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# COMBINED USES OF WTF, CMB AND ENVIRONMENTAL ISOTOPES TO INVESTIGATE GROUNDWATER RECHARGE IN THE THIAROYE SANDY AQUIFER (DAKAR, SENEGAL)

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## CONTEXT AND AIM OF THE STUDY

The sahalien climate in Dakar region is characterized by low mean annual rainfall (450-500mm) occurring exclusively during the rainy season which lasts 3-4 months (July to October), high temperature (between 21 and 29°C) and high evapotranspiration (561 mm). About 1/8$^{th}$ of the total precipitation is estimated to percolate through the sandy soils; the remainder is lost through evaporation and run off to local depression zones. Climate conditions and increasing water demand for the Dakar city require accurate estimation of groundwater recharge for proper and sustainable management.

## PHYSICAL SETTING

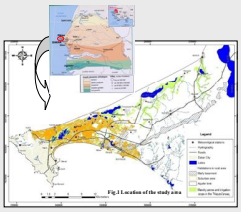


Fig.1 Location of the study area

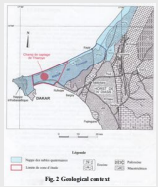


Fig. 2 Geological context

Research area is located in the Midwestern part of Senegal. It extends as a peninsula and bounded between 14°55' and 14°35'N and 17°3 and 17°05'E (Fig.1).

The main morphological feature are the eastern depression " Niayes" along the ocean façade. The studied hydraulic system is located from Dakar to Kayar (300km$^2$). The shallow Thiaroye aquifer reservoir is composed of unconsolidated quaternary sand.

Geology of the area is registered on the general context of the senegalo-mauritanian basin (fig.2).

## MATERIEL & METHODS

In order to investigate groundwater recharge approaches are based:

- On groundwater–level data with the daily water table fluctuations at different observation wells (P3.1 & PSQ1) located in the suburban area in response to precipitation during time period (2010-2011). Data collected with "Thalimede Orpheus mini" recorders from February 2010 to March 2011 and a specific yield for the sandy matrix between 15 and 32% are used to computed recharge rate.
- Chloride masse Balance approach widely used in arid regions was considered in this context to assess the recharge by rainwater. Data concern the Cl concentrations in drainage water in the unsaturated zone and in precipitation. Chloride profiles were conducted at different sites in the north-eastern part of the aquifer system.
- Stables isotopes of water ($\delta^{18}O$ and $\delta^2H$) and the tritium ($^3H$) measured in groundwater and precipitation from different stations were used to investigate origin and age of groundwater.

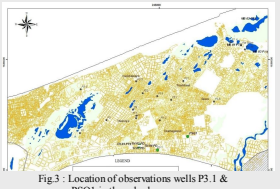
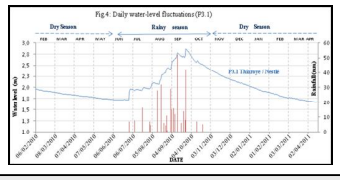
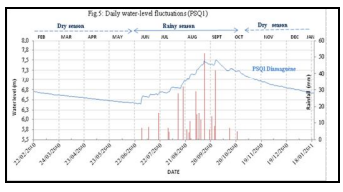


Fig.3 : Location of observations wells P3.1 & PSQ1 in the suburban area





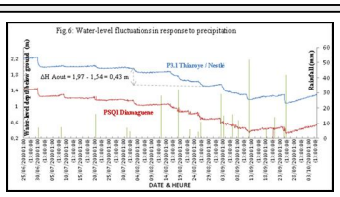




**Tab.1: Monthly change in water level and groundwater recharge in the Thiaroye basin**

| Wells | Month | Change in water level, ΔH(mm) | Recharge(mm) |
|---|---|---|---|
| P.3.1 Thiaroye / Nestlé | June | 592 | 29 |
| | July | 80 | 12 |
| | August | 430 | 63 |
| | Sept | 570 | 85 |
| PSQ1 Diamagueune | June | 150 | 22 |
| | July | 165 | 24 |
| | August | 459 | 68 |
| | Sept | 482 | 72 |

Using the Water Table fluctuations method (Schict & Walton, 1961) the computed mean recharge during June, July and August 2010 is ***180mm/y*** with 331mm annual rainfall recorded in the Thiaroye basin (Tab.1)





