydrochemistry and quality of groundwater in alluvial aquifer of Karonga, Malawi. *Environmental Earth Sciences*, *76*(9), 335.

Tiwari, T., and Mishra, M. (1985). A preliminary assignment of water quality index of major Indian rivers. *Indian J Environ Prot, 5,* 276–279

Rice, E.W., Baird, R.B., Eaton, A.D., Clesceri, L.S. (eds). (2012). Standard methods for the examination of water and wastewater, 22nd Edition. American Public Health Association, American Water Works Association, Water Environment Federation, Washington