Policy Brief

APRIL 2021

Groundwater Resources Management in the Lake Victoria basin, Kenya

Kenya is categorized as a water scarce country with per capita freshwater endowment of about 527m^3 (NWP 2019) against the UN standard of minimum 1,000m^3 for countries which are not water stressed. Groundwater is therefore, a crucial resource to the countries efforts of achieving the Sustainable Development Goal (SDG) 6 of ensuring availability and sustainable management of water and sanitation for all. Despite the huge water resources of Lake Victoria, surface water supply for portable purposes in the surrounding areas is still low due to costs of treatment and infrastructure. As a result, dependence on groundwater is high, being driven by high population density (300 persons per km^2) and economic activities in the region. In parts of Lake Victoria basin-Kenya, groundwater resources accounts for around 30% of portable water supply (Olago 2019).

Figure 1. Groundwater use is common in Kisumu city and the rural Kano area. This includes boreholes and shallow wells, which are either publicly or privately owned.

Nitrate pollution

Nitrate is emerging as the most widespread groundwater contaminant associated with anthropogenic activities. High nitrate concentrations (> 50 mgL^{-1}) in water are both a health and environmental hazard promoting eutrophication, poses high risks to methemoglobinemia (blue baby syndrome) in infants and colorectal cancer (Kendall et al., 2007; Schullehner et al., 2018). Given the high population density, urbanization and industrialization being witnessed in the Lake Victoria basin, groundwater resources have become vulnerable to anthropogenic contaminants. The groundwater pollution risk in the basin's major urban centers (e.g. Kisumu) is intensified by inadequate sewage network and treatment infrastructure. It is reported that less than 30% of households in these urban centers are connected to sewer system (LVBC, 2017). In addition, unplanned urban expansion have resulted in the mushrooming of slums and high discharge of untreated wastewater (Nyilitya et al., 2020). This happens against the backdrop of limited sciencebased monitoring data in the basin and lack of clear information on groundwater nitrate pollution sources. The purpose of this study was to establish chemical water quality status and sources of groundwater nitrate pollution in the basin using the case of Kisumu City and its adjacent Kano plains.

Study findings

Chemical groundwater quality

Nitrate concentrations in Kisumu and the Kano area showed a wide variation ranging from < 0.04 to 70.0 mg L^{-1} and from < 0.04 to 90.6 mg L^{-1} in boreholes and shallow wells, respectively. Highest nitrate concentrations (50 – 91 mg L^{-1}), mostly above the WHO limit, were observed in shallow wells located in Kisumu City and boreholes located in Ahero town (Fig. 2). Seasonally, nitrate concentrations in shallow wells were significantly higher in the wet season compared to the dry season. On the other hand, nitrite concentrations were significantly higher (and mostly above WHO limit of 0.2 mg L^{-1}) in the dry season compared to the wet season for both boreholes and shallow wells. In this study, 63% of boreholes and 75% of shallow wells exceeded the WHO limits of nitrate and nitrite, respectively (Fig. 3).

