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AQUAREL: Project Aimed at Improving Water Management in French Dairy Plants

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Abstract: The AQUAREL project was launched in 2015 by the CNIEL (French Dairy Interbranch Organization) to propose solutions to dairy processors for the development of water reuse scenarios on their plants. The project focused particularly on the valorization of water from milk which is water obtained during concentration and evaporation processes of milk and its by-products. Firstly, a literature review was done to identify the current uses of water from milk on French plants but also on foreign sites, the technologies used to treat it and the regulations related to water reuse in food industry. Secondly, a field survey was led to establish an overview of the water consumptions and practices existing on the plants. Then, samples were collected on five dairy plants in order to determine the physico-chemical and microbiological composition of water from milk. Thus, the important collection of results obtained was used as a basis for exchanges with water treatment equipment suppliers in order to identify the suitable technologies to treat and reuse water from milk. Two treatment channels were identified, each of them including a filtration and a disinfection step. All this work led to the writing of reports which are now available for the dairy sector professionals.

Key words: Water from milk, water reuse, treatment technologies.

1. Introduction

Water scarcity is becoming an issue that directly impacts the dairy sector. Dairy processors have to reduce water usage and find alternatives. Recycling solutions exist in the French Dairy Industry but all possibilities have not been exploited. The water content of milk constitutes an important source of water which could potentially be reused. Water from milk is non-potable water and covers reverse osmosis permeates and condensates which are respectively generated during concentration and evaporation processes of milk and its by-products. In France, it is currently used as boiler feedwater, clean-in-place solutions, floor cleaning and for cooling tower water. However, in some countries the water is treated and reused in more advanced purposes like in Belgium where a dairy plant reuses this water for the final rinsing [1]. The AQUAREL project, which was launched in 2015 by the CNIEL (French Dairy Interbranch Organization), has aimed to bring solutions to processors for the development of reuse scenarios on their plants. Thus, this project focused on the identification of existing and new treatment technologies to increase reusable quantities of water from milk.

2. Project Organization

The AQUAREL project began on January 2015 and ended on June 2018. During these three and a half years, several actions works were led (Fig. 1). Firstly, a literature review was carried out to identify the current uses of water from milk in French and foreign sites and the technologies used to treat it. An analysis of the regulations related to water reuse in food industry was also done to highlight the differences concerning the practices in France and other countries. Secondly, a field survey was led to establish an overview of the water consumptions and practices

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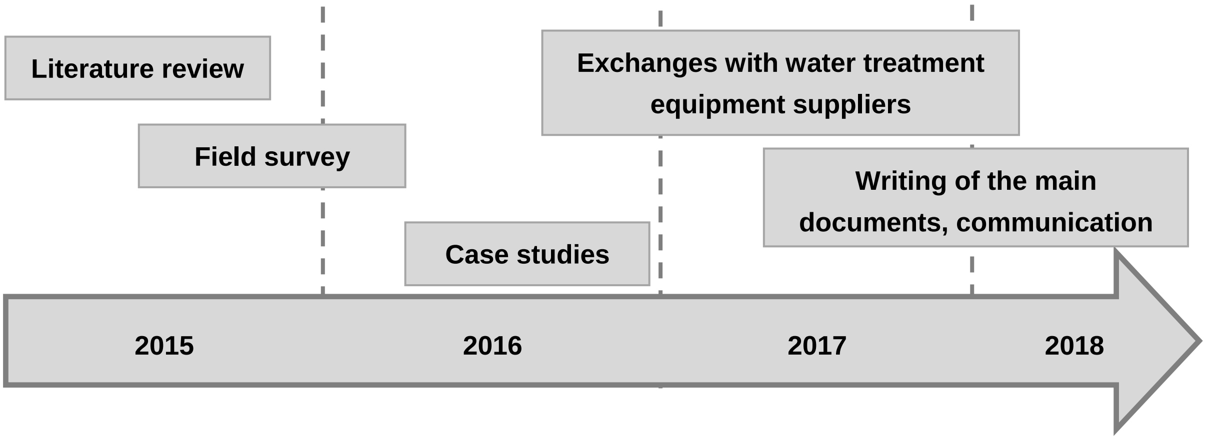

Fig. 1 Steps of AQUAREL.

