CHARACTERISING THE HYDRAULIC PROPERTIES OF QUATERNARY SANDS ATTENUATING FAECAL EFFLUENT IN THE THIAROYE AQUIFER OF DAKAR USING PEDO-TRANSFER FUNCTIONS

Pouye A., Cissé Faye S., Diedhiou M., Gaye C.B.

Geology Department, Faculty of Sciences and Techniques, University Cheikh Anta Diop, Dakar

Groundwater Quality 2019

Background

In unconfined sedimentary aquifers, the unsaturated zone plays an important role in the attenuation and transfer of solutes, particles (e.g. viruses, bacteria) and non-aqueous phase liquids from human effluents to the surface and near-surface environments, especially in densely populated urban areas. In Dakar (Senegal), the most pervasive source of human effluent derives from on-site sanitation facilities primarily in the form of septic tanks. Here, we seek to develop an improved understanding of the hydraulic properties of the unsaturated zone to evaluate pollutant transport from these sources in the Thiaroye aquifer of unconsolidated Quaternary sands in Dakar.

Material and methods

- **Study area:** Unconfined sand aquifer of the Cape Verde peninsula in the Dakar region;
- **Field activities:** 20 logs of the unsaturated zone (up to 3 meters) following core sampling at a watershed scale (fig 1);

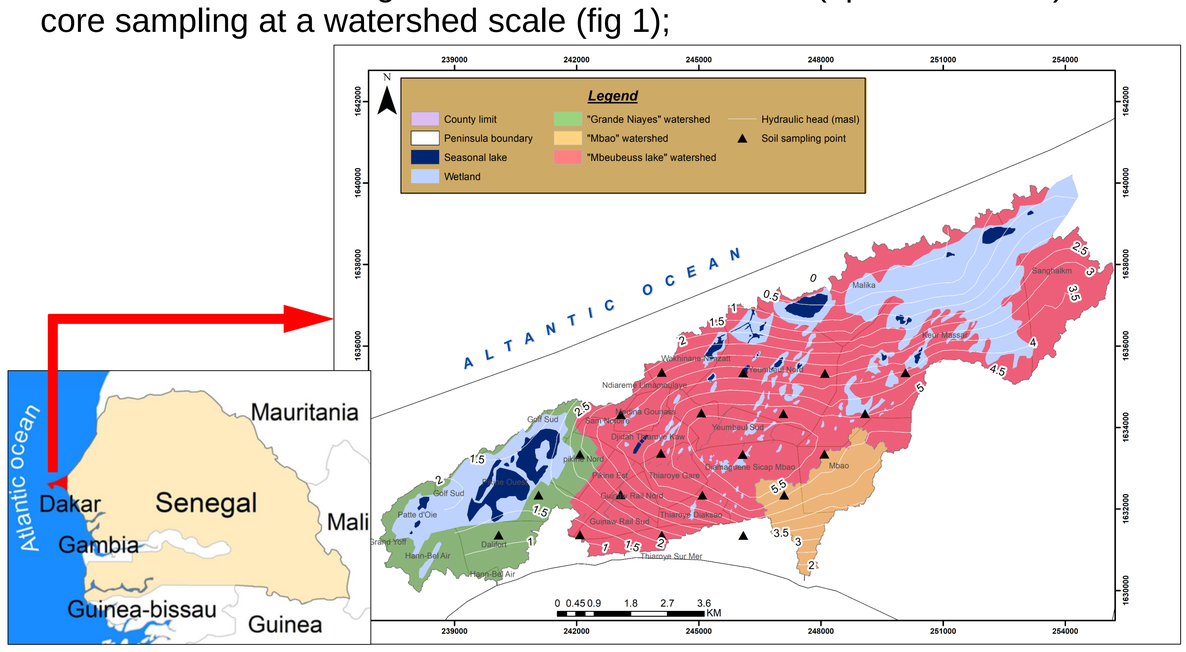

Figure 1. Location of the study area

- **Laboratory measurements**: Gravimetric analyses are used to assess bulk density, moisture content and total porosity; Particle-size analyses are carried out by hydrometer tests according Milford protocol (Lesikar et al, 2005); Organic matter assessed by digestion with hydrogen peroxide (Gee et Bauder, 1986).

