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## *Original Paper*

# Research and Application of Best Practices for Water Saving in Industry

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### **Abstract**

*Water is a crucial resource for the earth and therefore for all living beings on earth such human. This article is focused on how to optimize water usage (saving) in industrial environment. This sector has a huge impact on water: usage, pollution, etc. The first step was to define and apply a water management and the second step to make research on each opportunity identified and to implement it. All those actions have been carried out in a pharmaceutical manufacturing site. Water saving have been done on different application: washing machine, heat pump on chiller system, osmosis inverses system on purified water and continuous measurement device of water quality. The site's water consumption has been reduced by 40% in less than 6 years.*

### **Keywords**

*water saving, water management, water reuse, wastewater*

## **1. Introduction**

Water is a vital resource for humans, plants, etc., and it becomes very scarce in many areas in the world (Van Vliet et al., 2021). There is an unequal distribution of this resource between countries. Pollution also impacts this resource.

In industry, water consumption is high because water is used for several application such as product manufacturing and cleaning (Hong et al., 2020). Therefore, this article is focused on reducing and optimizing the use of water in industry while not negatively impacting equipment's performance and water quality.

Several research have been done on an industrial site (a pharmaceutical site). The first research is about the reusing of wastewater from a purified water station (instead of rejecting the wastewater to a wastewater plant). The second research is about water usage optimization on a washing machine. The third research consists of making water saving thanks to a heat pump on a chiller system. The last

research is regarding the significant water usage of a water quality monitoring device.

Research has been done under a strong water management (Biswas, 2008; Keovilignavong et al., 2021; Haque et al., 2021). This water management includes several interlinked themes:

- Involvement of each user (from operators to the site's direction members)
- Identification of potential savings through studies, audits, seminars etc.,
- Water savings action plan
- Water meters and software (Alvisi, et al., 2021): It is crucial to have a reliable information technology software,
  - Targeting,
  - Monitoring,
  - Reporting,
  - Etc.

Site's water consumption has been reduced by 40% in less than 6 years. Each research of this article has led to a best practice that can be duplicated.

## **2. Water Reuse**

The industrial site uses purified water principally for manufacturing products, cleaning equipment, and controlling quality of products in laboratories. This purified water is produced by a purified water station inside the site. The purified water station is fed by city water. Purified water consumption is mainly due to production and therefore the first idea that comes to mind is to reduce production for reducing the purified water consumption. Nevertheless, it is complex to carry out that action because it depends on business need.

Among the ideas for reducing purified water consumption, one is very interesting. This idea is water reuse (like heat recovery on thermal equipment). Therefore, research on water reuse has been launched. The first step of the research consists of making a water balance to research potential of water reuse: wastewater, non-use water etc. (Salgot & Folch, 2018). The second step consists of launching an analysis campaign on those waters that can be reused to know their physico-chemical characteristics and variations.

### *2.1 Identification of Water Reuse Potential*

The purified water station has a Reverse Osmosis (RO) system. It is a water treatment process that removes contaminants from water by using pressure to force water molecules through a semipermeable membrane. During this process, the contaminants are filtered out and flushed away, leaving clean water (Inukai S. et al., 2015).

It has been identified an important amount of wastewater on the RO system. More precisely, it is water concentrate from second stage of the RO system.



**Figure 1. Reverse Osmosis System (Black Cylinders)**

On the other hand, an investigation has been done to identify where this wastewater can be reuse. The purified water represents 30% of site’s water consumption. The others high consuming equipment on site are the cooling towers 35% and the automatic washing machine 32%.

Due to quality requirement, it is not possible to use this concentrate water in production and laboratories areas. Regarding cooling towers, there is a possibility to us this concentrate water as make-up water (Afshari et al., 2019).

*2.2 Water Analysis*

A technical analysis of RO and city water has been done (divided in two parties):

- 1) Determine the impact of mixing RO water with city water in the cooling towers water circuit (i.e., impact on the treatment and characteristics to be maintained to avoid legionella (Paschke et al., 2019)).
- 2) Study of the extra volume and regularity of supply.

Table 1 shown the characteristics of the city water and RO wastewater.

**Table 1. Average Results of Water Quality Analysis Done by Laboratories**

|                                   | City Water | RO Wastewater Min | RO Wastewater Max |
|-----------------------------------|------------|-------------------|-------------------|
| pH                                | 7,5        | 7.8               | 8,2               |
| Water hardness ( ºF)              | 10         | 0                 | 0                 |
| Alkalimetric title ( ºF)          | 0          | 0                 | 0                 |
| Complete alkalimetric title ( ºF) | 8          | 11                | 23                |
| Chlorine (mg/l)                   | 35 to 88   | 42                | 190               |
| Conductivity (µS/cm)              | 260 to 430 | 430               | 1 160             |

Given the proportion of RO water compared to city water, the overall characteristics will only be

slightly modified. The chlorine level will slightly increase but without limiting the concentration factor. The hardness of the water will be reduced which is an advantage in view of the high level of hardness of the water currently in the circuit.

