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INTRODUCTION OF WATER MANAGEMENT IN FOOD PRODUCTION PLANT: A CASE STUDY MARGARINE PRODUCTION FACILITY

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Abstract
The food processing industry consumes relatively high volumes of water for different purposes (production, cleaning, heating and cooling). Beside, wastewater discharged from the production process has high organic load. The industry has huge potential for water conservation and reuse if audited properly.
This paper presents the results of water consumption auditing and identifying water consumption centres in a margarine production line in Serbia. Based on the results of the auditing and performed technological and economic feasibility studies, several measures related to reducing water consumption and increasing water reuse in production process were proposed, implemented and valuated. Implemented the measures the company significantly reduced specific water consumption (from 2.71 m3/t of produced margarine to 0.71 m3/t of produced margarine in two-year period). The study shows that water management activities (as a comprehensive and systematic approach for reducing water consumption, increasing water reuse and reducing wastewater creation) are environmentally and economically feasible in a margarine production company.

Keywords: *margarine production, water consumption centres, specific water consumption, water conservation and reuse*

1. INTRODUCTION

The perception of water being a never-ending and cheap resource with unlimited renewable capacity belongs to previous times and water conservation measures should be prioritized in all sectors (households, industry, agriculture, energy, public water supply). The world is facing the on-going risk of water shortages, particularly given the uncertain impacts of climate change.
Globally, industry uses approximately 20% of the freshwater extracted by humans, around twice as much as is used for household purposes [1]. Water is vital to many manufacturing processes, therefore its efficient use should be a priority in order to ensure that water shortage and increasing price of water have minimal effects on production. The economic reasons as well as environmental issues have led to reduction of water consumption during the past years.
Food processing systems consume extensive amounts of water since water has been traditionally a key processing medium throughout all steps in the food process as an ingredient and as a process aid (cleaning, heating and cooling). As a result of the need to use water in these processes, large volumes of wastewater are generated.
Cost of water used in food processing is the sum of costs of supply, disposal, loss of potential revenue from product discharged and the energy with the discharged effluent. Food processors may follow several strategies in order to reduce fresh water consumption and wastewater [6-10].

Margarine production basically involves the preparation of oil phase and water phase which are carefully mixed through proportionating systems (*Figure 1*). The resultant mixture is passed through a pasteurizer and then through chilling unit, where it is cooled to bring about emulsification and crystallization. Chilling unit is cooled by a separate ammonia cooling system.
In margarine production water is used as a raw material (part of the final product), but it is used for various processes and sub processes also: different heating and cooling processes, cleaning and cleaning-in-place (CIP) processes.
It should be also emphasized that wastewater discharged from the production process has high organic load. As a result, rivers with low water flows and ground-waters are dangerously polluted exceeding the values of parameters from water quality standards.
Beside, impact of worm waste water on the environment in terms of thermal pollution which is the degradation of water quality is also important. When water used as a coolant is returned to the natural environment at a higher temperature, the change in temperature decreases oxygen supply and affects ecosystem composition.

