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A Systemic Approach to Design for Sustainable and Circular Use of Water in Food Service

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During the investigation of the use of resources such as food, energy, water, and human work in a food service facility through observation studies in a broader research study, water turns out to be the element less considered in all its different uses, especially in the quantity of its wastage. Starting from this finding, this research investigates the water use in the food service sector and its importance for life on the Earth for humans—the 21st-century gold that will become more scarce and expensive in the future. The goal is to understand the contribution of design to a more sustainable and circular use of water in this sector. To answer this question, the research starts with collecting data in the literature about the specific water usage in the industry to frame the problem. Afterwards, it presents case studies on product designs, actions and projects concerning the management of sustainable and circular use of drinkable water. As a result, this research proposes the use of a systemic approach for the research in design for sustainable and circular use of water as a driver for designing different and innovative solutions to close and open circular loops in the food service sector. The approach is based on the nano-micro-meso-macro scale of interventions in the circular economy studies, proposing different potential solutions to close and open loops. It ends with further research questions to implement the draft future scenario proposed.

KEYWORDS: water, food service, systemic design, circular economy, closing resources loops, sociotechnical system

RSD TOPIC(S): Methods & Methodology, Socioecological Design, Sociotechnical Systems

Introduction

Eating is a fundamental act of our life, and we have food on our plates thanks to a food value chain composed of four food supply subsystems (according to FAO (2016): (1) agricultural production, food retail and provisioning; (2) food storage, transport and trade; (3) food transformation; (4) food retail and provisioning. They influence the food environment, described by FAO (2016), as the contexts where to buy and consume food, the interface and link among food systems and diets where, according to our diet, we make decisions on what to eat. One of the dark sides is that the global food system is responsible for massive greenhouse gas emissions, around 30% of the global ones, and "could preclude achieving the 1.5°C and 2°C climate change targets", following Clark et al. (2020).

This research focuses on food service (FS), a food environment and a part of the food transformation subsystem. In the FS sector, where food is prepared and served to many people, the two major components needed to perform this action are the kitchen and the serving area. If the professional kitchen (PK) of an FS is seen as a system, food and cooks create the connection among multiple kitchen equipment and other tools to produce and serve a meal, whereas the transformation and serving of food also requires other resources such as energy and water (Battistoni, 2023). Regarding the impact of FS on the environment, in scientific literature, it is possible to find few studies, such as Fusi et al. (2016) on the evaluation of the catering sector taking the case of pasta, or Baldwin et al. (2011) in a life cycle assessment of restaurant and FS.

In particular, Baldwin et al. (2011) divide the FS into four sub-activities and indicate the contributions of each to the total environmental impact of the sector:

1. Food procurement—the purchase of food and beverages (and related waste)—94.7%
2. Food storage—the energy used in storing food, beverages, and other products in the restaurant or FS (it did not include food)—0.7%
3. Food preparation and cooking energy and water used in preparing food, beverages, and other products at the restaurant or FS (it did not include food)—1.2%

4. FS and operational support—the energy used for lighting, heating, ventilation, air conditioning, water use, supplies (restroom, cleaning, disposable products), and administrative support—3.4%

A more recent study by Madanaguli et al. (2022) is a systematic review of the restaurant's relation to green practices that also identifies the type of unsustainability found in the studies: food waste, non-food waste (as packaging) and other wastes (electricity/energy, water, food-related gas emissions). Even if the impact on the environment of the FS seems minor in comparison to the other actors of the food system value chain that are more impactful, such as agriculture, “GHG emissions from the global food system largely occur from food production and from land being cleared for food production” (Clark et al., 2020), it is necessary also to focus the attention on it for the increasing of the sector in the modern culture and the future market, according to studies as Fortune Business Insight (2023).

An ongoing study presented in Battistoni (2023) is understanding the processes that happen in a PK in FS mapping the resources used for a single one and trying to track not only the one used by the different kitchen equipment but also from the other activities, thanks also to direct observation methods, drafting the map of the kitchen as a system. This process helps understand the design contribution and how to intervene with innovative solutions for a circular economy (CE) scenario**.** A primary result, from which the specific research part presented in this paper started, is the recognition of water as a resource that is less considered in the FS. Indeed, there are many references to water used in agriculture for food production—agriculture being the most important water consumer; according to UN Water (2021), “72% of all water withdrawals are used by agriculture, 16% by municipalities for households and services, and 12% by industries” (p.23). However, little is known about the other food subsystems, such as food transformation and processing. For example, in the database of the water footprint network (n.d.) for the calculation associated with food, there is data about pasta but associated with wheat needed, “one kilogram of wheat gives about 790 grams of pasta, so that the water footprint of pasta is about 1850 litre/kg” (water footprint network, n.d.), without considering the water for cooking.