## RESULTS & INTERPRETAIONS

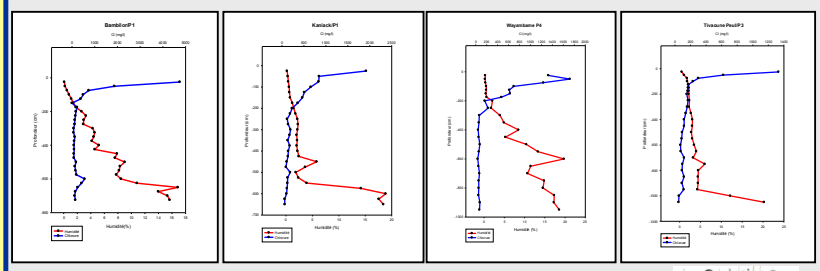




**Fig. 7: Chloride and humidity profiles at different Bambilor, Kaniack, Wayabame and Tivaouane Peulh sites**

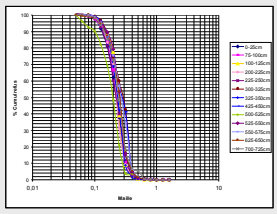




Fig.9: Particle size distribution of the Bambilor profile

**Fig.8 : Chloride profiles in unsaturated zone at Kaniack, Bambilor, Wayabame and Tiv ; Peulh sites**

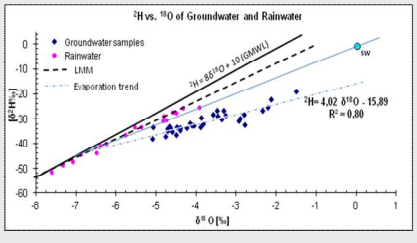
Tab.2 : Computed recharge rates at Bambilor, Wayabame, Kaniack and Tivaouane Peulh sites

| Site | Profil | Depth (cm) | Cl (Rain water) mg/L | Cl (Unsaturated Zone ) mg/L | Precipitation (mm) | Recharge (mm/y) |
|---|---|---|---|---|---|---|
| Bambilor | Pits 235 (P1) | 200 - 550 | 2.6 | 124.2 | 470.8 | 9.9 |
| Wayabame | Pits 128 (P2) | 300 - 950 | 2.6 | 65.7 | 470.8 | 18.5 |
| Tiv. Peulh | P2.7 (P.3) | 500 - 1050 | 5.1 | 91.7 | 442 | 23.7 |
| Kaniack | Pits 232 (P3) | 250 - 650 | 20.6 | 136.38 | 488 | 73.7 |

Daily groundwater level fluctuations evidence a systematic response to rainfall pulses at P3.1 and PSQ1 wells (Fig.4, 5). Analysis of calculated recharge can however, suggest an overestimated recharge rate which range from 0 to 81mm/year by other methods (Fig.6, Tab.1). The unsewered urban zone is likely to induce groundwater quality deterioration (Cissé Faye, 2004) and induced recharge which can lead to water table increase.

The Chloride Masse Balance approach widely used for estimating low recharge rates in arid regions (Cook et al. 1994; Edmunds & Gaye, 1994) was considered in this context to assess the recharge by rainwater. Obtained recharge rates (Tab.2) with chloride profiles at different sites (Fig.7) in the northeastern part of the aquifer system, chloride contents of rainwater (2008) range values between 9 and 73mm/year. The CMB approach uncertainties in our context can be linked to potential Cl contribution from other sources such as marine environmental or anthropogenic input.

The $\delta^{18}O$ and $\delta^2H$ in precipitation are linearly similar to the world meteoric water line (WMWL) (Craig 1961), with an equation of $\delta^2H = 7.40\delta^{18}O + 5.82$ ($r^2 = 0.98$); which appears to be similar to the local water meteoric line (LWML) ($\delta^2H = 7.93\delta^{18}O + 10.09$) defined by Travi (1987). Groundwater samples values show a significant depletion in $\delta^2H$ in relation to the WMWL





and deviation is observed with best fit curve of $\delta^2H = 4.02\delta^{18}O - 15.9$ ($r^2 = 0.80$).

## CONCLUSION

The overestimation of the recharge rates observed with the WTF method shows a probable contribution of induced recharge in the urban context of the Thiaroye aquifer. Results obtained with WTF and CMB methods reveal that wide variety of approaches should be applied in estimating recharge in order to reduce uncertainties and increase confidence in recharge estimates. As reported by Fontes et al. (1991) the trend of groundwater samples in $\delta^2H$ vs. $\delta^{18}O$ is typically characteristics of the sahalien aquifers. Relationship of $\delta^{18}O$ and $\delta^2H$ together with low $^3H$ values (0.8-5.3TU) shows clearly that the Thiaroye shallow groundwater is related to modern rainfall recharge.