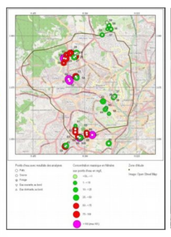

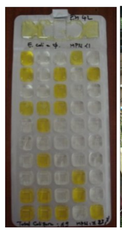




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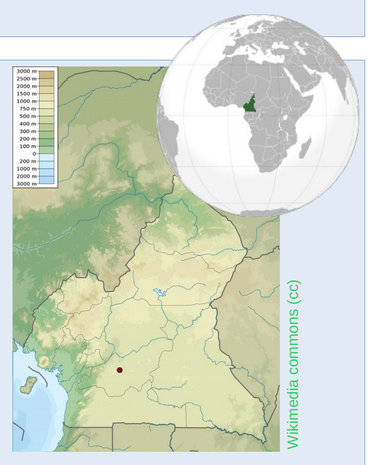
Anthropogenic water types in urban groundwater in Yaounde, Cameroon

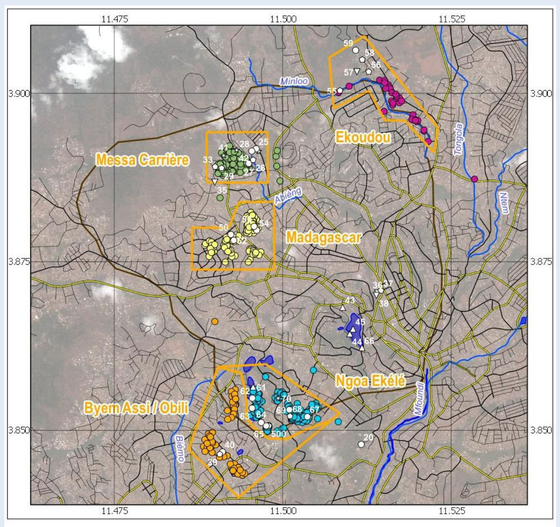
Kringel, Robert[2], Rechenburg, Andrea[3], Kuitcha, Dorice[4], Kengne, Ives[5] and Fomo, Marie Antoinette[1]

Anthropogenic groundwater types dominated by nitrate, ammonium, chloride and sodium are caused by input of urine from decentral sanitation into an urban aquifer in a sub-saharan capital

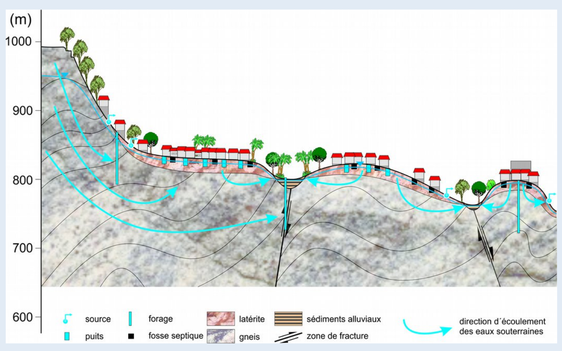
WaSH survey in Yaounde – use of urban groundwater

As an integral part of a Water, Health and Sanitation (WaSH) survey in 2012, 35 groundwater water points in Yaounde / Cameroon **(Fig. right)** have been sampled and analysed for an extended range of chemical and microbiological parameters at the end of tropical dry season. The study has been carried out within the framework of German-Cameroonian bilateral cooperation.
(Fig. below) Water points (WP) and households in their vicinity were chosen to represent different hydrological and socio-economic housing conditions in the Cameroonian capital .



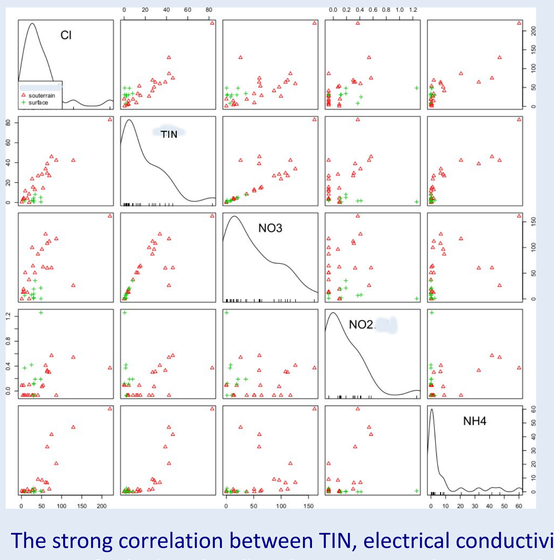


The WaSH survey has shown that 90 % of the urban population (survey zone) are connected to the central water supply, if the volume to meet the demand could be supplied. During frequent water cuts, only 65 % of the population can access or afford safe drinking water, forcing the rest to *resort to urban groundwater*
Fig. below: sampling of an unprotected spring.