This specific research focuses on the resource water, which is considered the gold of the 21st Century (ICWRGC, n.d.) as freshwater is limited and the need is increasing “global water demand is projected to increase by some 55%, due to growing demand from manufacturing (+400%), thermal electricity generation (+140%) and domestic use (+130%)” (OECD, 2012), contributing to water scarcity also caused by climate change (UN water, n.d.); indeed more countries in 2050 will face water scarcity (Baggio et al., 2021). Moreover, this research wants to investigate the FS's water use to understand its more sustainable and circular use. It can increase knowledge about the circular economy of water, which is a growing research topic and an economic framework to optimise the use of this precious resource (Morseletto et al., 2022). Another research question is focused on the contribution of design discipline in designing sustainable and circular water use in this sector. This paper proposes, as a result, a systemic approach for the design of research with water as a driver to design different and innovative solutions for circular resource loops.

Methodology

To answer the primary research question of this specific study, a primary literature review of water use in the PK was performed to retrieve also quantitative data on the use of water in the FS sector and the different activities involved. Afterwards, an identification of cases of products (concept or on the market) found in the review of formal and informal literature sources was performed to understand the contribution of product design in relation to the management of sustainable and circular use of water. Moreover, a review of technologies that learn from nature for sustainable and circular water use was performed. The main presence of a linear approach behind the product design cases led finally to the drafting of a different approach that is possible to use in research in design for sustainable and circular water use in the FS, applying a systemic approach to design different solutions.

The research methods are grounded in systemic thinking and systemic design approaches and methodologies, which results in effective design for the transition to a CE (Barbero, 2017; Ellen et al.). In particular, the holistic diagnosis method from systemic design (Battistoni et al., 2019) is used to investigate and explore problems with a holistic approach. The research process is supported by the creation of gigamaps

(Sevaldson, 2018) to collect information, map the current situation, find and underline opportunities, manage the complexity resulting from the project, and talk to other actors involved in the design project.

This research is framed in the shift from how to design to what to design (Sanders & Stappers, 2014) and in achieving SDG6–Clean Water and Sanitation; in particular 6.3—improve water quality, wastewater treatment and safe reuse, 6.4—increase water-use efficiency and ensure freshwater supplies, and 6.8—support local engagement in water and sanitation management. Moreover, the approach supports scope 3 of the greenhouse gas (GHG) protocol in industries because it is focused on the product-use phase.

Water use in the food service: current data

Looking for data for water use as input in the FS, it is possible to find many studies in the American context. The United States Environmental Protection Agency (EPA) (2012) stated that "Water used in hospitality and food service establishments accounts for approximately 15% of the total water use in commercial and institutional facilities in the United States". EPA (2012) also reported the percentage of end uses of water in restaurants: 52% kitchen/dishwashing, 31% restroom/domestic, 12% other, 4% landscaping, and 1% cooling and heating. Pacific Institute (2003) estimated the total water used in the restaurant industry by end-use, modelling the use in a day with a total amount of 9.91 gallons/meal/day (37.5 litres), considering five meals/seat/day, specifically:

- dishwasher 41.8% (pre-rinse nozzles 6,2%; pot and pan 12.4%; garbage disposal 5.6%; dishwasher 17,7%)
- restrooms 27.2% (employee-use restrooms 13.3%, customer-use restrooms 13.9%)
- food preparation 6.4% (preparation sink 1.2%, water used in food 5.1%)
- icemaker 13.9%
- general sanitation 6.6% (floor wash 1.5%, other-including laundry and landscaping 5.1%)
- miscellaneous 4.1%

In Australia, a study about understanding water consumption in commercial kitchens and FS (SA water, n.d.) identified a benchmark rating for water usage (litres per food item or meals prepared): good, less than 35; fair, 35-45; poor, more than 45. Moreover, they recognised that the majority of the water used in the kitchen comes from taps due to the frequency of use, which can consume 20-25 l/minute (kitchen tap), while the one with pre-rinse spray gun 15 l/min (SA water, n.d.).