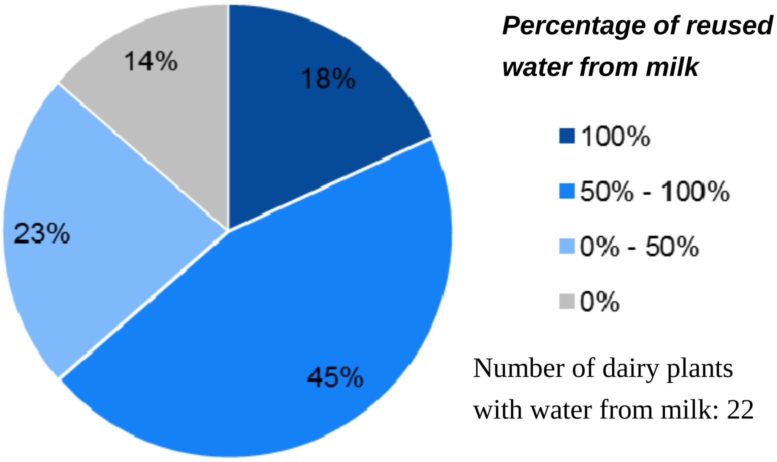

Fig. 2 Repartition of dairy plants (%) according to the percentage of reused water from milk.

(valorization or not of water from milk, application of good practices to reduce water consumption etc.) existing on the dairy plants. The survey was done with an Excel file containing questions classified on nine sheets. Then, analysis on water from milk was led to determine the physico-chemical and microbiological composition of this one. Seventeen samples of raw water from milk were collected on five dairy plants. Samples of water from other sources (public network, wells) and treated water from milk were also collected. Finally, the results obtained allowed the construction of a large database including more than 2,470 measures and from which exchanges with water treatment equipment suppliers happened to identify the suitable technologies to treat and reuse water from milk.

3. Main Insights of the Project

3.1 Results from the Survey

Fifty-eight dairies answered the survey. The quantity of milk received by this panel was estimated to 44% of the total quantity collected on the whole national territory in 2015 (total reaching 25 billion liters). Dairy plants of all sizes responded but a lot of results came from large sites. Indeed, more than half of dairy plants audited are submitted to the European directive on the industrial emissions (IED regulation).

The main results from this survey are the following:

- 62% of production plants use exclusively tap water for their process;
- 18% of dairy plants reuse totally water from milk (Fig. 2);

- 68% of dairy plants producing water from milk reuse it for cleaning uses (except final rinsing);
- 52% of dairy plants with water from milk do not treat it before their reuse. Only 29% applied, at least, a chlorination step;
- 1,130,000 m^3 of water from milk is not reused.

3.2 Water from Milk Composition

The analysis of the collected samples allowed establishing the characteristic composition of water from milk. Regarding the condensates, their composition can vary according to the raw material which is processed (milk, milk permeate, whey). Water from milk is essentially characterized by organic pollution. If the production plant processes milk or related products (milk permeates, recipes with milk) in powder, the average COD (chemical oxygen demand) concentration reaches 25.3 mgO_2/L. The BOD5 (biological oxygen demand on five days) represents about the half of this value (12.2 mgO_2/L) and the average TOC (total organic carbon) reaches 9.9 mg/L (Table 1). In the case of whey processing in powder, the average COD is doubled (56.5 mgO_2/L) as well as the average BOD5 (25.5 mgO_2/L). The average TOC reaches 14.4 mg/L (Table 2).

However, water from milk does not contain a lot of TSS (total suspended solids; <2 mg/L) and its pH is close to the neutrality (6.6 for the condensates from milk, 7.4 for the condensates from whey). French regulation about drinking-water quality indicates a reference threshold for the TOC. The value must be below 2 mg/L. Therefore, reusing water from milk on surfaces in direct contact with the food product requires an additional treatment to reach this reference threshold.

3.3 Treatment Channels Identified

First information about technologies used to treat water from milk was collected during the literature

Table 1 Composition of milk and related products condensates.

Parameters	Unity	Mean	Range of variation
pH	pH unity	6.6	[5.5-8.1]
Temperature	°C	49.0	[31.2-59.8]
Conductivity	µS/cm	9.8	[4.0-21]
Turbidity	NFU	0.6	[0.1-1.2]
TSS	mg/L	<2	/
Kjeldahl nitrogen	mg/L	0.74	[<0.50-1.7]
COD	mgO_2/L	25.3	[5.80-63.0]
BOD5	mgO_2/L	12.2	[2.10-37.0]
TOC	mg/L	9.9	[4.2-23]
Ammonium (NH_4^+)	mg/L	0.50	[0.21-0.77]

Table 2 Composition of whey condensates.

Parameters	Unity	Mean	Range of variation
pH	pH unity	7.4	[5.5-9.1]
Temperature	°C	41.3	[18.7-60.5]
Conductivity	µS/cm	22.8	[6.00-33.0]
Turbidity	NFU	0.36	[0.2-0.8]
TSS	mg/L	<2	/
Kjeldahl nitrogen	mg/L	3.1	[<2-5.2]
COD	mgO_2/L	56.5	[17.0-98.0]
BOD5	mgO_2/L	25.5	[1.3-80]
TOC	mg/L	14.4	[5.20-27.0]
Ammonium (NH_4^+)	mg/L	2.9	[0.38-5.3]

review. Many foreign production plants emphasized membrane filtration and disinfection steps to treat and reuse this water. This is the case in Australia [2], in England [3] and, as mentioned in the introduction, in Belgium where some dairies use ultrafiltration, reverse osmosis and disinfection processes like UV light or chlorination. Chmiel et al. [4] already demonstrated that the use of membrane processes allowed treating water from milk in order to reuse it in the plants.