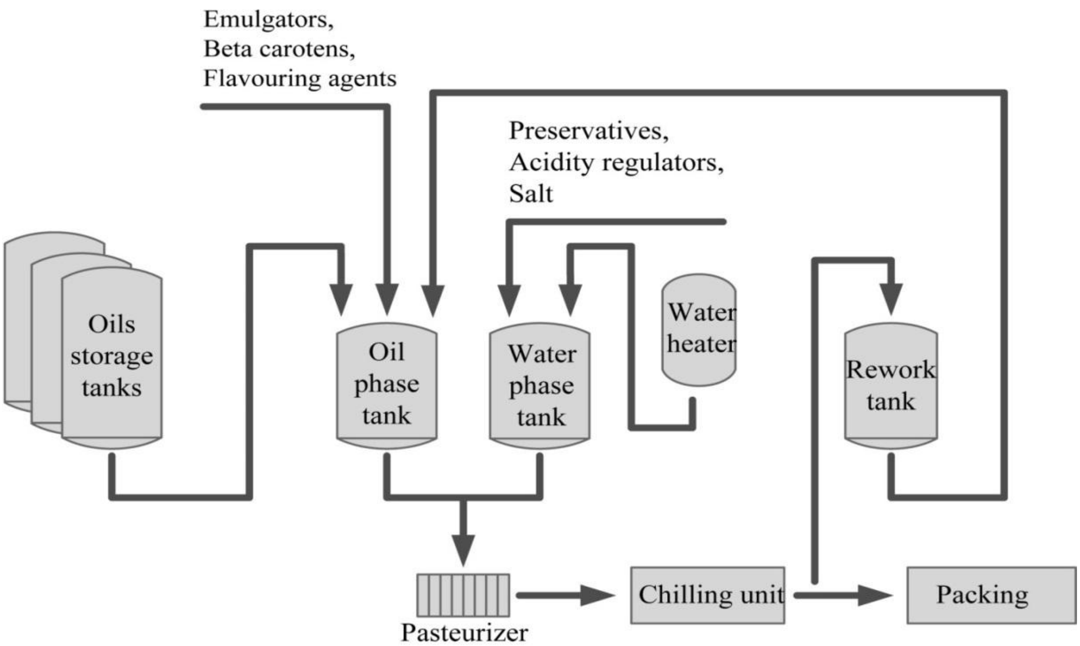

Figure 1 Margarine production process

Analysed margarine production line facility in Serbia had a problem of increased water consumption that influenced increased production costs. Therefore, it was decided to initiate a project of introducing a water management practice in the factory in order to reduce total costs of margarine production. As a rule, making decisions about water management within companies is clearly dictated by costs associated to water supply and effluent discharge [14]. In order to be effective, water management must examine not only theoretical optimisation values, but also investigate practical, behavioural and communication issues [15]. Results of project development are presented in this paper.

2. METHODS

The first step in establishing the system of water management practice in a company is water consumption auditing. Water auditing is an analytical tool which quantifies water flows and quality within a predefined boundary [1]. The water consumption auditing starts with collecting and analysis of information and data from processes. Data includes: lay-out of processes, water distribution system, sewage and drainage collecting system, equipment specifications, bills for water consumption and waste water disposal from previous period (at least one year), production volume from the period, readings of measuring equipment, etc. [11]

As a result of auditing, performance indicator of company's water consumption – specific water consumption (water consumption in m^3 per ton of produced margarine) is determined. Whenever it is possible, determined specific water consumption should be compared with the specific water consumption of "similar" companies (same industry, similar production program, similar production volume).

The water management auditing also considers defining a water consumption centre (WCC). Each WCC represent different operating segment (plant, department, group of equipment or single equipment) in which important activities are performed with significant water consumption [7].

Based on readings of existing/portable measuring instruments and bills for water consumption water demand of each WCC is calculated. Consumption is to be prioritized by classification of consumed water quantities using the ABC curve concept where it is graphically possible to identify the highest water consumers. The ABC curve concept aims to sort items according to their relative importance [11]. Usually, this curve is split into three parts: "A", "B" and "C". "A" represents the most important items which require special attention, "B" is the intermediate group and "C" indicates the group with less importance.

Analysing collected data, the major locations and activities that correspond to the increased water consumption in the production process are identified. Depending on the results of monitoring adequate corrective and preventive actions are undertaken.

3. RESULTS

Analysing the data of water consumption for the base year (2014.), it was calculated that the water consumption in the company was 14367 m^3. Since annual margarine production was 5309 tonnes, specific water consumption was 2.71 m^3/t of produced margarine, which is significantly higher than the values from other branch companies in other European countries (*Table 1*).

Table 1 Specific water consumption of some branch margarine producing companies

	Spain	**Belgium**	**Hungary**	**Romania**
Specific water consumption (m^3/t of produced margarine)	0.77÷0.82	0.84÷1.18	0.97÷1.05	0.87÷0.95

Ref: Data obtained from personal communication with plant managers of branch margarine producing companies

Therefore, the company management initiated an action to explore ways on how to reduce the water consumption to the level of other branch margarine producing companies. It was decided that for the activities only very limited budget was available i.e. the emphasis should be given on good housekeeping measures and improved maintenance of existing equipment.

Analysing available distribution network diagrams and measuring water consumption in the process, WCCs were mapped and marked. Different centres were designated based on type and temperature of water (*Figure 2*). Measured or calculated value of daily water demand of each WCC is presented in *Table 2.*

Table 2 Water demand of each WCC

WCC	WCC No	Water demand (m3/day)	Percentage
Cooling system	WCC2	21.75	46.93%
Pasteurization process	WCC1	9.63	20.78%
Cleaning	WCC4	5.21	11.24%
Raw water	WCC1	3.78	8.16%
Steam production	WCC5	3.75	8.09%
Hot water production	WCC3	2.23	4.81%

ABC curve (*Figure 3*) was created using the value of water consumption of each WCC. The major locations and activities that correspond to the highest water consumption in the process were identified. Three WCCs (cooling system, pasteurization process, cleaning) which consumption corresponded to almost 80% of total water consumption were in "A" range.

