DEVELOPMENT OF A METHODOLOGY FOR ENVIRONMENTAL, SOCIAL, AND ECONOMIC ASSESSMENT OF WIDESPREAD REUSE PRACTICES.

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INTRODUCTION

Climate change is a well-documented and long-recognized phenomenon. Its effects are currently observable worldwide and are expected to increase by 2100. Among these effects, water shortages have become more frequent since the late 20th century, particularly in arid or coastal regions (Bixio et al., 2006). France and its Mediterranean regions as Occitanie are being impacted.

In response, adaptation solutions are being implemented to meet water demand. One of the most promising is the reuse of wastewater (Bates et al., 2008). Some countries, such as Israel and Spain, reuse 67% (Inbar, 2007) and 14% (Prigent, 2024) of water from treatment plants, respectively. In contrast, in France, the reuse of treated wastewater is estimated at only 0.5% (Frank-Neel, 2020). As a result, experiments and public policies around REUSE are multiplying to bridge this gap. However, few studies have examined the consequences of this practice on the broader water cycle. More specifically, while the processes of the global water cycle (Alcamo et *al*., 2003; Klemeš, 1983; Shuttleworth, 1988; Vörösmarty et *al*., 1989, 2000) and the local water cycle (Grimmond et *al*., 1986; Mitchell et *al*., 2001) are well understood and modeled, few articles address the quantitative interactions between these two cycles. REUSE, which is an activity related to the small water cycle, can have impacts not only on this cycle but also on the global water cycle. It is therefore important to develop a comprehensive understanding of the impact of REUSE on both cycles.

The TERR'REUSE project aims to assess the impacts and benefits of water reuse (REUSE) on both the small and large water cycles, along with the associated externalities. Its consists of several stages. The first is to analyze the impacts of REUSE on both the small and large water cycles (quantitative aspect), as well as any potential upstream-to-downstream rebound effects. Based on these observations and the existing literature, the effects on ecosystems, the economy, and public policies can be explored. The identification of key parameters and direct or indirect effects related to REUSE practices will then be used to support the Living Labs (LL). These parameters will be incorporated into the co-construction and comparison of different water management scenarios to adapt to climate change. This paper focuses on the first stage of the project, which aims to better understand and examine the effects of REUSE on the global and domestic water cycles through their interactions.

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METHODOLOGY

A typology of "typical" situations was developed, involving water withdrawals, consumption, and/or discharges at the scale of a hypothetical watershed, without REUSE, to describe their impact on surface water resources. The effects of introducing REUSE practices were then considered to characterize the consequences of REUSE on surface waters. Surface waters here represent a part of the global water cycle but do not encompass the entire global water cycle, which also includes atmospheric and underground exchanges.

The objective is to observe the effects of reuse on surface and groundwater volumes, initially for domestic use (Drinking Water Supply). The model will also be further developed with more configurations, including withdrawals from unconfined aquifers, confined aquifer withdrawals, inter-basin transfers, agricultural use, and consideration of evapotranspiration.

Figure 1 present an example of watershed type. We consider a watershed where withdrawals and discharges occur within surface waters. The water withdrawal is intended for drinking water supply. After treatment at the wastewater treatment plant (WWTP), a portion of the water is re-treated and then reallocated for use. Numbered points from 1 to 5 are used to facilitate the interpretation of the results.