(Fig. left) Porous laterite aquifer on top of fractured old basement rock. The upper aquifer provides numerous shallow wells, natural springs **(Fig. above)** and a few deep drilled production wells penetrating to the basement. *Ubiquitous decentral sanitation* in dense unplanned quarters, *cess pits* and unserviced *septic tanks* are in close proximity to WP's without protection zones.

From rainwater to urban groundwater

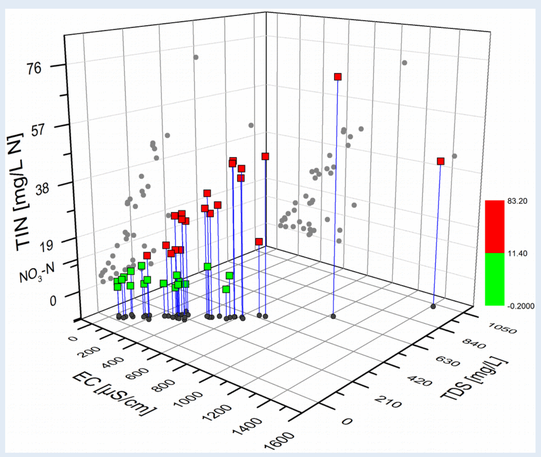


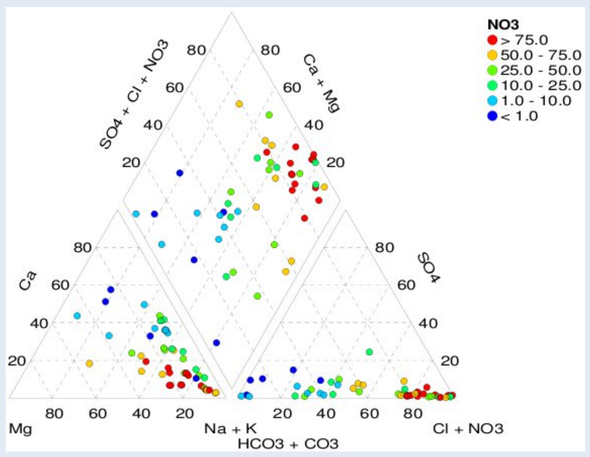
Groundwater under **landuse forest** originates from acidic, weakly mineralized and nitrogen poor rainwater. A moderate increase in dissolved salts through rock weathering, deposition and plant litter occurs on the flow path (Braun et al. 2005).

The scatter plot matrix **(Fig. left, read triangles for groundwater)** shows the correlation of chloride (Cl) with nitrate (NO3), nitrite (NO2) and ammonium (NH4) for **urban landuse** groundwater. Positive correlation with chloride is found for both nitrate and ammonium. The sum parameter total inorganic nitrogen (TIN) (NO3+NH4+ NO2) shows a better correlation. While chloride in forest groundwater can reach up to 1 mg/l, the median value in Yaounde is 27 mg/l.

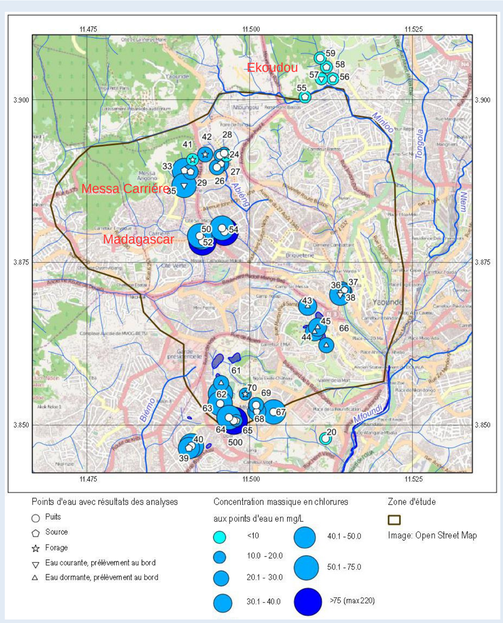
The spearman rank correlation coefficient for sodium shows decreasing correlation strenght for Cl > EC > TDS > TIN = K > NH4 > HCO3 > NO3.

