Ferrara, November 30th, 2020

**Abstract of the PhD Thesis**

Due to the rising global population and the steady growth of the health care sector, the consumption of pharmaceuticals increased consistently in the last decades. Although modern medicine significantly developed, this brought to the possibility that residues of these compounds reach surface water, soil, and plants through several routes during their manufacture, use, and disposal.
Nowadays, many studies regarding the occurrence of pharmaceutical and personal care products (PPCPs) in different environmental compartments can be found in the existing scientific literature. In this regard, great attention has been paid to monitoring residues of PPCPs in wastewater treatment plant (WWTP) effluent, and, broadly speaking, in sewer networks (*e.g.*, in combined sewer overflow, CSO). Nevertheless, considering a whole catchment, and especially in rural or peri-urban areas, pharmaceutical compounds may enter in the water environment also *via* soil water flows (e.g., surface runoff, tile drainage, interflow, and groundwater) originated from arable lands in which sewage sludge or animal manure have been amended as fertilizers.
It is well-known that these organic wastes may contain measurable traces of PPCPs, which, when applied onto the soil showed to persist, in some cases, for long periods, up to months. Therefore, in the case of particularly intense rainfall events, or during crop irrigation, these contaminants can be remobilized in the water phase, until reaching the receiving stream.

This thesis takes place in this background, aiming to, firstly, characterize the content of PPCPs in sewage sludge and zootechnical wastes originated from different animals and with various characteristics. Afterwards, the remobilization of these micropollutants was studied in order to have an overall view of their potential occurrence in the soil water flows and of the main factors influencing it (such as soil characteristics, physico-chemical properties of the compounds, sludge application rate and method, and so forth).
These two first steps were carried out through a comprehensive and exhaustive literature review and were essential to prepare a general overview of the state-of-the-art on the topic.
Then, all the elements were on the table to try to estimate the contribution of different sources (among them WWTP effluent, CSO, and surface runoff from manure or sewage sludge-amended soils) to the occurrence of selected pharmaceuticals in surface water, on a catchment scale.
This last task was conducted in collaboration with the Institute for Water Quality, Resources and Waste Management of the TU Wien, and focused on a specific case-study regarding an Austrian peri-urban watershed. The result was the development of a modelling approach in order to identify the most relevant sources and emission pathways of pharmaceuticals, with particular attention to the significance of agricultural land runoff.
The strength and weaknesses related to this model are discussed in this thesis, in order to lay the groundwork for moving from a case-study to an overall discussion of the topic.
Finally, as a consequence of the work done, one last task was performed investigating the potential toxic effects on edible crops due to their irrigation with surface water contaminated by residues of PPCPs.

The subject was explored in collaboration with the Department of Environment and Geography of the University of York, through a laboratory experiment in which garden cress plants – an edible crop commonly cultivated in northern Europe – were treated with mixtures of PPCPs simulating the irrigation with surface water similar to those that can be sampled worldwide.
The results of this work showed that residues of micropollutants might cause visible effects on plant biomass even when occurring at very low concentrations (ng $L^{-1}$ level), due to the synergistic and additive effects between the compounds.
In conclusion, the findings of this thesis highlighted that the effects of the occurrence of PPCPs in the agricultural agroecosystem (soil, water, and plants), and *mutatis mutandis* in the receiving water environment, are measurable. This thesis pinpoints some issue related to this complex *phenomenon*, and the necessity to further investigate in this field to exhaustively deepen the problem.

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