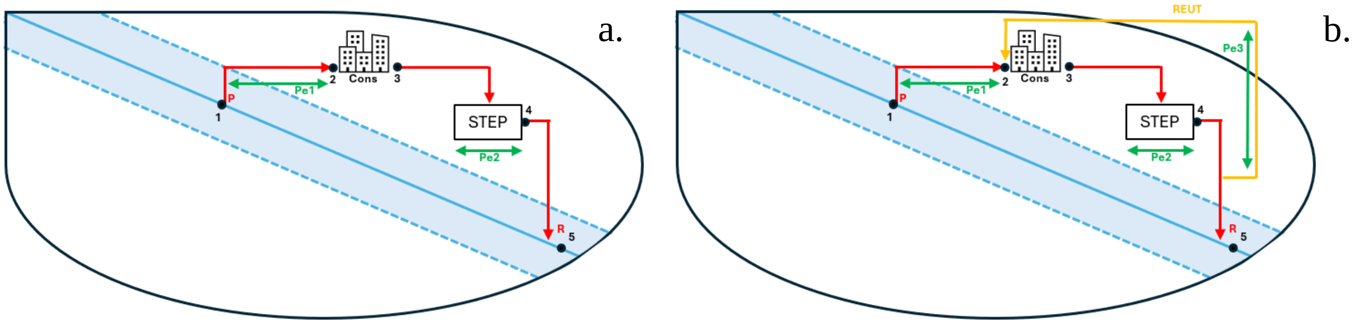


Figure 1: Watershed Typology: a. without wastewater reuse, b. with wastewater reuse.

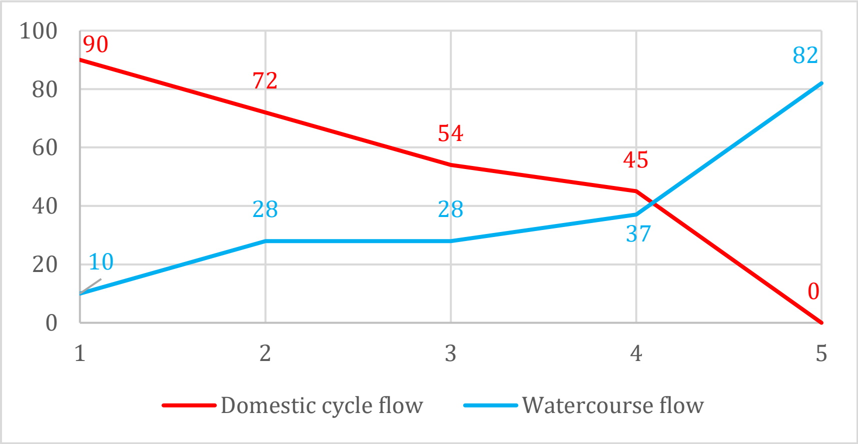
Main variables of the model and theirs main assumptions are presented in Table 1.

Table 1. Main variables of the model and their assumption

Variable	*Equation*	*Comments*
River flow upstream of the small cycle ($Flow_{upstream}$) and *Withdrawal* (W):	$W_{initial} = 90\%$ and $Flow_{upstream} = 100\%$ $W_{REUSE} = W_{initial} - REUSE$	To maintain the good condition of watercourses, French legislation requires a minimum flow (or reserved flow) to be left in rivers, set at 1/10th of the annual average flow. (Préfecture du Gers, 2013) . We are considering here the most extreme scenario where 90% of the river flow would be extracted.
Leaks *(L1)* :	$L1 = W \times 0.2$	According to E*aufrance* (s. d.), losses in the distribution network are estimated at 20% of the withdrawal, resulting in a network efficiency of 80% (French average). The commonly accepted definition of the distribution network is the section from the withdrawal to the point of use. These losses, due to infiltration, are returned to the watercourse and, consequently, to the large water cycle.
Consumption (Cons)	$Cons = W \times 0{,}2$	According to the Ministry of Sustainable Development (Ministère de la Transition écologique et de la cohésion des territoires, s. d.), at the scale of the Rhône-Mediterranean and Adour-Garonne basins, approximately 20% of the withdrawn volume is actually consumed. This confirms the assumptions of Fabre (2015), who considered a consumption rate of 20% for the Ebro and Hérault watersheds. For the Rhône-Mediterranean basin, the annual withdrawal volume is 1,500 million cubic meters, and the volume consumed, or "lost" from the perspective of the small water cycle, is 325 million cubic meters, which corresponds to 20% of the withdrawn volume.
Leaks (L2)	$L2 = W \times 0{,}1$	Unlike the losses in the distribution network (L1), which have been studied and documented primarily for economic aspects, the network for recovering wastewater up to treatment and subsequent discharge is poorly documented. Apart from the identification of leaks through observations of bacterial contamination, few if any French studies acknowledge the interactions (resource losses or gains) between the wastewater collection and treatment network and the natural environment. According to the Egyptian model losses in the treatment process (excluding the transport of wastewater) can be estimated at 10% of the withdrawal. Therefore, we will retain this figure in the absence of more precise data on this aspect. We will consider, as with L1, that these losses are returned to the environment through infiltration.
The discharge (D)	$D = W - (Cons + \Sigma(L))$	corresponds to the withdrawal (P) from which losses, namely network and treatment leaks (L1, L2), as well as consumption (Cons), are subtracted
REUSE	$REUSE = D \times 0{,}1$	The objective of the Water Plan is to achieve a 10% reduction in current withdrawals (Gouvernement Français, 2023). We will therefore consider that this reduction will be achieved exclusively through the process of Reusing Treated Wastewater from the withdrawn waters
Leaks (L3)	$L3 = REUSE \times 0.1$	The losses associated with the reuse loop are estimated, like the losses from the wastewater network, at 10%