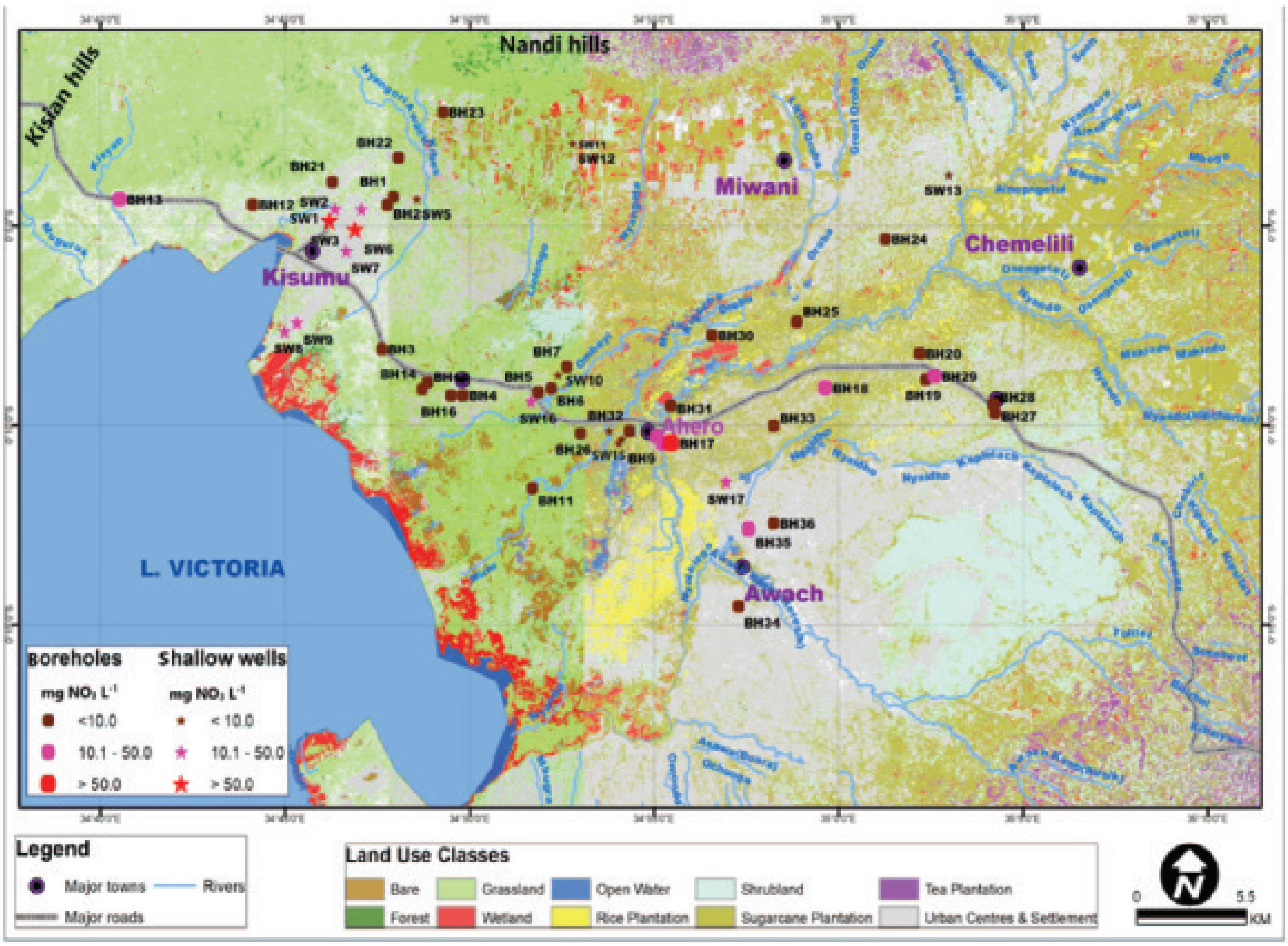

Figure 2. Land use map and groundwater nitrate concentration of Kisumu and the Kano area, represented in ranges by bullet sizes; squares for boreholes, stars for shallow wells.

Groundwater in the area has also high fluoride levels as shown in Fig. 4 where 70% of the samples exceeded the WHO limit (1.5 mg L^{-1}) for drinking water. This is a health risk since excessive intake of fluoride is known to cause dental or skeletal fluorosis, cancer, low hemoglobin levels, osteoporosis, reduced immunity, and thyroid disorders.

Electrical conductivity ranged from 248 to 2,562 µS cm^{-1}, with 90 % of the samples having exceeded the WHO limit of 500 µS cm^{-1} for fresh water. This is caused by increase in dissolved salts and is an indicator of level of salinity in water.