Exchanges with water treatment equipment suppliers which happened during the project allowed highlighting two treatment channels.

Filtration on Sand and Active Charcoal Followed by UV Disinfection

This first treatment channel is well appropriate to the treatment of condensates with low organic content. It is composed of three processes which roll out in the following order: sand filter, active charcoal filter and UV disinfection step (Fig. 3).

Sand filter allows the removal of eventual total suspended solids to avoid a faster clogging of the active charcoal filter. Moreover, it allows the reduction of the turbidity. The active charcoal filter is used to remove the organic content of water from milk and the UV system is used to ensure the sanitation of this one before its reuse. A recirculation loop at the last storage tank level is needed because UV disinfection is not long-lasting.

Recommendations need to be fulfilled to use this treatment channel (Table 3). Therefore, to obtain a TOC concentration below 4 mg/L, the parameter

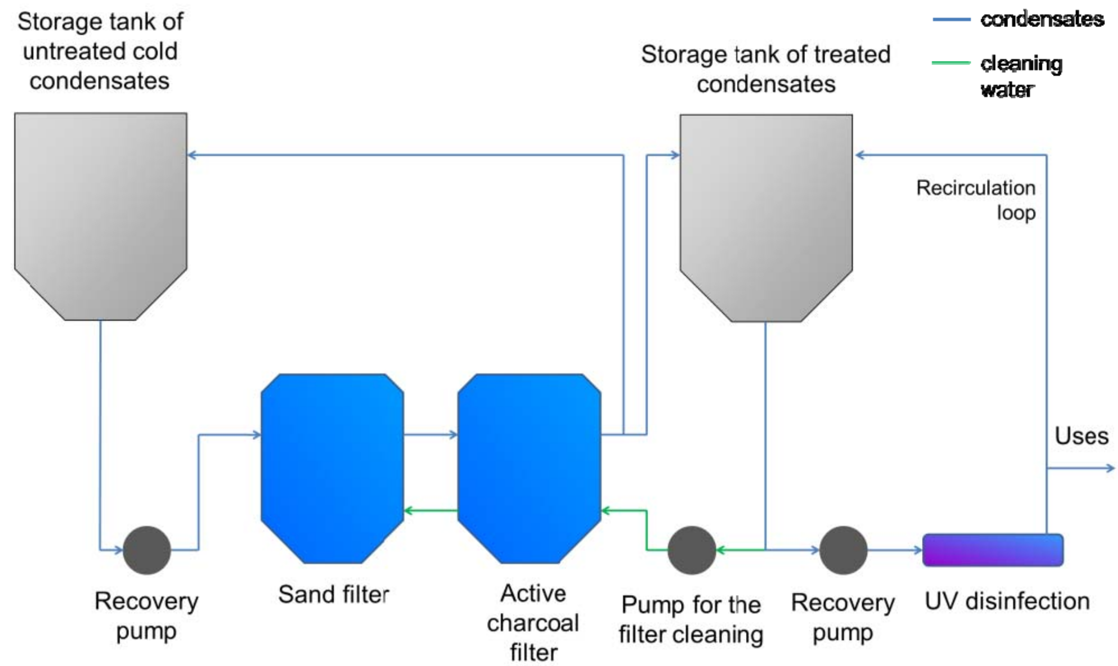

Fig. 3 Treatment channel including sand and active charcoal filters.

Table 3 Water quality at the inlet and the outlet of the treatment channel.

Parameters	If value (untreated condensates)	Then, value (treated condensates)
Turbidity	5 NFU maximum	<2 NFU
TSS	10 mg/L maximum	<2 mg/L
COD	60 mg/L (average) with peaks up to 100 mg/L	<10 mg/L
TOC	25 mg/L maximum	<4 mg/L (possible to go below 2 mg/L by installing a condensate sorter)