Regarding the water in output, in literature, it is possible to find studies that worry about the content of oil and grease in wastewater derived from FS and the problem of clogging pipes, but also proposing some possible different uses as ZhiLiang et al. (2020) in the microbial fuel cell, or Chan (2010) with multiple solutions to remove and recycle pollutants contained in restaurant wastewater, Dong Y. et al. (2017) with a test on an enzymatic pretreatment system, Ahmad et al. (2022) for creating bioenergy from wastewater and Yau et al. (2021) recycling oil and grease into valuable products as biofuel. There are also studies providing a larger vision, as Madanaguli et al. (2022), in their systematic review of the relationship of restaurants to green practices, identified studies on unsustainability in restaurants related to water that are focused on inefficient menus and recipes, employee mismanagement, and inefficient water practices.

Design for sustainable and circular use of water: cases of solutions

Along with the literature review of scientific written contributions, this research in design provides a part of the state-of-the-art review dedicated to the research of products that were designed for a more sustainable and circular use of water. This research was done on diverse platforms, such as the one related to awards for design. The results collected in Table 1 were divided into some categories related to their scopes:

- products that use water and are working on the reduction of water consumption
- products that prevent water consumption, eliminating water use
- products that reduce water through their product design
- products that can purify water through their product design

- product design to close or open water loops
- products that use natural techniques for water filtration
- products with filtration technologies to produce drinkable water

Indeed, along with methods, solutions, and technologies such as purification methods with current technologies like carbon filters or others used in city water management systems, products can also be developed with different characteristics or functionalities to take care of the value of water without wasting it.

Table 1. Results of the research for cases performed in June 2023.

Category of cases	**Example**	**Note**
Products that use water and are working on the reduction of water consumption	Appliances and electronic equipment for PK: icemakers, dishwashers, washing machines and specialised ones such as pasta cookers	In the sector, equipment producers are working on reducing water consumption. For example, Electrolux Professional (n.d.)
Products that prevent water consumption eliminate water use	A washing machine orbit by Elie Ahovi for Electrolux (Wired, n.d.)	concept
	Eco toilet by ECOLOO Group that saves clean water and improves sanitation (Uplink, n.d. a)	
Products that reduce water through their product design	Pre-rinse spray valve, “ Replacing one old, inefficient pre-rinse spray valve with a high-efficiency, DOE-compliant model can save a typical commercial kitchen more than 7,000 gallons of water per year.” (EPA, n.d.)	
Products that can purify water through their product design	Flowform technology	These examples can be found in Barbero and Pallaro (2015). These products often use peculiar properties of water, such as the ability to carry information, to self-depurate and structure itself in relation to the stimuli received, and the recognition of the intelligence of water (Toso, 2015).
	Vortex Generator	
	Water Egg (legacy of Romans’ knowledge and of Schauberger’s teachings)	
	Original Vortex Water Energiser™	
	Lily impeller	
	Extractor	
Product design to close or open water loops	LOOPZ, a shower that can recirculate water used (uplink n.d. b)	
	KITCHEN NANO GARDEN, an integrated hydroponic garden in the domestic kitchen that uses the water from the kitchen sink (Trend Hunter (2011)	concept

Category of cases	Example	Note
	Rainwater collectors related to rainwater catchment history in countries oppressed by water shortage (Kinkade-Levario, 2007)	
Products that use natural techniques for water filtration	BIOLOGIC by Whirpool (Behance, 2012), a washing machine uses plants to filter the water, applying the concept of phytodepuration	concept
Products with filtration technologies to produce drinkable water	LIFESTRAW ® (n.d.): advanced hollow fiber membrane technology and additional filtration technologies to obtain drinkable water from non-drinkable one	
	VILLAGEPUMP 500 by Rob van Opdorp filters water from surface water like ponds, lakes, streams and rivers, but also from storage systems, for example, harvesting rainwater (ADI, 2015)	Adi award in 2015
	SMART TAP purifier for domestic use (Red et al., n.d.)	red dot winner 2023
	AQUACYCL can work without a sewer and electricity grid, providing clean water from wastewater and generating electricity (Uplink, n.d.)	
	Odoardo Fioravanti's ZERO is a household drinking water purification system that uses a reverse osmosis process without the use of electricity for pumping water (Fioravanti, n.d.).	

Regarding water management and purification systems with techniques learned from nature, it was decided to deepen the investigation in two databases, Ask Nature (n.d.) and Blue Economy (n.d.), which contain these kinds of examples. The results can be seen in Table 2.

Table 2. Results of the research for water management and purification systems with techniques learned from nature, performed in June 2023.