Figure 2. Field investigation (a) core sampling and lab measurements (b) hydrometer test

- **Pedo-transfer functions** are used to describe water retention and hydraulic conductivity curves;

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{[1+(\alpha h)^n]^{1-1/n}}$$ Van-Genuchten equation (1980)

$$K(S_e) = K_0 S_e^L \left\{1 - \left[1 - S_e^{n/(n-1)}\right]^{1-1/n}\right\}^2$$ Mualem equation (1976)

Where θ_r and θ_s are residual and saturated moisture respectively, α *and* n are the curves shape parameters, L is an empirical parameter, h is pressure head, K_0 the saturated hydraulic conductivity and S_e is the effective saturation.

- **ROSETTA** is used to estimate Van-Genuchten water retention parameters and saturated hydraulic conductivity, as well as unsaturated hydraulic conductivity based on Mualem's pore-size model (Shaap et al, 2001). Hierarchical Neural network prediction allowed to estimate the parameters from basic soil properties as input data (Sand, silt, clay contents and bulk density).

Material and methods

Results show bulk density varies from 1.54 to 1.84 g/cm^3 with a total porosity ranging from 31 to 40%. Soil texture in the unsaturated zone is fine sand (92-99%). Silt and clay fractions are minimal ranging from 0 to 5% and 0 to 6% respectively. Matrix is depleted in organic matter (<3% or <30 g/Kg). Retention curves obtained show the residual moisture is 5% whereas saturated moisture content varies from 29 to 37% ; specific yield is inferred to be between 24 and 32%. Saturated hydraulic conductivities range from 2000 to 10000 mm/d.

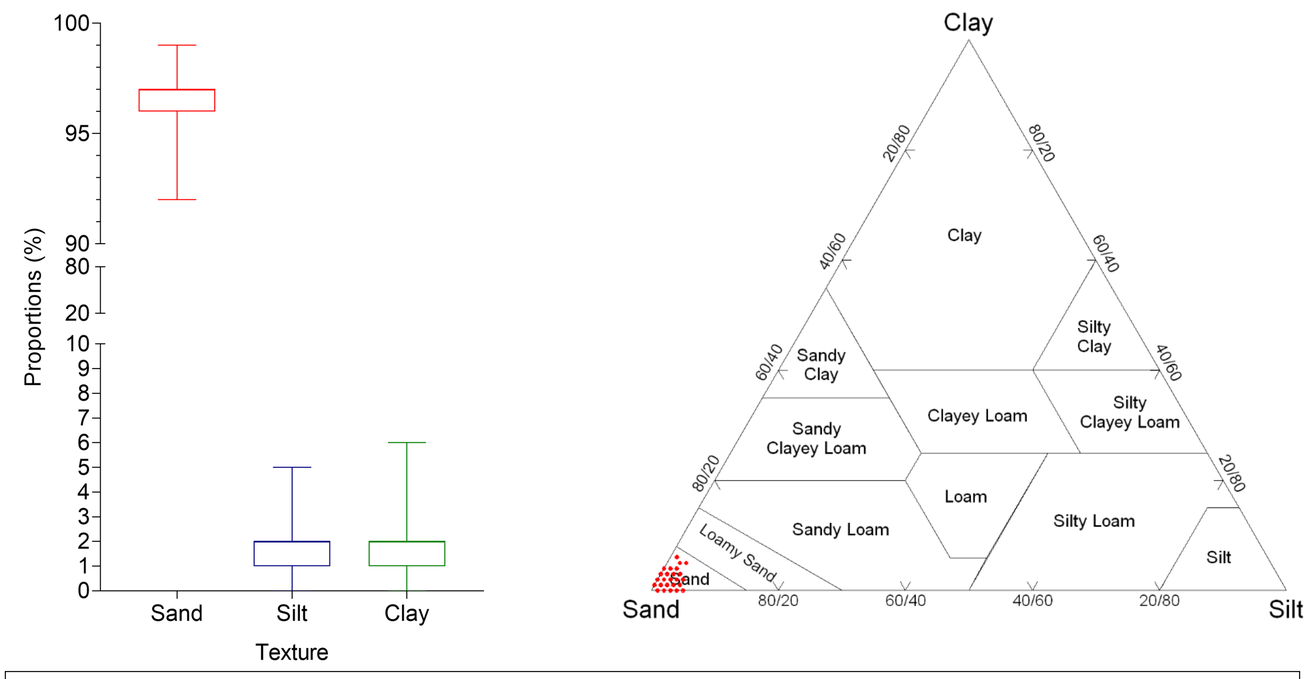

Figure 3. Particle size distribution (a) Sand, Silt and Clay proportions; (b) USDA texture classification of samples