At the bacteriological level, water from osmosis is often of very good quality and will not affect biocidal treatments.

The recovery of RO water is positive (saving city water without altering the treatment and operation of the cooling tower).

Water recovery from the osmosis concentrate is estimated at 300 l/h or 2 500 m<sup>3</sup>/an.

### 2.3 Modification of the Installation

The main modifications of the installation after the research are as follows:

- Storage of RO wastewater in a tank equipped with level contact and overflow as represented in figure 2.
- Batch pumping from the RO wastewater tank to the cooling towers (thanks to a new and appropriate pump as shown in figure 3).
- Implementation of a device for measuring automatically and continuously chlorine, pH, and temperature
- Pipework: water piping in stainless steel 316 diameter 22 from the purified water station to the cooling towers room (nearly 100 m); PVC piping for draining; insulation of stainless-steel pipework with rock wool thickness 30 mm.
- Electrical connection: counters, electrical cabinet etc.



**Figure 2. RO Wastewater Tank**

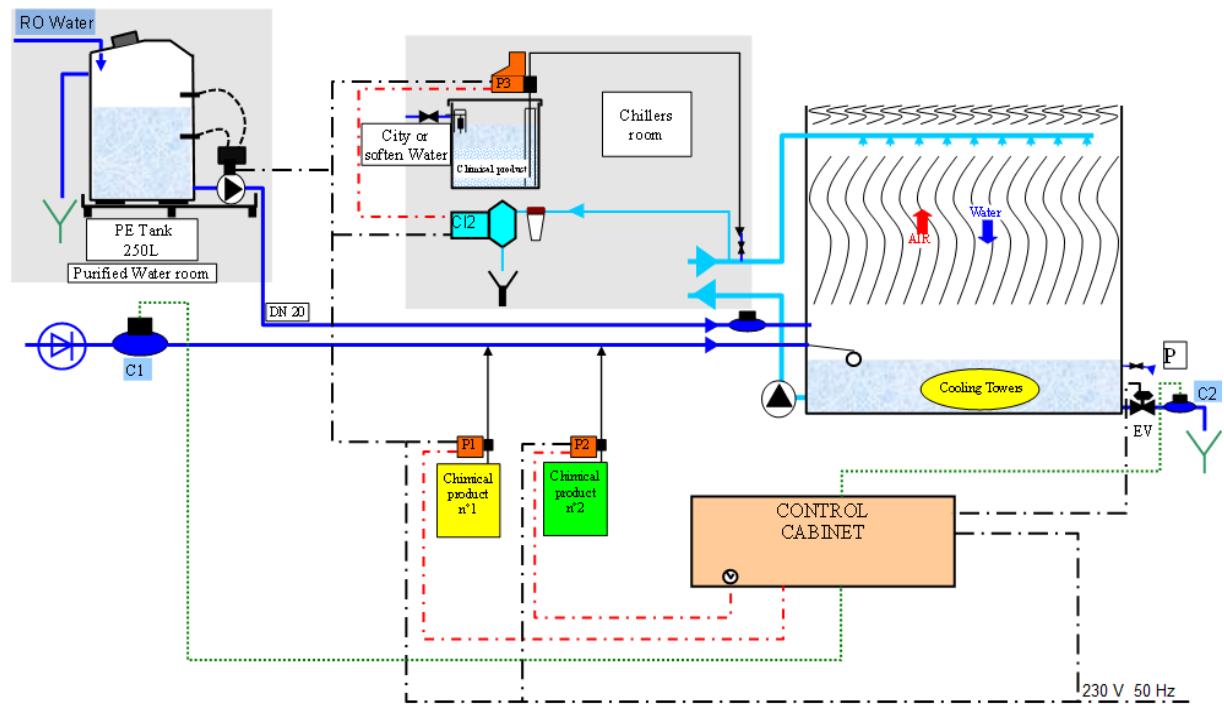


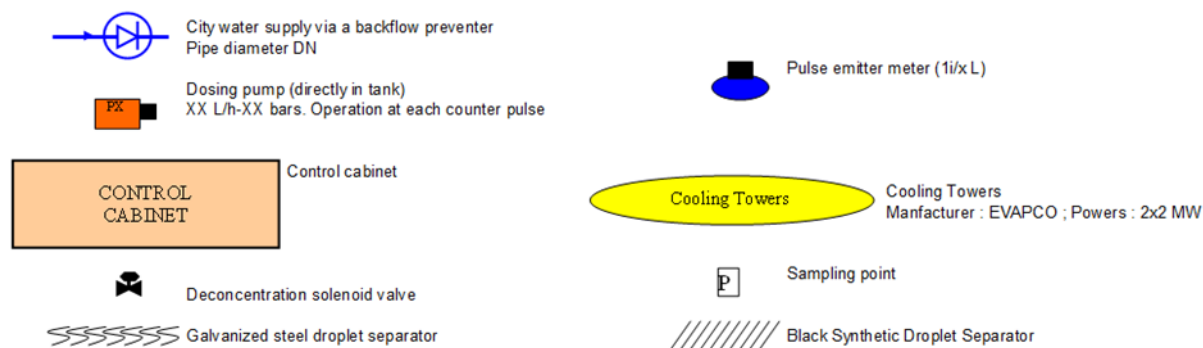
Figure 3. Wastewater Recovery Pump and Counter