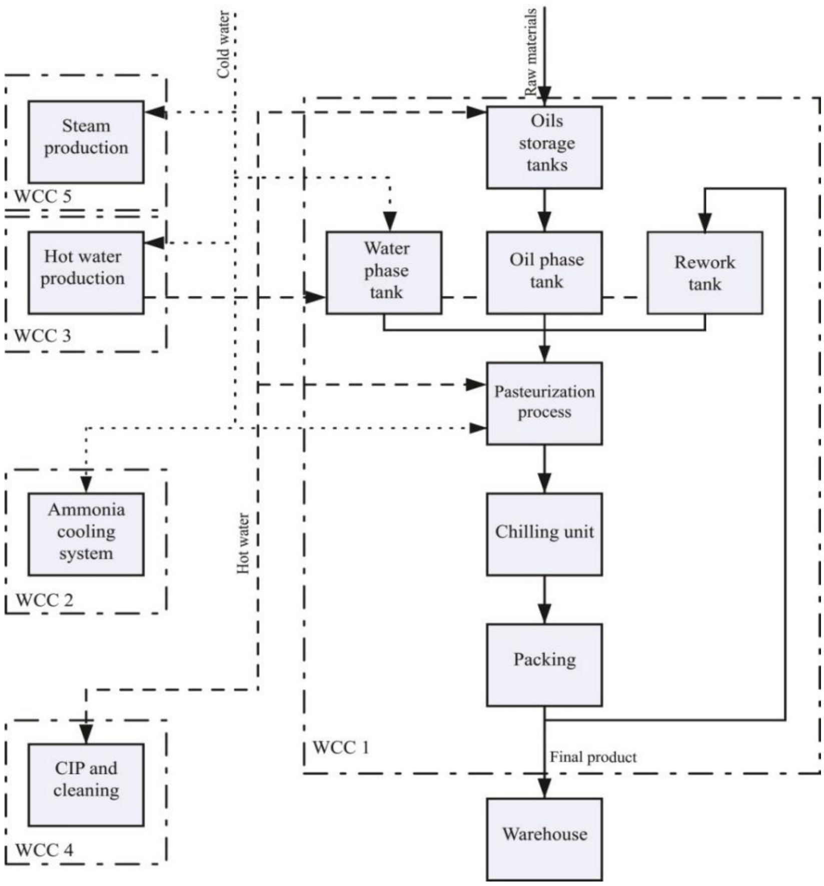

Figure 2 Water consumption centres (WCCs) in analysed margarine production

Since the biggest consumption was in cooling system, the first priority was given to cooling tower performance analysis. As a result of control and inspection of the cooling tower, it was established that it had been in a very poor condition as a result of poor maintenance. Therefore, the efficiency of the cooling tower was greatly reduced and the water consumption was significantly higher. The absence of any chemicals addition in make-up water led to the increase in precipitation and scale formation which also significantly undermined the efficiency of the system.
General overhauling of the cooling tower considered detailed cleaning and the installation of chemical dousing unit for the control of scale build-up and corrosion. The overhauled cooling tower

became operative at the beginning of 2015. Water consumption in the company was 9249 m^3 and margarine production was 4885 ton in 2015. It can be seen that while margarine production was decreased for 8%, water consumption decreased for 35.6% in 2015. In this way, specific water consumption was reduced from 2.71 m^3/t to 1.89 m^3/t of produced margarine which was remarkable result, but still above the targeted values presented in *Table 1*.