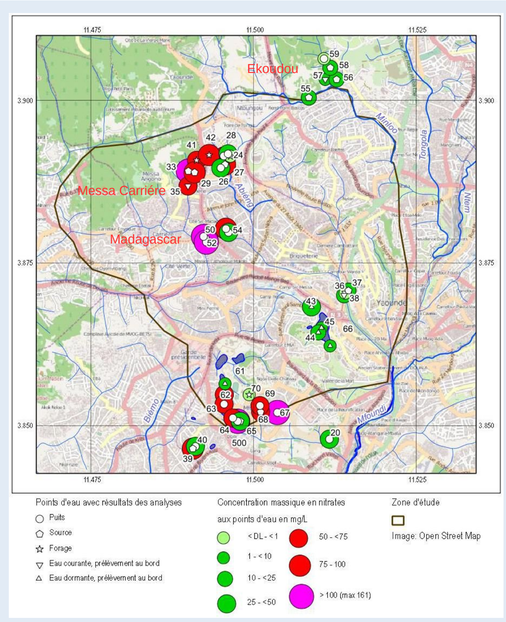
The strong correlation between TIN, electrical conductivity/calculated TDS **(Fig. left below)** points to *urine* as the primary source of salts (NaCl, KCl) and nitrogen in urban groundwater. The piper plot **(Fig. right below)** shows the compositional relationship and dominance of potassium (K), sodium (Na), chloride (Cl) + nitrate (NO3).





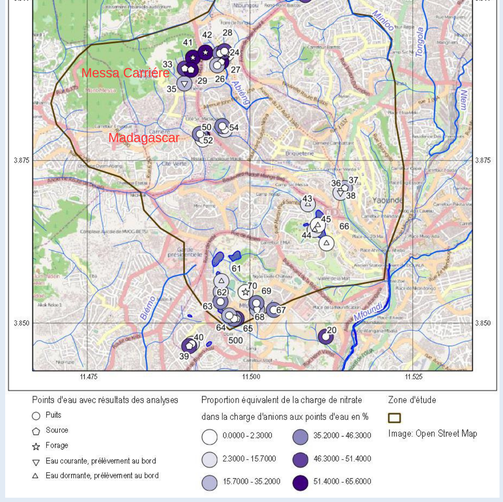
Spatial distribution of chloride and nitrate concentrations





The distribution of chloride **(Fig. above left)** shows little affected water points (WP) in periurban "Ekoudou" (North), significantly affected WP's in unplanned "Messa Carriére" near to the recharge area and strongly affected water points in urban "Madagascar". Nitrate concentration **(Fig. above right)** follows this pattern closely. More than 50 % of the WP's were found to exceed the WHO guideline value for nitrate of 50 mg/l with a median of 51 mg/l for dug wells and of 76 mg/l for springs. Unacceptable concentrations (>50 mg/l)were detected *just a short distance downstream* of the onset of unplanned, dense settlements. Ammonium was equally detected in high concentrations with a median value of 6 mg/l (dug wells) and 3 mg/l (springs). These contamination levels were found at the end of dry season in a fast flowing groundwater environment with rapid recharge of 86 mm/a during the rainy season (Fouepe Takounjou et al. 2009).

Anthropogenic groundwater types



The *coexistence of nitrate and ammonium* in shallow wells and springs indicates that the nitrification process is incomplete in the shallow laterite aquifer. A high anthropogenic nitrogen load, short reaction times and adverse conditions for nitrification such as the *acidic pH* are invoked to explain the phenomenon.

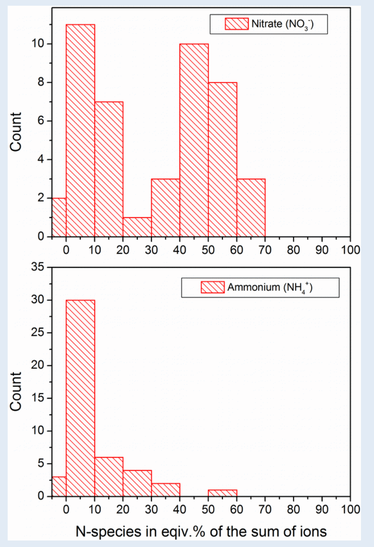
N.B.: The proportion of the electrical charge of an ion in relation to the other ions present (cation or anion) is a direct measure of its significance for the groundwater composition. The proportion is used to classify into water types which stand for the dominating (geo)chemical processes.

Fig. right shows that *nitrate* can reach a proportion of up to 65% in the equivalent sum of anions. *Ammonium* easily reaches up to 35% in the equivalent sum of cations.

This leads to the consequence that *anthropogenic water types* like:

- Na-Ca-NO3*-Cl-HCO3,
- Na*-Cl-NO3 and
- NH4*-Na-HCO3*-Cl

where found.



The spatial distribution of the equivalent proportion of nitrate in the sum of anions **(Fig. above)** is useful to demonstrate the *anthropogenic influence independent of concentrations*: while still of acceptable quality, periurban "Ekoudou" groundwater shows the same degree of nitrate influence like densely settled unplanned "Messa Carriére" with largely unacceptable groundwater quality.

Preventing urine from entering the groundwater would significantly improve urban groundwater quality with respect to nitrogen and salts. Additionally, the reuse of urine as fertilizer could help close nutrient cycles in urban/periurban agriculture.

Resources and acknowledgements

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