Table 1: Van Genuchten - Mualem model parameters and inferred Specific yield

	Van Genuchten - Mualem model parameters						Specific yield
Type	θr	θs	α	n	l	Ks (mm/j)	Freeze and Cherry (1979)
1	0.05	0.29	0.00312	3.59	0.5	5437.7	0.24
2	0.05	0.30	0.00332	2.87	0.5	2793.8	0.25
3	0.05	0.31	0.00311	2.97	0.5	3678.1	0.26
4	0.05	0.32	0.00312	3.25	0.5	5140.5	0.27
5	0.05	0.33	0.00314	3.83	0.5	8301.9	0.28
6	0.05	0.34	0.00347	3.56	0.5	6452.7	0.29
7	0.05	0.35	0.00328	3.63	0.5	7229.3	0.30
8	0.05	0.36	0.00316	3.61	0.5	7569.5	0.31
9	0.05	0.37	0.00314	3.66	0.5	8081.2	0.32

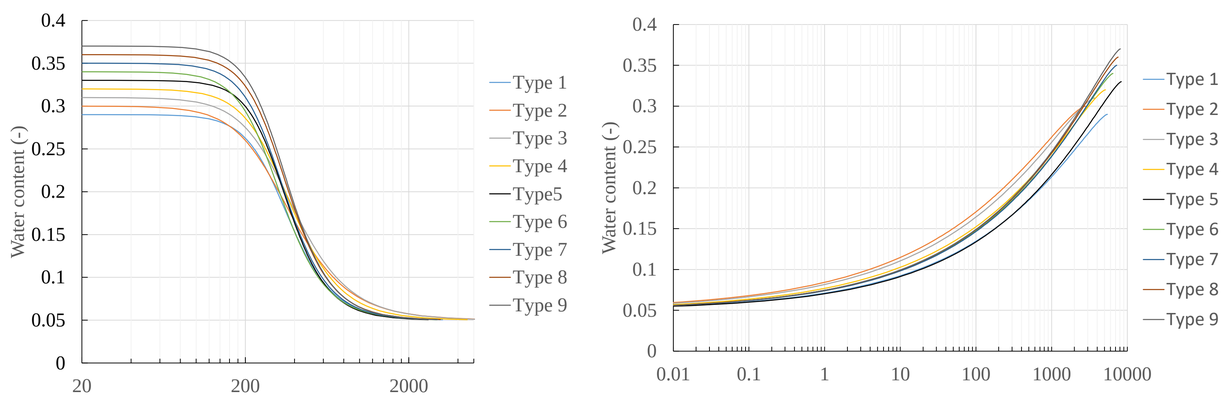

Figure 4. (a) Soil water retention and (b) hydraulic conductivity curves for 9 typical vadose zone samples

Discussion and conclusion

- Particle size analysis show a sandy homogeneous vadose zone with low proportion of silt and clay.
- Depletion of clay as well as organic matter likely cause a low holding capacity.
- The retention and conductivity curves show water transfer from the surface to shallow groundwater occurs relatively quickly amplifying pollution risk.

Future investigations will focus on an experimental device implementation on the field for direct measurements of unsaturated zone hydraulic properties to monitor water flow and solutes transport from the pollution source (septic tank) to the groundwater.

Acknowledgements:

This document is an output from the AfriWatSan project funded by The Royal Society Africa Capacity Building Initiative and the UK Department for International Development (DFID) (Grant Ref. AQ140023). The views expressed and information contained in it are not necessarily those of or endorsed by the Royal Society or DFID, which can accept no responsibility for such views or information or for any reliance placed on them.

References.

Freeze R. Allan, Cherry John A., 1979. Groundwater / PRENTICE HALL, Englewood Cliffs, NJ 07632. Prentice Hall, Inc., USA.

Gee G.W., and J.W. Bauder. 1986. Particle-size analysis. p. 383–411. In A. Klute (ed.) Methods of soil analysis. Part I. SSSA and ASA, Madison, WI

Lesikar Bruce, Hallmark Charles, Melton Rebecca, Harris Bill, 2005. Soil particle analyses procedures. Agri Life Extension, USA.

Schaap M.G., Feike J. Leij, Martinus Th. van Genuchten, 1998. Neural Network Analysis for Hierarchical Prediction of Soil Hydraulic Properties. Soil Science Society of America 9.

Schaap M.G., Feike J. Leij, Martinus Th. Van Genutchen, 2001. Rosetta: a computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. ELSEVIER 14.