Extreme rainfall events increase pollutant loads to shallow groundwater

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New observations recorded in the AfriWatSan urban monitoring facility in Dakar show how extreme rainfalls flush faecal pollutants from septic tanks into shallow groundwater.

***Figure 1**. Flooding in Keur Massar on 27th August 2020*

In August and September of 2020, extreme rainfall events caused widespread flooding in Dakar *(Fig. 1)*. A new monitoring facility within the *AfriWatSan* urban groundwater observatory in the Thiaroye and Keur Massar suburb of Dakar *(Fig. 2)* provides new insight into the hydrological impacts of such events.

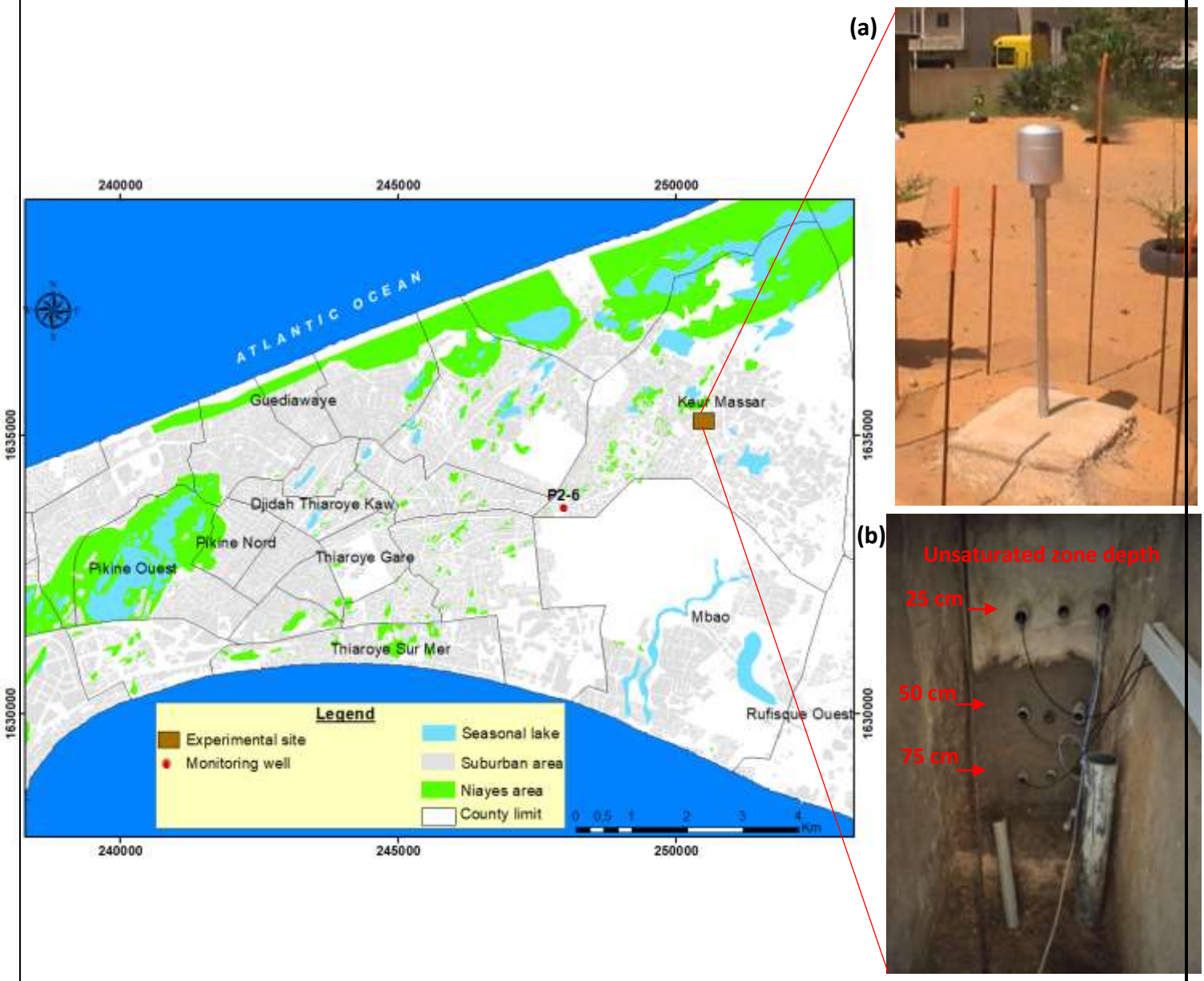

***Figure 2**. Map of the AfriWatSan urban groundwater observatory including new rainfall (a) and soil-moisture monitoring (b) facility in Keur Massar.*