Reference	Keyword searched	Results (June 2023)	Description
Ask Nature (n.d.)	water purification	Algal Turf Scrubber by Hydromentia	“it pulses water to stimulate algal growth, creating an efficient environment for pollutant removal”
		Aquaporin	“a selective membrane inspired by Aquaporin channels filters and purifies water”
		Baleen Filters by from Baleen Filters Pty Limited	“Baleen Filters use self-cleaning filters to clean wastewater without the use of chemicals”
		BioHaven Floating Island by Floating Island West	“a floating garden that naturally cleans water and improves habitats”
		Retein	“natural water purification inspired by Ocean

Reference	Keyword searched	Results (June 2023)	Description
			Diatoms—stabilises aquaporins in lipids and silica to desalinate and purify water.”
		Sahara Forest Project	“multifaceted desert regeneration system inspired by ecosystems—creates a saltwater value chain to generate electricity, produce freshwater, and revegetate desert lands.”
		Xylem tissue	“how trees lift water with little effort—the structure of the cells in xylem passively moves water from roots to leaves through a system of chambers and valves, and filters out pathogens.”
		Biolytix BioPod	“chemical-free water filtration system inspired by forests—a waste treatment system that uses organisms to convert raw sewage and wastewater into high-quality irrigation water.”
		Eco-Machine from John Todd Ecological Design	“refined wastewater treatment system inspired by aquatic ecosystems—a custom-built wastewater treatment system that purifies water without chemicals.”
Blue Economy (n.d.)	water	Vortex technology (case 1)	“inspired by the observation that dirty water purifies itself like a flowing river. The continuous swirling motion forces air in and out of the water, discouraging and stimulating beneficial microorganisms.”
		Bacterial control without bactericides (case 13)	“Peter and Staffan realized that the seaweed practically speaking jams the communications amongst the bacteria.”
		Hot water for 25 Years (minimum) (case 15)	“luminescence-based water heating device”
		Clean water without sewers (case 18)	“through a combination of ventilation, heat recovery, water purification and drainage systems”
		Dry and separation toilet (case 19)	“separation system based on the Aquatron vortex that secures a rapid and complete separation of solids and water. The solid matter dries out in a matter of hours”
		Clean without soap (case 23)	“with the Lotus Effect, which is based on hydrophobicity (water repellent) combined with nanoscale surface design that dramatically reduces adhesion of particle”
		Water from air (case 39)	“air-to-water systems rely on the decrease of temperature as a means to control the dew point”

Design for sustainable and circular use of water in the food service: a proposed systemic approach

The application of a systemic approach to the research in design for the FS permits to move the attention from the product itself to the context and ecosystem where it is nested. Taking into account the different scales where CE intervenes in nano, micro, meso and macro as defined by Tognato et al. (2021), the different levels of intervention were defined in:

- nano level: product/process in the FS activity;
- micro level: the PK and serving area in the FS activity;
- meso/macro level: local territorial ecosystem where the FS activity is located.

When focusing on water flow and its current management in this sector, the use of the resource is linear. At the product level, the water is mainly used for the function (e.g. dishwashing) and then is flushed away (Figure 1). At the micro level, many processes performed in the PK, through also the use of products, are using drinkable water that is the only quality of water available as input, and then the wastewater is collected, separating grey and black water (Figure 2). The drinkable water in input, which comes from the natural ecosystem, is provided by the net and managed by the local water manager, who is also the manager of the treatment of the wastewater in output, collected by the sewer that after treating processes is released in the natural ecosystem (Figure 3). The connection with the local territorial ecosystem is strong if focusing on the use of the resource water. Another characteristic of water management is that currently, water is considered only in few main qualities: drinkable water as input for all the activities related to human beings that is also used for most commercial activities, and grey water as wastewater in output (diverse from the black water coming from toilet). But all the products/processes that happen in the PK may require not always drinkable water but different qualities of water in input and produce different qualities of water in output. For example, washing vegetables produces cold water with organic residues or the pre-rinse of dishes how water with soap and food waste.

