Assessing the impact of water reuse strategies using an integrated modelling approach

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1. Introduction

Within a context of increasing water scarcity, wastewater reuse in agriculture is considered as a cost-effective solution to reduce the water demand for irrigation. At the same time, highly urbanised cities are developing innovative strategies aiming at an efficient (re)use of resources (e.g. water, energy, etc.), usually belonging to the so-called "*smart cities*" actions.

However, several emerging practices could result in major drawbacks, as a high potential of cross-contaminations of hazardous substances. These pollution phenomena could involve contaminants of emerging concern (CECs), that are characterized by high persistence in the environment and are likely to negatively affect the metabolism of a living being [1]. Thus, the impact assessment of innovative resource management strategies on the environment and human health is strongly needed before implementation.

This study aims at evaluating the effect on the environment and human health of a series of innovative resource management strategies related to geothermal heating in an urban and peri-urban water catchment. Particularly, an integrated model was developed and adapted to simulate the environmental fate of a series of recalcitrant CECs (e.g. carbamazepine) under different water reuse scenarios.

2. Materials and methods

The case-study was constituted by the "Navigli Project", currently under development in the municipality of Milan, Italy. The project consists in re-constructing the ancient hydraulic continuity between northern water streams and the irrigation system of the agricultural area located south of the city. Groundwater heat pumps are intended to provide for a more sustainable heating and cooling energy supply, withdrawing water from the unconfined aquifer and discharging in the waterways, being water subsequently reused for irrigation of edible plants (e.g. wheat and rise). Figure 1 shows the case-study conceptual scheme.

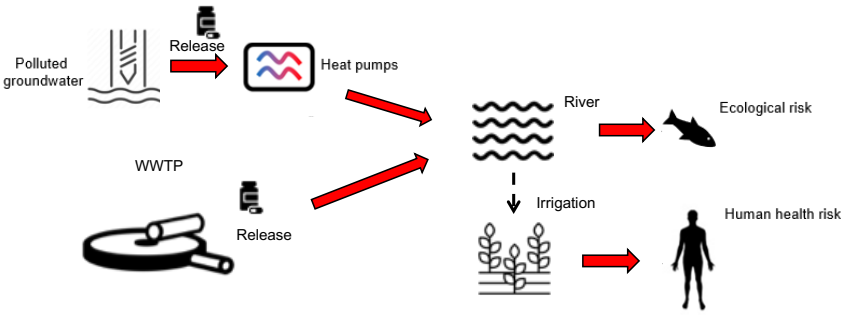

Figure 1. Conceptual scheme of the modelled urban and peri-urban water system.

The case study was modelled through the Integrated Urban Wastewater and Stormwater (IUWS_MP) model library extended with a plant uptake model [2] to describe CECs fate across urban and peri-urban water catchments. Model inputs (aquifer concentrations, WWTP effluent concentrations, etc.) and CEC parameters (degradation half-life, solid-water partition coefficient, etc.) were obtained from local measurements campaigns [3] and literature studies, respectively.

Predicted concentrations in the waterways and edible plant organs (e.g. fruits) were compared with predicted no effect concentrations and admissible daily intake. Risk assessment for the environment and human health was performed using the risk quotient approach. Model inputs-parameters uncertainties were propagated to model outputs by Monte-Carlo simulations.

3. Results and discussion

Annual predicted concentrations of carbamazepine in the waterways (Figure 1) shown higher variability with respect to the current situation (i.e. no reconnection). This was mainly due to the flow of groundwater heat pumps, which follows a certain seasonality due to the expected heat demand of the city. Predicted concentrations and associated uncertainties were always below the predicted non-effect concentration (9 μg L^{-1}) [4], indicating no additional environmental risk. Moreover, future concentrations are expected to be, on average, lower than the current concentrations, due to the dilution effect of groundwater. Also, human health risk shown a reduction of 30% with respect to the current situation [2]. Future developments include running the integrated model for more CECs, in order to perform a more exhaustive risk assessment.

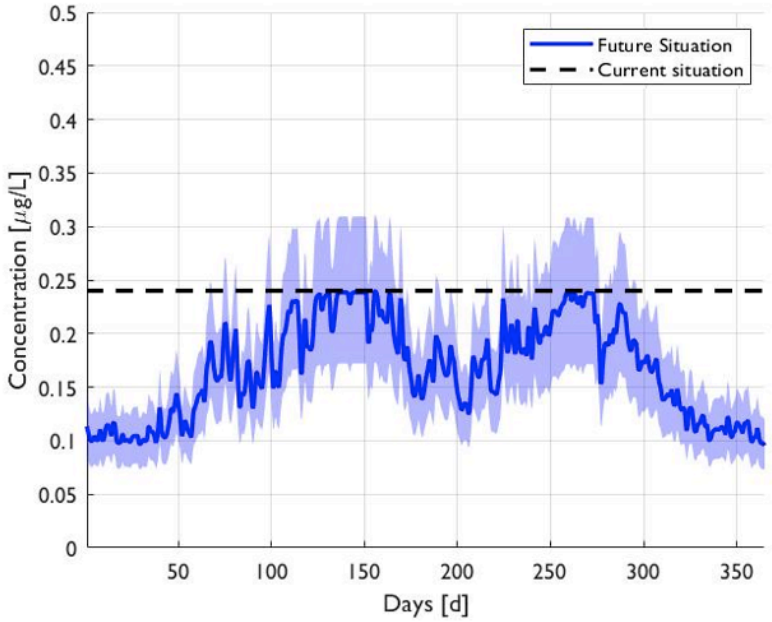

Figure 2. Predicted annual concentration of carbamazepine in the waterway.

4. Conclusions

The developed model is a useful tool for assessing the fate of CECs and the impact of different water reuse practices in complex urban and peri-urban areas. The model can support decision makers in evaluating future water management strategies and the related risk on environment and human health.

5. References

[1] Daughton, C.G., Ternes, T.A. (1999). Pharmaceuticals and personal care products in the environment: agents of subtle change? Environ. Health Perspect. 107, 907–938.

[2] Delli Compagni, R., Gabrielli, M., Polesel, F., Turolla, A., Trapp, S., Vezzaro, L., Antonelli, M. (2019). Risk assessment of contaminants of emerginc concern in the context of wastewater reuse for irrigation: an integrated modelling approach, Chemosphere, 242.

[3] Castiglioni, S., Davoli, E., Riva, F., Palmiotto, M., Camporini, P., Manenti, A., Zuccato, E. (2018), 'Mass balance of emerging contaminants in the water cycle of a highly urbanized and industrialized area of Italy', Water research, 131, 287-298.

[4] Zhao, W., Wang, B., Wang, Y., Deng, S., Huang, J., Yu, G. (2017b). Deriving acute and chronic predicted no effect concentrations of pharmaceuticals and personal care products based on species sensitivity distributions. Ecotoxicology and Environmental Safety, 144, 537–542