SUPPORTING RISK ASSESSMENT AND MANAGEMENT OF RECLAIMED WATER REUSE IN AGRICULTURE IN AN INTEGRATED APPROACH

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Abstract

Water reuse is a potential solution to support sustainable resource management in an integrated urban wastewater and reuse system (IUWRS). Current regulations provide minimum requirements for water quality, in terms of maximum concentration limits of physical-chemical and microbiological parameters, and establish the necessity to develop and assess water reuse risk management plan (WRRMP) in order to ensure protection for human health, animals and environment. In the Horizon 2020 Project Digital Water-city (DWC), a demo case of wastewater reuse in agriculture is set up in a peri-urban area of Milan, integrating digital solutions to support risk management and minimization.

Keywords: water reuse; risk management; urban wastewater treatment; QMRA

Problem Identified: The sustainable management of water and resources is a crucial topic for the development of green and circular systems. In an IUWRS, wastewater can be treated and reused in agricultural applications. However, the reuse of reclaimed water depends on many and different types of obstacles, not only related to technology implementation, but also to health, socioeconomic and legal aspects (Foglia et al., 2021). The new EU Regulation 2020/741 on "Minimum requirements for water reuse" establishes limits on contaminant concentrations and defines risk management strategies to identify, characterize, minimize and monitor risks. However, current regulations, as well as other guidelines such as DEMOWARE's project deliverable, WHO's manuals for Sanitation Safety Planning, WHO's manual for Quantitative Microbiological Risk Assessment (QMRA) and Water Safety Planning and WHO's Guidelines for the safe use of wastewater, excreta and greywater, provide only general approaches, that need to be adapted to the specific case-study. Moreover, the implementation of digital solutions, such as innovative sensors or knowledge- and data-driven analysis, can help to support decision making based on multi-sources data platforms, including quality and quantity monitoring.

Methodology used: The preliminary semi-quantitative approach was followed to obtain a Risk Matrix of Peschiera Borromeo wastewater treatment plant (WWTP), where wastewater is reclaimed for agricultural reuse. The different treatment steps were identified as critical nodes and, for each one, possible hazardous events were identified, according to expertise judgement and past occurrences verified. Scores were attributed to the likelihood, considering the occurrence frequency, and to the severity, depending on the gravity of the related outcomes. Specific control measures were evaluated to reduce the risk scores and integrative ones were suggested. According to the outcomes of the Risk Matrix, a QMRA was performed to evaluate microbial risks from pathogens and compare them with health target provided by

WHO and US-EPA guidelines. From the WWTP monitored parameters, data of concentrations of *E.coli* at the effluent were available for 2 years' time period. Considering reference log removals of treatment units provided by Australian Guidelines, influent concentrations were determined. Since *E.coli* are microbiological indicators, ratios pathogens-indicators were assumed from literature, in order to obtain the influent concentrations of the reference pathogens considered, namely *Campylobacter*, *Cryptosporidium* and *Rotavirus*. Log reductions of the different process treatments were applied to obtain the effluent values of microbial contaminants. The routes of exposure included ingestion, inhalation and product consumption. Exposure groups were considered as fieldworkers and consumers of final products. Tomato was chosen as the crop to be irrigated by reclaimed water. According to (Haas et al., 2014), a Beta-Poisson model was assigned to *Campylobacter*, *Rotavirus* and *E.coli* and an exponential model to *Cryptosporidium*, to calculate the probability of infection. Dose response models were assumed for each pathogen according to literature, as well as illness/infection ratios. Monte Carlo simulation was further performed to enlarge the numerosity of sample population and obtain risk outputs. Each input variable was described by a probability distribution function. Because of the lack of measured data, most of them were assumed from literature, while a deeper analysis was performed for *E.coli*, whose trend fitted with a Weibull distribution. Different exposure scenarios were simulated for workers and consumers.

Main results obtained: The results demonstrated that WWTP processes are efficient control measures for the removal of pathogens, especially regarding bacteria and protozoa, while performances are less effective for viruses. Consumers were found to be the most exposed population group, and fieldworkers were characterized by levels of risk lower than the acceptable limits. In case only technological barriers of WWTP processes are considered, the results for consumers showed that *Rotavirus* exceeded the WHO target of $1*10^{-6}$ DALYs, while *Campylobacter* and *Cryptosporidium* were below the threshold (Table 1). If further barriers are applied, as for Scenario 2, where product washing before consumption are considered, risks can be further reduced of about 1 order of magnitude.

Table 1: DALYs of reference pathogens for the different scenarios

Exposure scenario	Exposed group	*Campylobacter*	*Cryptosporidium*	*Rotavirus*
Scenario 1: only WWTP barriers	Consumer	1.52E-08	2.45E-08	6.40E-05
	Worker	1.09E-11	1.82E-11	5.15E-08
Scenario 2: product washing	Consumer	1.54E-09	2.42E-09	7.05E-06

Most relevant conclusions: A multi barrier approach is suggested for risk minimization, coupling log removals of WWTP processes with non-technological barriers. Irrigation techniques, such as drip irrigation, can be selected to minimize risks. Further barriers could be applied in situ and to final products, including access restrictions to the irrigated field, die-off periods or product processing before consumption.

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