Geophysical Research Abstracts, Vol. 7, 00296, 2005
SRef-ID: 1607-7962/gra/EGU05-A-00296

Preliminary isotope balance model applicable for evaporative water loss estimation and ecological management in the source regions of the Nile

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Since the intervention of the IAEA in isotope hydrological study in Ethiopia via its TC projects very useful amount of isotope data have been obtained and used in groundwater and geothermal resources assessment and management. This work uses the data available in various projects of the IAEA TC program to calibrate a preliminary isotope balance model that is applicable in water resources and ecological investigation and management in the source regions (Ethiopian highland and Equatorial Lakes) of Nile river.

The work develops a simple yet sound water isotope model (δ^{18}O and δD) to investigate the water flux particularly the evaporative water loss from lakes, rivers, swamps and wetlands in the region. Furthermore the model is applicable in understanding and tracing solute pathways in complex systems such as swamps and interconnected lakes. Given that evaporative water loss from open water bodies is estimated using physical approaches, the isotope model can be used in estimating total water inflows in ungauged lake basins, which is usually the case in the region. Cases from Ethiopian part of the Nile Basin and some cases from the Equatorial African lakes are presented.

The model combines isotope and water balance equations of open water body. Combining the two this work proposes a Modelled Regional Evaporation Line-MREL (figure 1) as a reference with which the isotopic composition of any water body in the Basin is compared to gain a rapid quantitative/qualitative hydrological fluxes and to

understand the hydrography (catchment characteristics; degree of interconnection in lacustrine and swamp systems; salinity; surface water- groundwater interaction, water residence time etc) of large and complex systems. Table 1 shows how to interpret the comparison between MREL and the isotopic composition of water bodies or river waters emerging from different sub basins in the region in terms of their evaporative water loss and hydrography. Some examples (the majority IAEA data) of measured isotopic composition of water bodies from Nile Basin are included in the table.

Figure 1 . MREL from various x (Evaporation to inflow ratio) values under upper Nile hydro-climatic conditions.

δ^{18}O	δD	x (E/I)	Lake Class	*Some examples*
$<$ $4.5\%_{\circ}$	$<$ $27\%_{\circ}$	$<$ 0.5	Outflow dominates evaporation, Major loss of inflow is to outflow	Lake Tana during wet seasons Small artificial reservoirs like Koka, Dire Lake Victoria (tropical Africa)
4.5	27	0.5	Outflow equals evaporation, Inflow equally partitioned between evaporation and outflow	Lake Tana on annual scale Lake Wonchi Lake Zengena, Lake Tirba
4.5-6.0	27-36	0.5-0.75	Evaporation slightly dominates outflow loss, or the important part of inflow is lost to evaporation	Lake Tana during dry season, Lake Naivasha(Kenya)
6.0-7.2	36-42	0.75-1	Evaporation dominated Lake, Evaporation is the dominant water loss, minor outflow	Laks Langano, Ziway, Shalla, Babogaya
7.2	42	1	Terminal lake	Lake Hora
>7.2	>42	Should be computed based on site specific data	Lakes with hydrogrphic or lake connectivity effects. Isotopic composition of the lakes not entirely the function of their hydrology but also that of their catchment characteristics • Lake with upstream swamps • Lakes with large catchement to lake area ratio • Lakes fed by upstream lakes	Lakes Gamari, Abijata, Hayk,
14	82	"	The maximum attainable composition for lake with simple catchement	
>14	>82	"	Small lakes with upstream evaporated water inflow at their shrinking stage	Lake Gamari
other	other	x $\delta^{18}O$ $\neq$ $\neq x$ δD	Salt Lakes affected by dissolved salt effect	Lake Afrera

Table 1. The relation between isotopic compositions of water bodies and their E/I under upper Nile basin hydroclimate conditions.

In addition to the modeling approach developed for the upper Nile basin, this work discusses the differences in isotopic composition of meteoric waters in the Nile basin as an opportunity of quantifying water flux and tracing sources of groundwater recharge

around the confluence areas where isotopically depleted and high d-excess waters coming from the Ethiopian highland (70% of the Nile flow) merges with isotopically enriched low d-excess waters coming from the equatorial lakes of Africa (20% of the Nile flow).

This work envisages the refinement of the simple model, its extension to other water bodies in the Nile and its inclusion in the water resources management initiatives/activities such as the "Nile Basin Initiative Program" which is a partnership of the riparian countries of the Nile (Egypt-Sudan-Ethiopia-Kenya-Uganda-Brundi-Uganda-Rwanda-DR.Congo).