In addition to a previously constructed network of monitoring wells recording hourly groundwater levels, the new facility provides hourly observations of rainfall and changes in the quantity and quality of soil moisture. This integrated observatory now enables observation of the processes by which infiltrating rainfall contributes to soil moisture and ultimately replenishes groundwater flowing within a shallow sand aquifer. Critically, the new facility is located beside a large septic tank beneath a school toilet block.

During a wetter than normal rainy season in 2020, one of the most extreme daily rainfall events of 69 mm occurred on the 27th of August (69 mm) when rainfall intensities reached 43 mm per hour. Within 3 hours of rain falling, sharp increases in soil moisture were observed at depths of 25 and 50 cm with a slightly lagged response of 4 hours at a depth of 75 cm *(Fig. 3)*. The subsequent decline in soil moisture reflects the drainage of soil moisture

to the underlying water table. Sampled soil waters associated with the extreme event of August 27th show temporary, dramatic rises in nitrate concentrations from a baseline of 340 to 390 mg/L to more than 2000 mg/L at depths of 50 and 75 cm *(Fig. 4)*. Five days after the extreme rainfall event, nitrate concentrations in soil moisture at these depths had returned to values of between 500 and 750 mg/L.

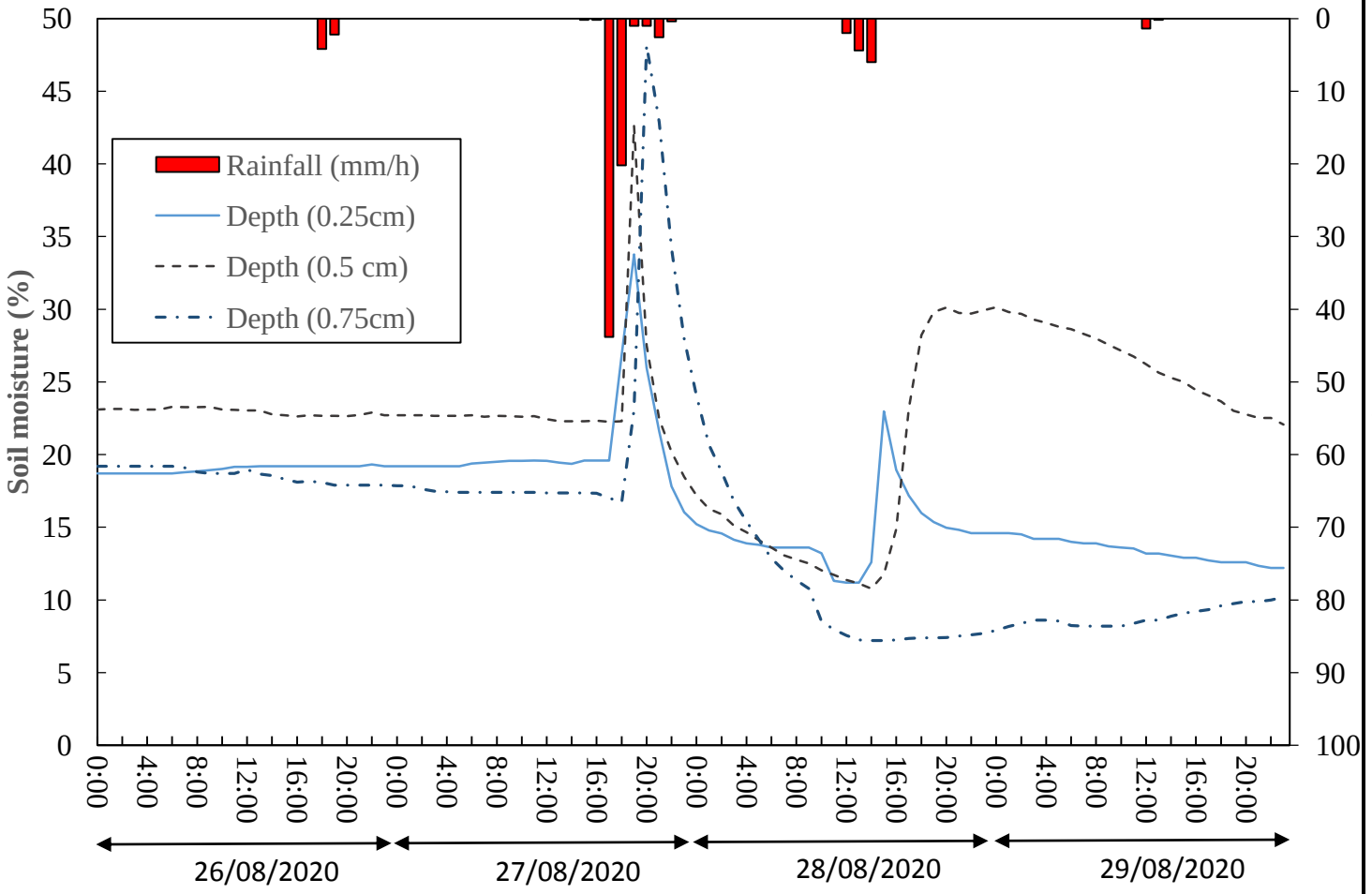

***Figure 3**. Hourly variations in rainfall and soil moisture at Keur Massar from 26th to 29th August 2020.*

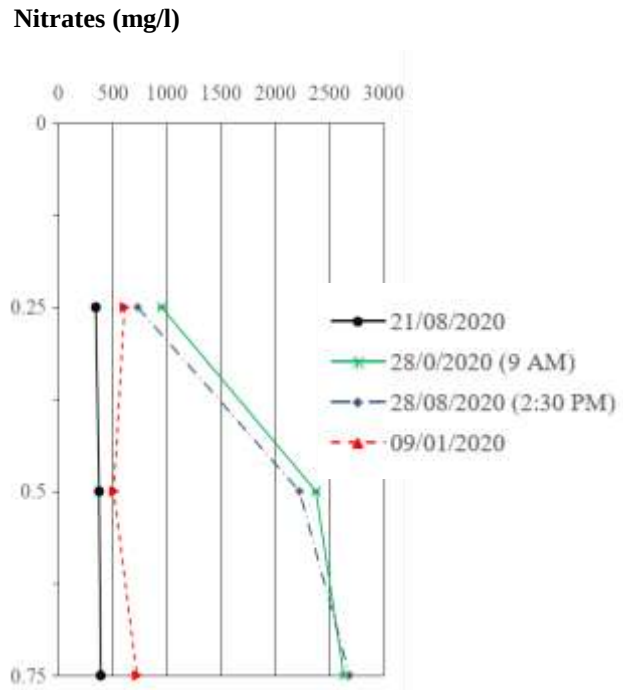

***Figure 4**. Temporal and depth variations in nitrate concentrations in soil moisture from spot sampling before, during, and after the extreme rainfall event of the 27th of August 2020.*

Monitoring of groundwater levels from the 26th to 29th of August shows a pronounced rise in the water table representing recharge from rainfall infiltrating during this extreme event (Fig. 5). High-frequency observations of groundwater levels and daily rainfall over the last 4 years highlight the importance of heavy rainfalls in generating groundwater recharge indicated by sharp rises in water tables to heavy rainfall events.

