Le projet RECYCLO : Traitement et réutilisation des eaux usées de blanchisseries

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ABSTRACT

The laundry industry uses large quantities of water, resulting in a significant production of polluted wastewater. In Europe, 2.7 billion kilograms of textiles are washed each year, requiring around 42 million cubic metres of water, which is discharged as wastewater [MELIAN *et al.* 2023]. Laundry wastewater contains a complex range of pollutants, including phosphorus compounds, allergenic fragrances and large quantities of anionic and non-ionic surfactants [BRAGA et VARESCHE 2014 ; COLLIVIGNARELLI et al. 2019]. These surfactants, have a negative environmental impact even at concentrations below 1 mg/L, [BLASCO et al. 2003 ; JARDAK et al. 2016]. Laundries also emit endocrine disruptors from the washed clothes and the detergents used, ranging from nanograms to milligrams per litre [KANIKLIDIS 2022 ; DODSON et al. 2012]. These contaminants can affect aquatic ecosystems and even threaten the survival of certain species [FERRARI et al. 2003 ; SUMPTER et al. 2013]. Laundry effluent can also contain pharmaceutical compounds, especially from the washing of hospital linen, which are difficult for treatment plants to remove, leading to the contamination of surface and groundwater. [CHOUBERT et al. 2011 ; SOULIER et al. 2011 ; VERLICCHI et al. 2012 ; BOURGIN et al. 2018 ; TRAN et al. 2018 ; TURRUL *et al*. 2023].

Water is a key resource for the global economy, playing an essential role in the production of energy, food and various industrial activities. Climate change increases the risk of water scarcity in several European regions, which could slow down economic activity, especially in water-intensive sectors [VAN VLIET et al. 2021]. From an environmental point of view, the pressure on water resources is intensifying as agricultural, industrial and urban activities increase their discharge of pollutants into surface and groundwater [SCHWARZENBACH et al. 2006].

The recycling of laundry wastewater is an ideal solution to reduce water consumption and limit the discharge of emerging pollutants that affect the environment and health [KUMAR et al. 2022].

In France, the regulations for the reuse of treated wastewater are strict, and the use of treated grey water for laundry hygiene is only permitted on an experimental basis (Decree of 12 July 2024 on the sanitary conditions for the use of water unfit for human consumption for domestic purposes). Rainwater can be used if it meets A+ quality standards, i.e. absence of E. coli, enterococci and Legionella pneumophilia bacteria, turbidity < 2 NFU and total organic carbon (TOC) less than 5 mg/L. In Spain, treated grey water is allowed to be used and no limit exists for laundry hygiene.

The study presented here proposes a solution for the treatment of laundry effluent. It was tested on a laboratory scale on different laundry effluents and then confirmed by installing a demonstrator in a laundry in Spain. This work was co-funded by the European Commission under the LIFE-Environment programme.

The treatment process studied consists of three modules: (1) a pretreatment by coagulation-flocculation to remove suspended solids (SS) and particulate and colloidal chemical oxygen demand (COD), (2) an advanced oxidation process using UV rays and hydrogen peroxide to degrade organic pollutants, and (3) a final treatment by adsorption on activated carbon to remove residual pollutants. The aim of this treatment is to obtain treated water that can be used in all stages of laundry washing and rinsing.

The GRUPFRN laundry washes linen for hotels, hospitals, professionals and private individuals. Wastewater was monitored and analysed over a period of 9 months (Table 1). Samples were taken from a 1.5 m^3 homogenised tank. The water was whitish and turbid. Its composition remained relatively stable over time, and the slightly alkaline effluent had a COD close to 1 g/L. The concentration of anionic and non-ionic surfactants is quite variable.

Table 1. Characterisation of the wastewater, averaged over a 9-month monitoring period.