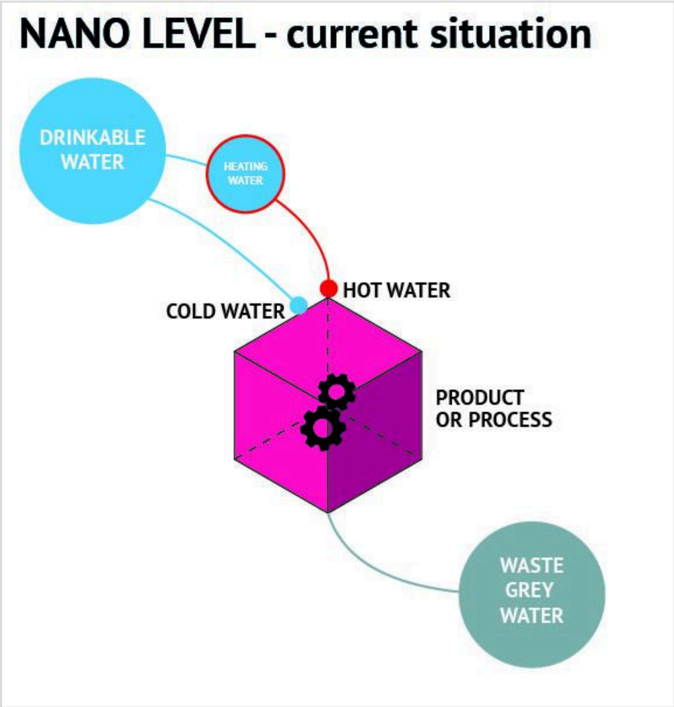

Figure 1: Representation of the nano level—interaction of product/process with water.

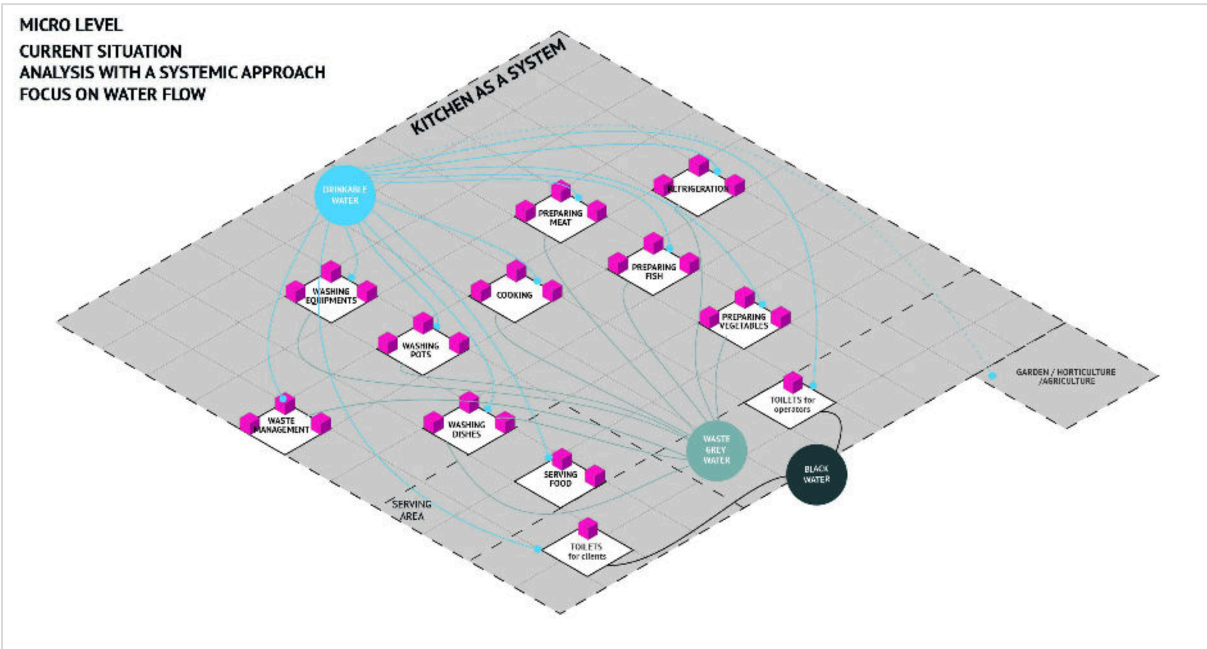

Figure 2: Representation of the micro-level interaction with water.