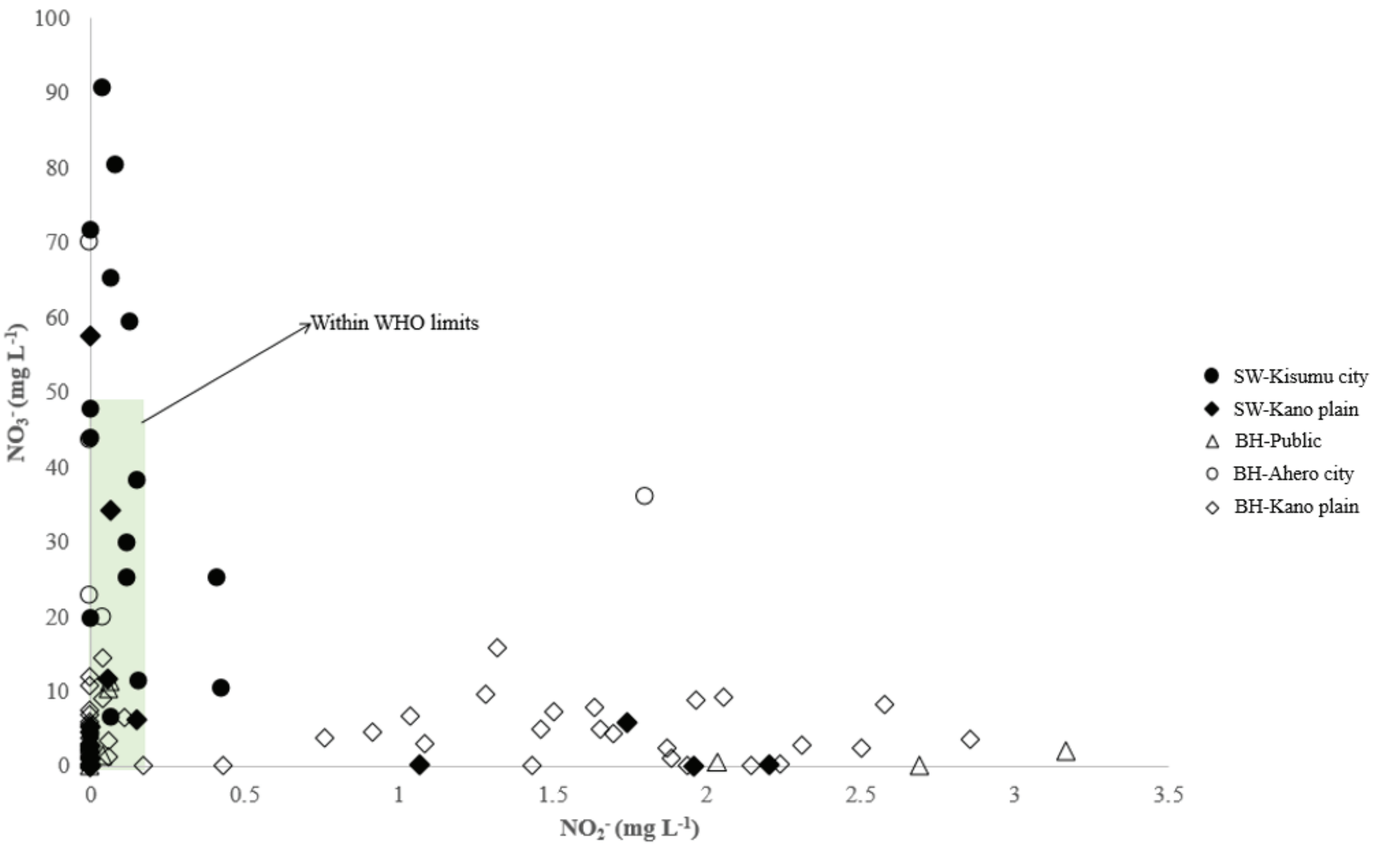

Figure 3. Nitrate and nitrite concentrations in groundwater from Kisumu and the Kano area exceeded the WHO limits in 63% of boreholes and 75% of shallow wells; SW = shallow well and BH = bore hole.

Sources of groundwater nitrate pollution

By applying hydro-chemical and isotopic (δ^{15}N- and $\delta^{18}O$-NO_3^-, and δ^{11}B) methods, it was revealed that sewage was the main source of nitrate input in shallow wells located in informal settlements in Kisumu City (Obunga, Nyalenda), in boreholes located in Ahero town and those in public institutions like schools. In locations where sewage dominates groundwater nitrate input, high nitrate concentrations above the WHO limit were also observed. These areas are characterized by high human population density and lack of sanitary facilities. In addition, pit latrines are commonly used in Kisumu's informal settlements and in schools and homesteads within the Kano area. Sewage contaminated streams (e.g. Auji) pass through Kisumu's Nyalenda slums, while Ahero town has no centralized sewage treatment facility (Fig. 5). Therefore, it appears that infiltration of untreated sewage and human wastes into groundwater is happening in the informal settlements of Kisumu, Ahero town and in some public institutions.

On the other hand, manure was found to be the major source of nitrate input in shallow wells and boreholes located in the Kano area and in some formal estates of Kisumu (Migotsi and Kibos). These locations recorded low nitrate levels (< 10 mg L^{-1}) and are characterized by livestock keeping and small holder farming of food crops – implying some level of animal manure contamination of groundwater.