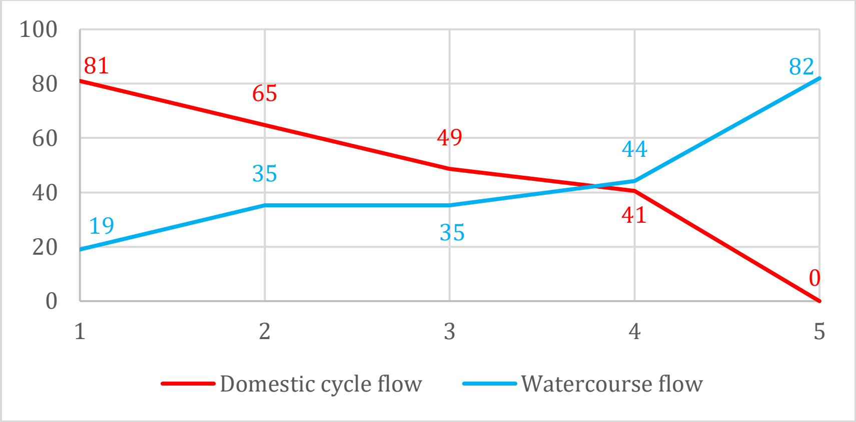
FIRST RESULTS

Figure 2 reveals several consequences of REUSE : the reduction in withdrawals in case 2b leads to a decrease in pressure on the watercourse, changing from 10 to 19, representing an increase of 9%. Therefore, REUSE contributes to supporting low flow conditions. This result also shows the REUSE in support of the water demand in the domestic cycle.



a.

	Domestic cycle flow	Watercourse flow
1	90	10
2	72	28
3	54	28
4	45	37
5	0	82



b.

	Domestic cycle flow	Watercourse flow	REUSE Flow
1	81	19	8
2	65	35	8
3	49	35	6
4	41	44	5
5	9	82	9

Figure 2: Flows of the small and large water cycles (in %) without (a.) and with (b.) reuse of treated wastewater (1: Withdrawal, 2: Losses L1, 3: Consumption, 4: Losses L2, and 5: Outflow from WWTP).

PERSPECTIVES ET CONCLUSION

This model is an expert opinion model, an initial construction that requires further refinement with data that may be more realistic than those selected. The initial parameterization can therefore be modified. Additionally, this model only accounts for a portion of the large water cycle and overlooks atmospheric and underground interactions. Finally, this model will support the co-construction of scenarios with various private and public stakeholders in the region with the implementation of the PBRM (Perception-Based Regional Mapping) method *(Bonin & Le Page, 2000; Caron, 1998; Saqalli et al*., 2009).

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