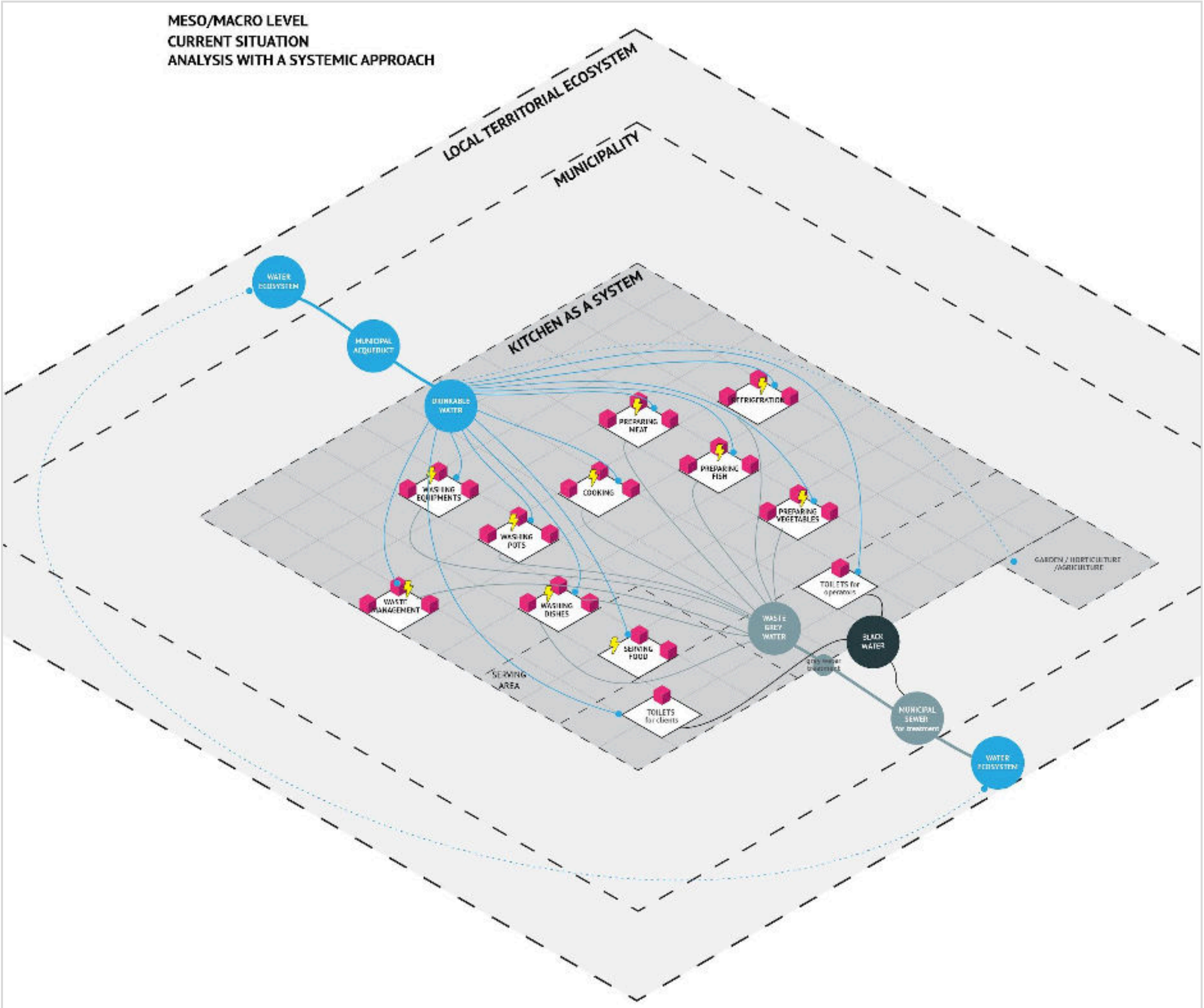

Figure 3: Representation of the meso/macro level interaction with water.

In order to implement sustainable and circular use of the water, potential actions to work on the closing loops—according to the CE—or opening loops creating open systems—according to the systemic design approach—can be improved. Here some are listed:

- prevent the use:
  - into the process/activity/equipment;
  - inside the PK;
- manage wastewater inside the PK:
  - close loop inside the same process/activity/equipment;

    - open loop, reusing it for another process/activity/equipment inside the PK;
- manage wastewater, taking into account the relationship between the PK and the local ecosystem;
- open the loop outside the PK and reuse it for another process/activity/equipment (e.g., laundry room).

Figures 4 and 5 are visual representations of these potential strategies to apply in the FS. However, in this sector, water should meet certain quality standards to ensure food safety and compliance with health regulations set by countries, which can compromise their implementation.