Parameters	Units	Average
pH	/	7,64 ± 0,59
Conductivity	mS/cm	0,816 ± 0,109
SS	mg/L	105 ± 16
COD	mgO_2/L	953 ± 225
UV_{254} transmittance	%	9,8 ± 6,2
Anionic surfactants	mg/L	66 ± 44
Cationic surfactants	mg/L	0,5 ± 0,2
Non-ionic surfactants	mg/L	85 ± 40
N global	mg/L	8,6 ± 1,8
P total	mg/L	< 2
AOX	mg/L	0,33 ± 0,06
TOC	mg/L	296 ± 48

The treatment steps have been optimised on a laboratory scale. To remove organic pollutants (surfactants, endocrine disruptors, etc.) by advanced oxidation, it is necessary to increase the UV transmittance at 254 nm to allow UV radiation to reach and activate the hydrogen peroxide molecules. The addition of aluminium polychloride followed by an anionic flocculant eliminates 48% of the COD and increases the UV transmittance to 66%. Suspended solids are removed in the form of a sludge, which is filtered through a 100 µm mesh. The clarified water is then treated by UV/H_2O_2 advanced oxidation. By varying the amount of H_2O_2 introduced and the UV dose applied, it is possible to degrade more than 95% of the remaining COD. The water leaving the treatment no longer foams, the surfactants have been degraded. However, removing 95% of the COD using this process is very energy intensive and therefore not suitable for a large-scale application. By reducing the treatment time of the advanced oxidation process and adding activated carbon adsorption post-treatment, the remaining COD can be removed more economically.
A demonstrator consisting of the 3 building blocks presented above (coagulation-flocculation, advanced oxidation process (AOP) and activated carbon) has been installed in the laundry (Figure 1). It treats 200 L/h and covers the cold water needs of the laundry.

Figure 1. GRUPFRN laundry demonstrator.

Similar to the laboratory tests, the coagulation-flocculation treatment removes 54% of the COD and increases the UV transmittance to 65% This stage also removes 97% of the iron and 40% of the copper and zinc present in the water. Treatment of one cubic metre of water produces approximately 3 kg of wet sludge. This sludge has low or zero levels of metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) and can therefore be recycled by composting. The advanced oxidation treatment is carried out in a reactor with 12 x 600 W lamps. Water is circulated twice in the reactor to achieve the required UV dose. Hydrogen peroxide is added gradually throughout the treatment. As mentioned above, achieving very low COD at the AOP outlet results in high operating costs. Therefore, a COD target of 150 mg/L is set at this stage. On average over the 9 months of monitoring, the COD at the AOP outlet was 130 ± 36 mg/L and 93% of the anionic and non-ionic surfactants were degraded. In addition, this treatment effectively disinfects the water, eliminating coliform, E. coli and enterococcus bacteria. Finally, the water passes through an activated carbon filter with a contact time of 55 minutes. After treatment, the water has a COD of less than 15 mg/L and a total organic carbon (TOC) of around 5 mg/L, which means it can be reused in the washing process. Just before the machines, in case bacteria develop in the REUSE tank, a 10 µm filter and a UV-C lamp are added. This treatment removes more than 90% of the COD and TOC. (Table 2). In addition, the micropollutants detected were completely eliminated during the treatment. For example, bisphenol S, an endocrine disruptor with a structure similar to bisphenol A, was completely degraded.

Table 2. Characterisation of the treated water, averaged over a 9-month monitoring period.

Parameters	Units	Treated water	Average removal
pH	/	7,28 ± 0,37	/
Conductivity	mS/cm	1,181 ± 0,132	/
SS	mg/L	4,1 ± 4,0	96 %
COD	mgO_2/L	< 15	99 %
UV_{254} transmittance	%	94,7 ± 4,1	/
Anionic surfactants	mg/L	< 0,1	99 %
Cationic surfactants	mg/L	< 0,2	80 %
Non-ionic surfactants	mg/L	< 0,2	99 %
N global	mg/L	2,0 ± 2,3	77 %
P total	mg/L	0,08 ± 0,01	92 %
AOX	mg/L	0,10 ± 0,04	70 %
TOC	mg/L	5,4 ± 3,6	98 %

Washing tests were carried out with treated wastewater. As the hot and cold water supply systems were separate, only the cold water was replaced by treated wastewater. The ratio of treated wastewater to mains water was therefore 6:4. The washing proved to be visually effective. In addition, standardised strips containing synthetic stains were introduced into the machines, demonstrating that the treated wastewater could effectively remove the stains.

Monitoring of the treatment for 9 months showed that the water obtained was of good quality (A+ quality) and could be used to wash laundry effectively. At the same time, effluents from 6 other laundries were characterised and effectively treated on a laboratory scale, demonstrating the robustness of the process. The demonstrator has allowed full-scale treatment to be optimised and will enable two further improved pilot plants to be built in France and Luxembourg in 2025.

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