The following regulation points have also been put in place:

- RO water has the priority in the circuit by lowering the city water level in the tower basin.
- Regulation of the biocide by continuous measurement in the water of the circuit (considering the city water and RO mixture).

The complete schematic of the installation after modification is represented in Figure 4.





**Figure 4. Schematic of the Water Reuse**

#### 2.4 Cost and Return on Investment (ROI)

Material (250 liters tank, measurement device, counter etc.) = 8 487 euros

Pipework and insulation = 6 550 euros

Total cost = 15 037 euros

The cost of city water is 2,5 euros/m<sup>3</sup>. The saving cost estimated is 6 250 euros (for 2 500 m<sup>3</sup>).

The ROI estimated is 2,4 years.

#### 2.5 Water Saving after the Modification of the Installation

The cooling towers are the largest water consumers on the site. The recovery of concentrated water is positive: saving city water without altering the treatment and operation of the cooling towers.

To date, the RO wastewater has been well recovered for several months and the monitoring parameters are consistent with the proper functioning of the cooling towers circuit.

Annual water consumption of cooling towers before action = 10 218 m<sup>3</sup>. Site's water annual consumption before action = 29 052 m<sup>3</sup>. It represented 35% of the site consumption.

Annual water consumption of cooling towers after action = 6 912 m<sup>3</sup>. Site's water annual consumption after action = 28 556 m<sup>3</sup>. It represents 24% of the site consumption.

Cooling towers water consumption has been reduced by 3 306 m<sup>3</sup>. It is even above the estimation/expectation. The reason is that other influent factors such as external temperature and production have an impact on cooling towers water consumption.

### 3. Automatic Washing Machine

#### 3.1 Old Washing Machine

The site has an automatic washing machine as shown in figure 5 for cleaning containers of different types and sizes. This cleaning is subject to cleaning validation to prevent cross contamination and adulteration of drug products (Jena et al., 2020).



**Figure 5. Old Automatic Washing Machine Entry**

The machine is inside a laundry. This laundry operates 3x8 hours a week and occasionally on Saturdays or weekends. About 30 to 40 containers are washed per day in the cabin. The maximum operating time of the washer is about 20 hours/day.

Wash cycles include:

- washing with tap water at a minimum temperature of 55 °C for 15 minutes,
- rinsing with purified water at a temperature between 10 and 15 °C for 5 minutes,
- drying with hot air for 20 minutes.

The washing cabin is equipped with:

- 4 side washing ramps, each equipped with five nozzles for cleaning the outside of the container, which sweep the container with a range of motion of 64 °
- a washing head in the lower position, fitted with 4 nozzles. Two nozzles ensure the internal washing of the valve and two other nozzles the external washing of the valve and the lower part of the containers,
- a mobile washing head in the high position, equipped with two nozzles for cleaning the inside of the containers.

### *3.2 New Washing Machine*

The current machine is obsolete and needs to be changed. Water use efficiency will be one of the main drivers of the project.

After a thorough selection (washing machine performance, water consumptions; manufacturer reputation etc.) a model of washing machine has been selected. Its main characteristics are:

- A self-rotating washing head ensures the interior washing of the containers. Position sensors allow the washing head to be stopped at different heights depending on the material to be cleaned.
- A vertically motorized nozzle ramp provides exterior washing thanks to a motorized raising and lowering mechanism outside the cabin.

- A lower oscillating ramp washes the lower part of the equipment to be cleaned.
- A fixed ramp washes the roof of the equipment to be cleaned.
- A water booster group, a heat exchanger (which allows, thanks to the regulation, to heat the water up to 70 °), an HVAC for drying containers etc.

Characteristics of the water supplies (purified water and city water):

- Instantaneous flow: 2.2 m<sup>3</sup>/h.
- Upstream water pressure: 2 bars minimum, 4 bars maximum.
- Temperature from 7 to 17 °C.

Table 2 contains a comparison between the old washing machine and the new one.