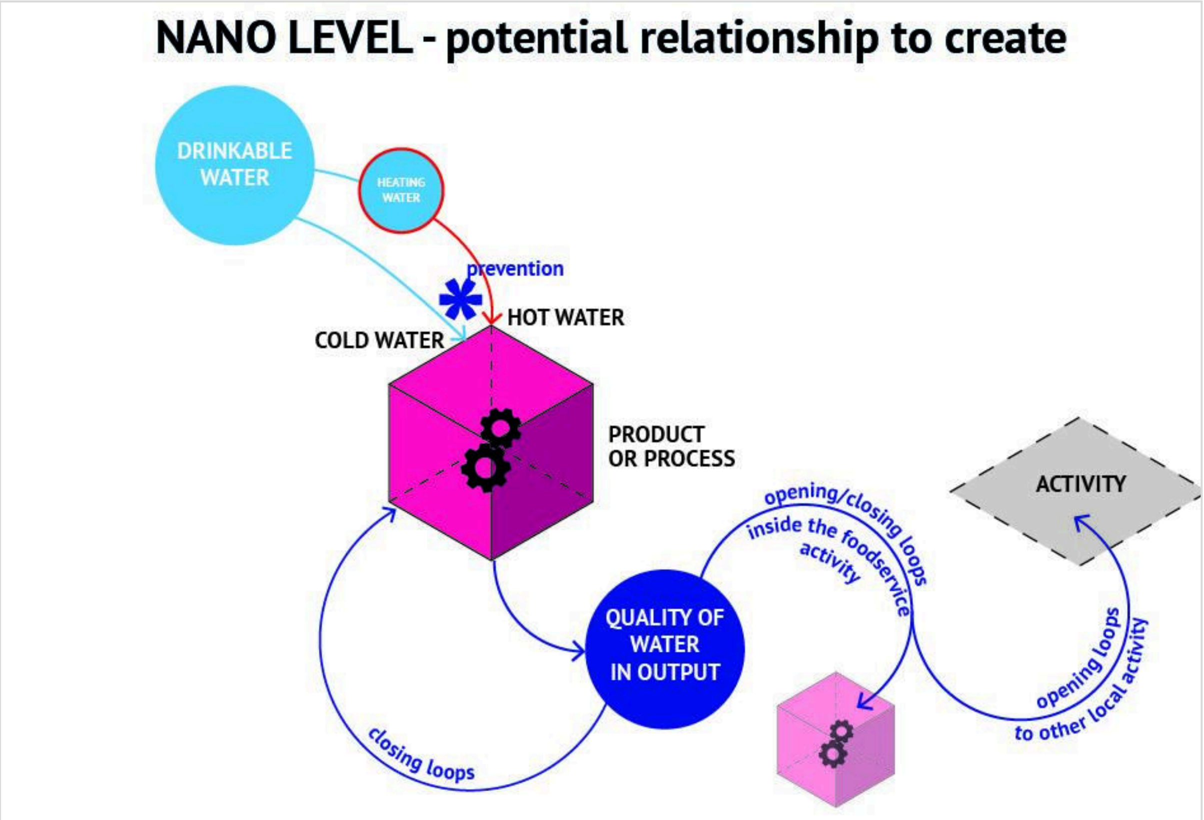

Figure 4: Representation of the potential actions to improve for sustainable and circular use of water at the nano level.