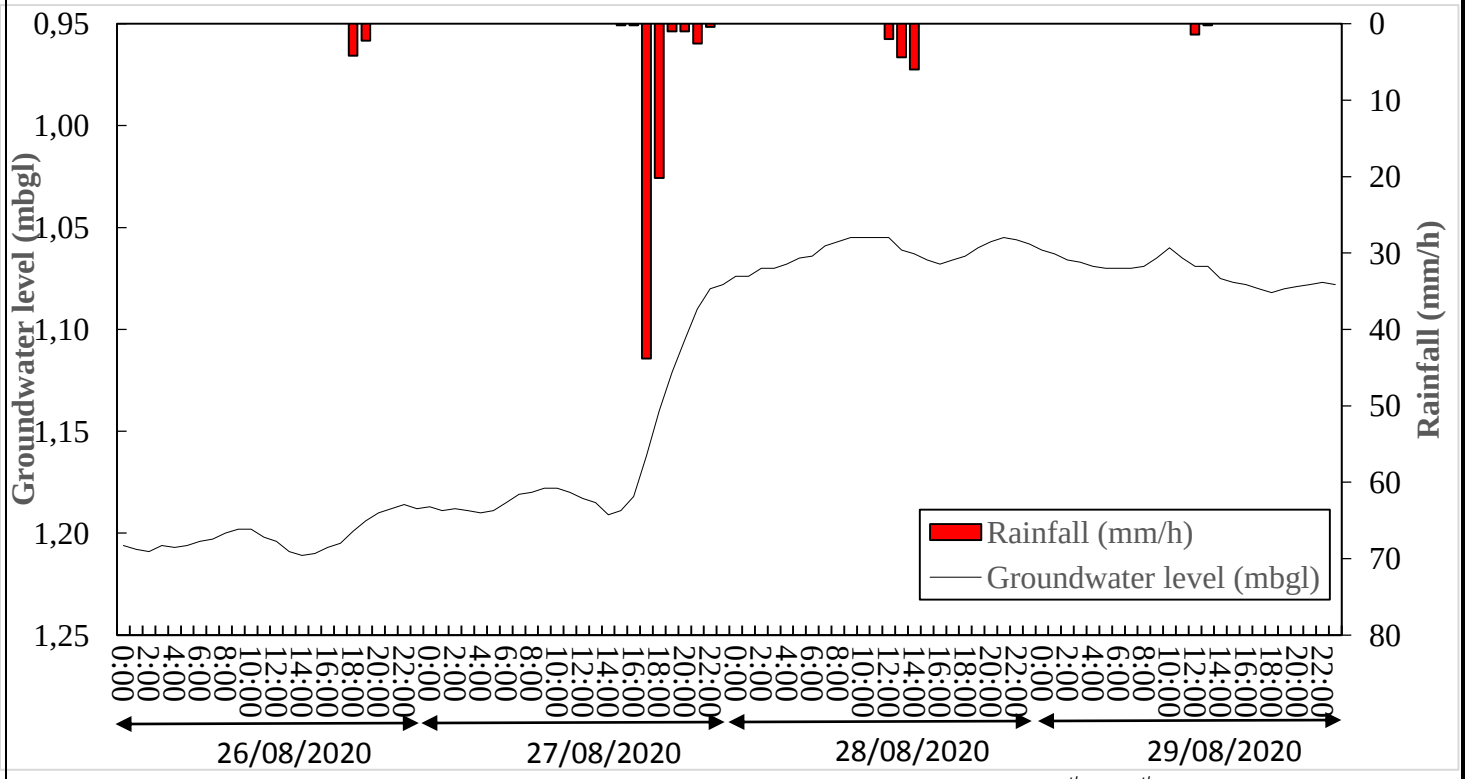

***Figure 5**. Hourly variations in rainfall and groundwater levels (P2-6) at Keur Massar from 26th to 29th August 2020.*

New evidence from the *AfriWatSan* urban observatory in the Thiaroye/Keur Massar suburb of Dakar shows how extreme rainfalls events lead to episodic flushing of faecal pollutants from septic tanks to the underlying shallow groundwater flowing in the Quaternary sands of the Cap-Vert peninsula. Previous research has traced the source of nitrate in shallow groundwater to faecal sources[1], recharge to heavy rainfalls[2], and demonstrated a statistically significant association between the density of septic tanks and nitrate concentrations shallow in groundwater[3]. The observations presented here provide for the first time direct, definitive evidence of how extreme, heavy rainfalls transport faecal pollutants from septic tanks to shallow groundwater.

Recommendation

- Issue boil-water advisories aimed at the communities of Thiaroye/Keur Massar, in Dakar, following heavy rainfall events, given the risk posed by use of untreated groundwater supplies.

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2. Cissé Faye, S., Diongue, M.L., Pouye, A., Gaye, C.B., Travi, Y., Wohnlich, S., Faye, S., Taylor, R.G., 2019. Tracing natural groundwater recharge to the Thiaroye aquifer of Dakar, Senegal. *Hydrogeology Journal*, Vol. 27, 1067-1080.

3. Diaw, M.T., Cissé-Faye, S., Gaye, C.B., Niang, S., Pouye, A., Campos, L.C., Taylor R.G., 2020. On-site sanitation density and groundwater quality: evidence from remote sensing and in situ observations in the Thiaroye aquifer, Senegal. *Journal of Water, Sanitation and Hygiene for Development*, Vol. 10, 927-939.