**Table 2. Water Consumption and Costs Comparison**

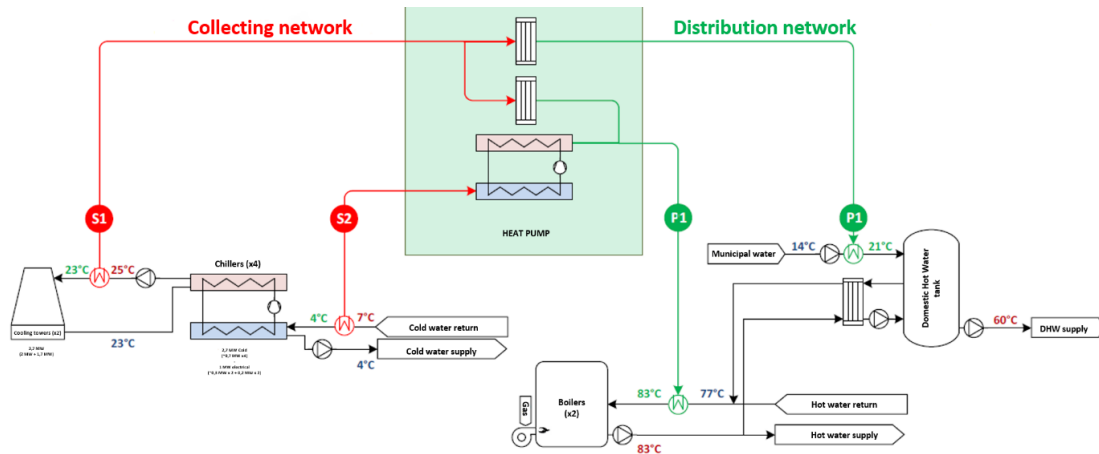
|                                    | Old Washing Machine: City Water | Old Washing Machine: Purified Water | New Washing Machine: City Water | New Washing Machine: |
|------------------------------------|---------------------------------|-------------------------------------|---------------------------------|----------------------|
| Annual consumption (35 cycles/day) | 7 500 m <sup>3</sup>            | 2 500 m <sup>3</sup>                | 5 800 m <sup>3</sup>            | 1 400 m <sup>3</sup> |
| Unitary cost                       | 3 €/m <sup>3</sup>              | 7 €/m <sup>3</sup>                  | 3 €/m <sup>3</sup>              | 7 €/m <sup>3</sup>   |
| Annual cost                        | 22 500 €                        | 17 500 €                            | 17 400 €                        | 9 800 €              |

The city water consumption has been reduced by 1 700 m<sup>3</sup> and the purified water consumption by 1 100 m<sup>3</sup>.

#### 4. Heat Pumps

The site needs chilled water for maintaining specific environmental conditions in production and laboratories areas. The chilled water is produced by several chillers. A heat pumps has been installed to recover the heat lost on the whole chiller system (M’Baye, 2022).

As shown in figure 6, one source of heating is the water going to the cooling tower. Before going to the cooling towers, the water enters in a heat exchanger at 23 °C and exit at 25 °C. The flow is 200 m<sup>3</sup>/h. There is less evaporation in the cooling towers and therefore the need to reinject water in the system is reduced. The heat recovered in the heat exchanger is used to pre-heat domestic hot water.



**Figure 6. PI&D of the Heat Pumps**

Water saving estimated = 3 930 m<sup>3</sup>/year. This represents nearly 15% of site’s water consumption (N.B: water consumption ratio in cooling towers for 1 thermal MWh to be cooled = 1,55 m<sup>3</sup>/MWh).

**5. Chlorine Meter**

A specific device is in place for measuring chlorine level in city water used to produce hot water.

The manufacturer of the device is Swan.

Sample flow in the instrument = approx. 100 l/h

Quantity of water used with the Swan = 878 m<sup>3</sup> per year

Frequency of measuring with the Swan = Continuously



**Figure 7. Current Chlorine Meter**

The current device consumes a large amount of water. Research has been done for finding a solution to reduce this high consumption.

The manufacturer of the new chlorine meter is Hach Lange. It contains a linear peristaltic pump to precisely control the volume of incoming samples and reagents.

Sample flow in the instrument = 70 ml /min. Water is taken every 2,5 min.

The total quantity of water used per year by the equipment is 91,98 m<sup>3</sup>.



**Figure 8. New Chlorine Meter**

The savings estimated with the new device is about 786 m<sup>3</sup>/year.

The chosen device consumes less water to make a test measurement and the sampling frequency will be reviewed (continuous monitoring is not necessary).

## **6. Conclusion**

This paper demonstrates that it is possible through research with methodology to identify and implement water saving actions in industrial environment. All key elements must be considered such as water properties, needs, reuse opportunities, etc.

This paper brings also to literature reproducible actions.

The water management and the best practices are a combination of powerful elements to reduce water consumption. The water consumption on the industrial site in this article has been significantly reduced. In fact, the consumption has been reduced by 40% in less than 6 years.

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