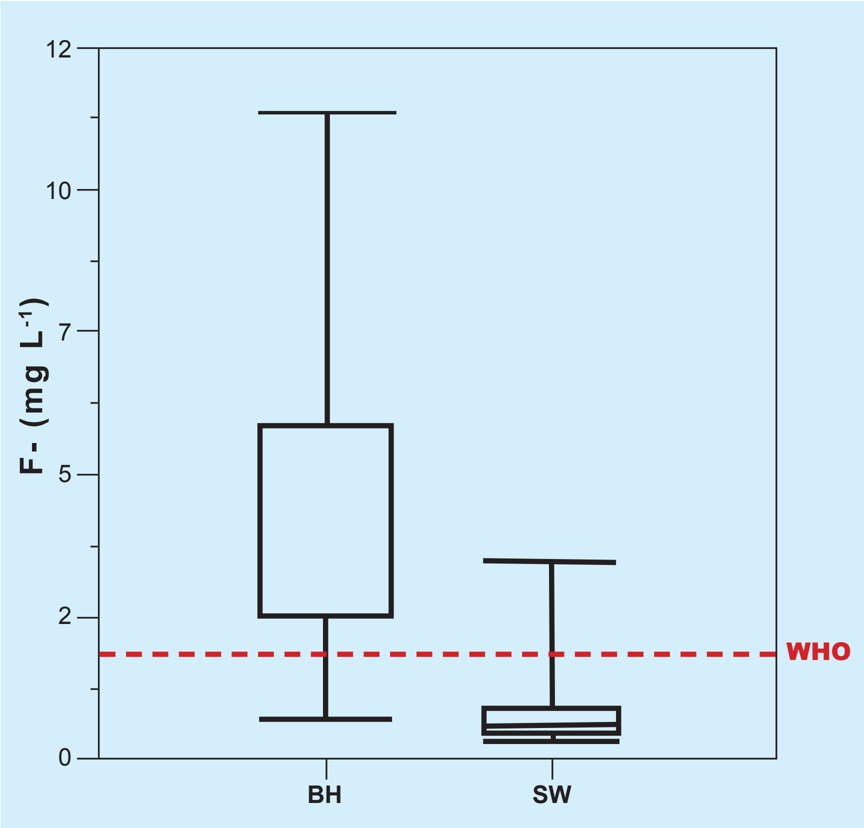

Figure 4. Fluoride concentrations in boreholes (BH) and Shallow wells (SW) in Kisumu and the Kano area. Red (broken) line shows WHO threshold (1.5 mg L^{-1}) of fluoride in drinking water, which was exceeded by 70% of the samples.

Groundwater field sampling and *insitu* measurements

Policy and practice interventions and measures

1. Improved wastewater treatment, including nutrient removal and expansion of sewage infrastructure also covering informal settlements in the major urban centers of the basin.
2. Environmental and sanitation awareness campaigns to slum dwellers and provision of incentives to develop formal planning for urban expansion.
3. Treatment of borehole water before use – focused on de-fluoridation, desalination and removal of microbial pathogens.
4. A phase-out program in the use of pit latrines and shallow groundwater in major towns.
5. Expansion of surface water (i.e. from Lake Victoria) treatment capacity to increase water supply in slums and rural areas in order to gradually eliminate the use of shallow groundwater.

Figure 5. Sewage contaminated streams and burst sewer lines are a major risk to groundwater nitrate pollution especially in Kisumu's informal settlements and in Ahero town.

Acknowledgements

This study was conducted by Ghent University and the University of Nairobi with TEAM Project funding No. ZEIN2016PR423 from the Flemish Interuniversity Council (VLIRUOS), Belgium. We also acknowledge the Ministry of Water, Sanitation and Irrigation (Kenya) for the human resources support.

Technical guidance for this work contributed by:

Prof. Pascal Boeckx
Isotope Bioscience Laboratory – ISOFYS,
Department of Green Chemistry and Technology,
Faculty of Bioscience Engineering,
Ghent University, Belgium

and

Dr. Stephen Mureithi
Department of Land Resource Management and Agricultural Technology
Faculty of Agriculture
University of Nairobi, Kenya

References

Lake Victoria Basin Commission (LVBC) and GRID-Arendal, 2017. Lake Victoria Basin: Atlas of Our Changing Environment. Lake Victoria Basin Commission and GRID-Arendal, Kisumu and Arendal

Kendall, C., Elliott, E.M., Wankel, S.D., 2007. Tracing anthropogenic inputs of nitrogen to ecosystems, in: Michener, R., Lajtha, K. (Ed.), Stable Isotopes in Ecology and Environmental Science, Blackwell Publishing Ltd., Oxford, UK, pp. 375 – 449.

NWP, 2019. National Water Policy, Ministry of Water & Sanitation, Republic of Kenya. https://doi.org/10.1017/S0022278X00014853.

Nyilitya, B.,Mureithi, S., Boeckx, P., 2020. Tracking Sources and Fate of Groundwater Nitrate in Kisumu City and Kano Plains, Kenya. Water 12, 1–18.

Olago, D.O., 2019. Constraints and solutions for groundwater development, supply and governance in urban areas in Kenya. Hydrogeol. J. 27, 1031–1050

Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C.B., Sigsgaard, T., 2018. Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. Int. J. Cancer 143, 73–79.

Correspondence

Dr. Benjamin K. Nyilitya
National Water Resources Department –
Water Research Division
Ministry of Water, Sanitation & Irrigation,
Maji House, Nairobi
P O Box 49720-00100, Nairobi.
Email: kyalob73@yahoo.com

University of Nairobi

GHENT UNIVERSITY

Republic of Kenya
Ministry of Water, Sanitation & Irrigation

vliruos SHARING MINDS, CHANGING LIVES