Reference: BWT

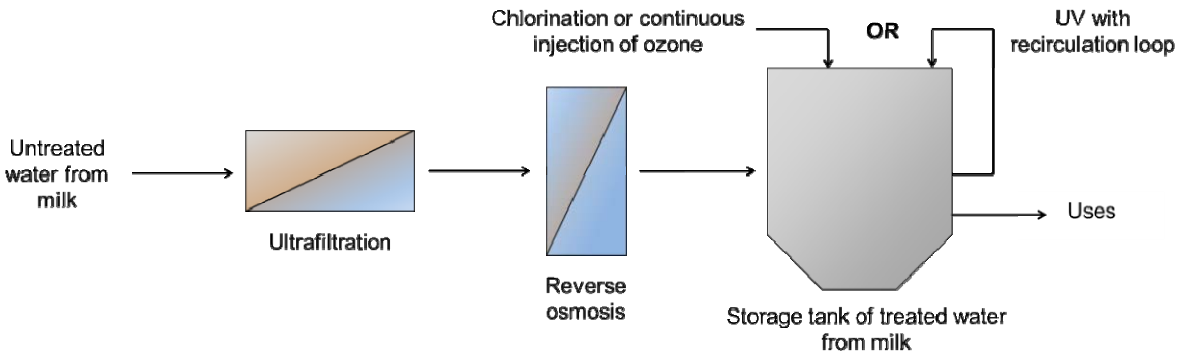

Fig. 4 Treatment channel including ultrafiltration and reverse osmosis.

Table 3 Water quality at different steps of a treatment channel including ultrafiltration and reverse osmosis.

Parameters	Ultrafiltration inlet	Reverse osmosis inlet	Treatment channel outlet*
Turbidity	nd	nd	<5 NTU
COD	20 mg/L	10 mg/L	nd
TOC	7.5 mg/L	3.7 mg/L	<2 mg/L
Reference: Nalco Water			

* An active charcoal filter is present at the end of the treatment channel, after reverse osmosis process.

concentration at the inlet of the treatment channel must not exceed 25 mg/L. This value of 4 mg/L is not compliant with French regulation about drinking-water quality. Consequently, to reach TOC concentration values below 2 mg/L, it is recommended to install a condensates sorter before the treatment channel in order to select those which are less loaded in organic matter.

Filtration on Membranes Processes Followed by Disinfection

The second treatment channel is appropriate to the treatment of condensates and reverse osmosis permeates. It is composed of three processes which are configured in the following order: ultrafiltration, reverse osmosis and disinfection step (Fig. 4).

Ultrafiltration allows a removal of eventual total suspended solids in order to protect reverse osmosis. Regarding this last process, it allows the removal of the organic content and of several solutes like ammonium (NH_4^+) or chlorites and chlorates which can be present and which are compounds monitored in dairies. Finally, a disinfection step is implemented, like in the previous case, to ensure the sanitation of water from milk before its reuse. Three types of disinfection can be applied: chlorination, ozone injection or UV system. Addition of chlorinated compounds allows a long-term effect of the disinfection. But, chemical products used are responsible of the presence of chlorites and chlorates in the installations. On the contrary, UV system and ozone injection do not generate undesirables compounds but their efficiency over a long period is very limited or inexistent. Therefore, storage of treated water from milk needs to implement a recirculation loop for the UV system or a continuous injection of ozone.

The efficiency of a treatment channel similar to this one was tested by a water treatment equipment supplier. A foreign dairy production plant which wanted to reuse its condensates tested a pilot installation including ultrafiltration, reverse osmosis and active charcoal filter. The results showed that this treatment channel was suitable for reaching TOC concentrations below 2 mg/L (Table 4).

4. Conclusion

Managing effectively water and developing water reuse are priorities of the French Dairy Industry. The

AQUAREL project, launched in 2015, allowed establishing a first overview of practices in dairies and estimating the volume of water from milk potentially reusable. This project also allowed identifying technologies and channels suitable for the treatment of this water and its reuse in advanced uses like final rinsing of surfaces in direct contact with the food product. Filtration and disinfection steps are constantly applied. Only technologies used for these unitary operations changed. Therefore, condensates with a low organic content can be treated with sand and active charcoal filters followed by UV disinfection. Regarding, reverse osmosis permeates and condensates with a more important organic content, they can be treated with a channel including ultrafiltration, reverse osmosis and disinfection. With an initial sorting of the different waters from milk in order to exclude the more loaded, the use of these treatment channels can allow to reach TOC concentrations below 2 mg/L which is the threshold value for this parameter in French drinking-water quality regulation.

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References

[1] AQUARAMA. 2014. “Friesland Campina Aalter met la barre plus haut pour affronter l’avenir.” *AQUARAMA* 65 (2014): 68-9.

[2] Baskaran, K., Palmowski, L. M., and Watson, B. M. 2003. “Wastewater Reuse and Treatment Options for the Dairy Industry.” *Water Science and Technology: Water Supply* 3 (3): 85-91.

[3] Alliance stratégique pour une utilisation optimale de l’eau (ASUOE). 2012. “Étude sur l’utilisation optimale de l’eau dans l’industrie agroalimentaire.” Study report. 124p.

[4] Chmiel, H., Mavrov, V., and Bélières, E. 2000. “Reuse of Vapour Condensate from Milk Processing Using Nanofiltration.” *Filtration + Separation* 37 (3): 24-7.