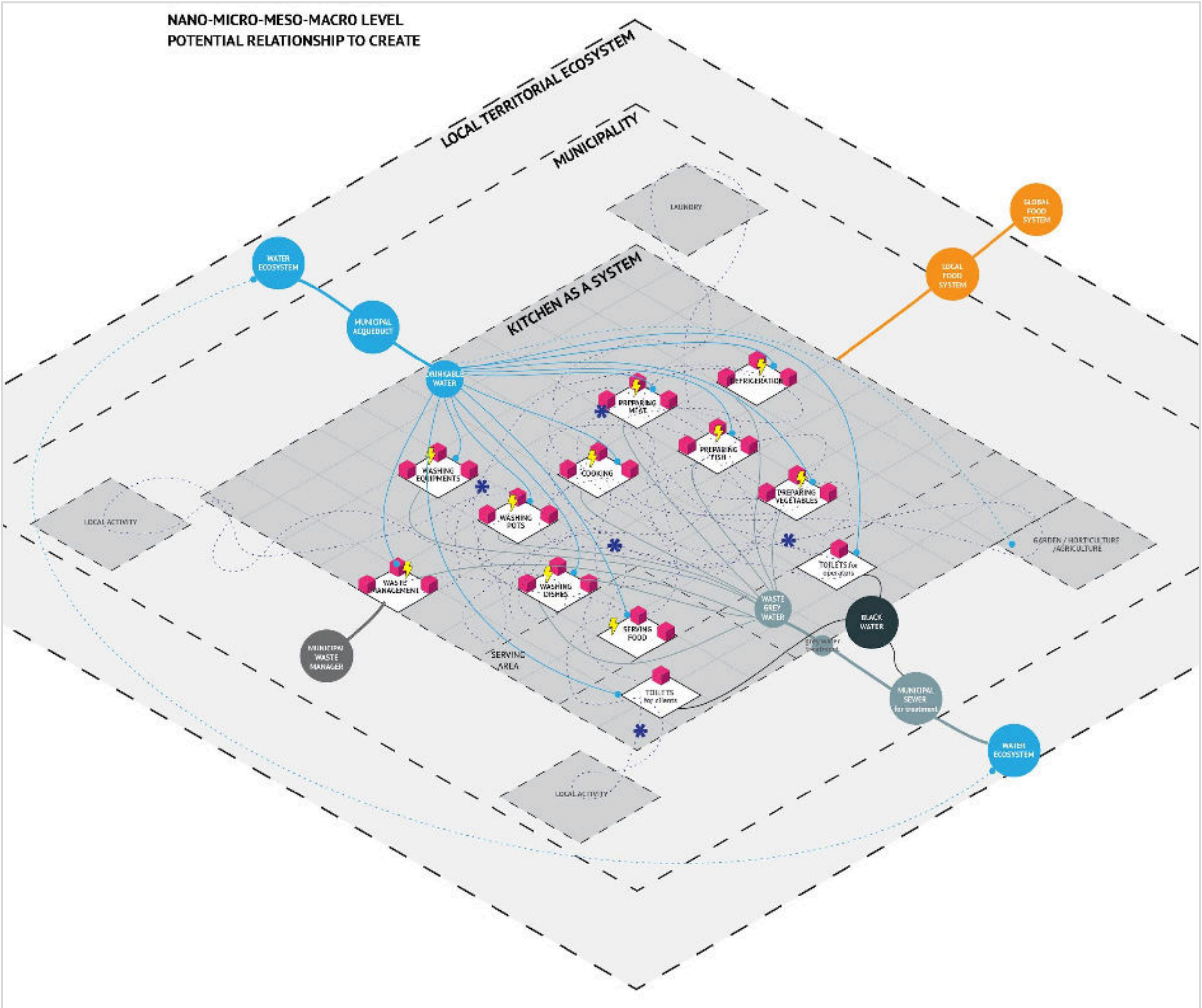

Figure 5: Representation of the potential actions to improve for sustainable and circular use of water at the nano-micro-meso-macro levels. The violet asterisks represent single interventions to work on the water flows, the ones in Figure 4.

To draft such a scenario, it is necessary to research different topics that go beyond the current management. Some future research questions were recognised as important in this research process, drafted as follows:

- at nano/micro level:
    - where is water used in the FS? In which processes, activities, and types of equipment?;
    - how much water is used in input and in output for each process? Which are the quantities?;

  - what kind of water is used in the input and in the output for each process? What are the qualities?;
  - how do workers use water? Has the user behaviour had an influence?;
- at meso/macro level:
  - where is this FS activity located?;
  - which is the relationship with the territorial system where is it nested?;
  - which actor and stakeholders are related to it?;
  - which territorial characteristics intervene in the system?
  - what is the local water manager, and how does it work?

The answers can be useful for understanding where intervention in the process is possible and for designing different and innovative solutions.

A continuous process of zoom-in and zoom-out from the nano and macro levels is recognised as fundamental in the design phase and added to the visualisation of the water flow as a design tool. In particular, the flow analysis in product design cited by the SD applied to product in Barbero et al. (2017) in addition to the HD (Battistoni et al., 2019) can be helpful. This step is also necessary for a co-design process with the involvement of experts and technicians on the water to consider chemical characteristics, hygiene constraints, and economic feasibility, assess the final environmental impact of the different solutions designed, and understand how to implement them. Indeed, for example, there is a need to understand that the water purification process should not be more energy-consuming than other water management methods.

Moreover, focusing on FS, the green measures adopted by restaurants identified by Madanaguli et al. (2022), which are above the attention on product use, need to be implemented: regular water audit, employee awareness education, menu reconfiguration, regular plumbing maintenance and appropriate water dispensers.

Conclusion

The research presented in this paper is part of a broader research that tries to understand how to design in the FS sector to improve sustainability through better management of the natural resources involved. Most contemporary studies focus on the impact of food waste on the food system, such as the one by Fassio and Tecco (2018), understanding the circular economy for food. This broader research understands instead the lack of attention to the quantities and qualities of water used in the FS sector. This can represent a problem mainly in geographical places where there is a large concentration of restaurants, often related to tourism, and also a scarcity of water due to severe weather conditions. Applying a systemic approach to this topic can be useful in understanding the link between the products used and the overall system where they are nested. Moreover, although there is great water consumption, the attention should also be to the quality of water because the input is always drinkable water for all uses, and the wastewater, after a process is performed, can be a value wasted, e.g. the loss of heat from hot water. Circular use of water can improve the sustainability of its management and increase awareness of the water-value for better use.

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