EGU24-13598, updated on 09 Mar 2024
https://doi.org/10.5194/egusphere-egu24-13598
EGU General Assembly 2024

Spatial Correlation Between Treated Wastewater Quality and its De-facto Reuse in Agricultural Irrigation: A Case Study of the Netherlands

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Globally, there are ongoing efforts to secure a consistent and sustainable freshwater supply, with a crucial focus on optimizing the use of existing water resources. An important strategy in this endeavor involves exploring unconventional water resources, such as the reuse of treated wastewater (TWW). Currently, de-facto (or indirect) reuse of TWW is prevalent, characterized by the extraction from surface water bodies for various purposes, including the irrigation of crops in agricultural regions. The widespread nature of de-facto reuse poses a challenge, especially since irrigation activities often coincide with dry conditions, during which TWW constitutes a substantial proportion of many surface water bodies. Hence, these practices could contribute to notable pollution concerns, potentially serving as one of the pathways for the introduction of contaminants into the groundwater system, as well as the soil-plant systems, eventually entering the food chain.

A notable gap in existing research lies in the absence of consideration for the spatial relationship between irrigated fields, affected by TWW of varying quality, and its emission source, namely the wastewater treatment plant (WWTP). Conducting this type of analysis holds the potential for a dual interpretation: i) comprehending the influence of different WWTPs contributing to pollution dispersion on individual fields, and ii) understanding the impact of a specific WWTP on all fields utilizing the discharged TWW from that particular facility.

To explore this issue in the Netherlands, we leverage prior research and use the outcomes of the Water Framework Directive (WFD) Explorer, a national water quality model used for policy support. The model employs a simplified version of the advection-diffusion equation to simulate reactive transport processes from contaminant sources—in our case, 363 WWTPs—throughout the national surface water network under steady-state flow conditions. We assume a constant flux of 1000 [g/s] of a conservative tracer emitted from each WWTP and examine its transport – from the point source to 18927 surface water units (swu), 33015 surface water abstractions (swa), and toward 366886 irrigated fields - during representative wet and dry periods in the Netherlands. Specifically, for spatial linkage, we assume buffer zones of 500m to connect relevant swu with swa and, consequently, irrigated

fields.

The spatial correlation and tracer propagation, primarily influenced by the dilution effect, offer direct insights into point i). To address point ii), we introduce the Spatial Impact Indicator (SII), quantifying a specific WWTP's influence on irrigated fields in its discharge area. This involves multiplying each field's area by the proportion of emitted tracer reaching it, summing these values for all affected fields, and then dividing by the total affected area. The SII serves as a weighted measure, emphasizing both the quality of TWW in individual fields and the overall affected area within the discharge zone of the WWTP. Furthermore, the SII enables the ranking of WWTPs and identification of the most impactful for indirect reuse in agriculture. This information could support decisions on which WWTPs to prioritize for improvement (e.g., transitioning into Water Factories) based on their environmental impact.

How to cite: Rakonjac, N., Pronk, T., and P. Bartholomeus, R.: Spatial Correlation Between Treated Wastewater Quality and its De-facto Reuse in Agricultural Irrigation: A Case Study of the Netherlands, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-13598, https://doi.org/10.5194/egusphere-egu24-13598, 2024.