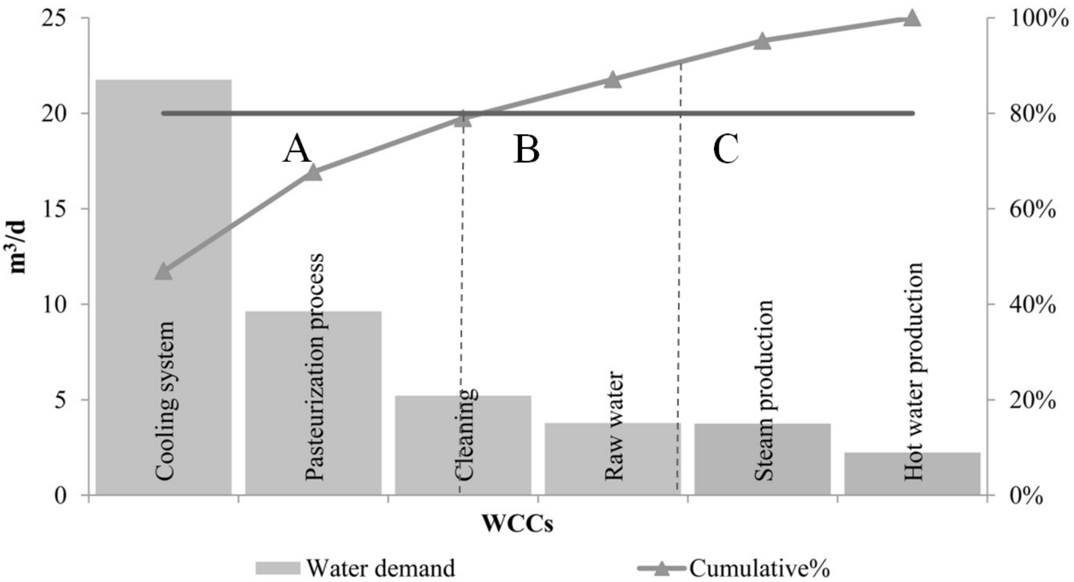

Figure 3 ABC curve - Water demand of WCCs

Since it was noticed that the water consumption for cooling processes is still significant, analysis was related to other possibilities of reducing water consumption in cooling processes. The main reason for such a high volume of water consumption is the fact that tap water used for ammonia compressor cooling was disposed after the cooling process to sewage as waste water. Therefore it was proposed to use conventional water cooling network with parallel configuration according to principles described in [13].

In the parallel configuration, make up cooling water is directly supplied to the pasteurizer and the compressor cooler as individual heat-exchangers. The hot cooling water from both heat exchangers is collected afterward in appropriate tank. Water is returned from the tank to the cooling tower (*Figure* 4).

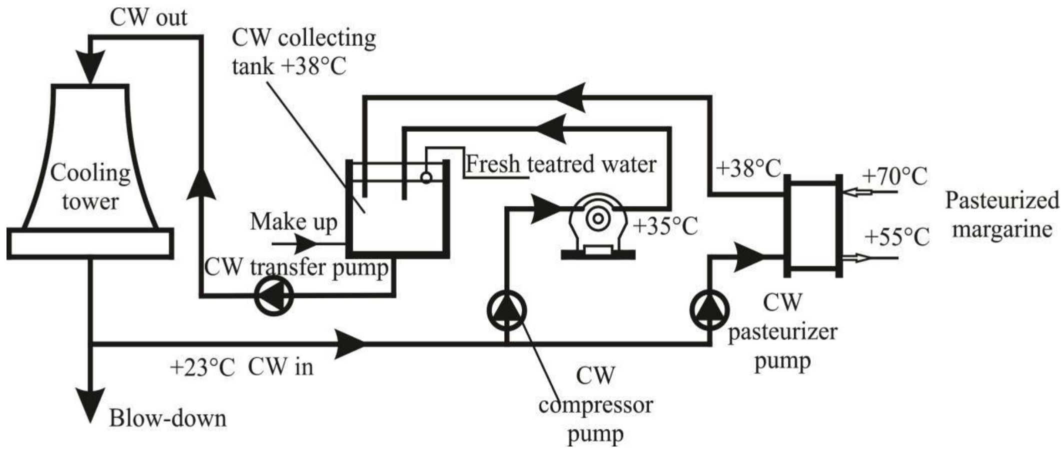

Figure 4 Implemented water reuse system

Additional benefit of modifying water reuse system was environmental protection since hot water (which temperature is 38 °C) is not discharged to sewer any more.
In order to create effective water management system, the other cost-effective measures to improve water consumption efficiency of the company were also evaluated. Measures related to the detection of physical losses, replacement of inadequate operations and operational improvements were considered in all WCCs. The proposed measures for reduction of the water consumption are shown in *Table 3.*

Table 3 Measures for rational water use

WCC	**Description of loses**	**Measures**
WCC1, WCC3, WCC4	Water leaks identified at pumps, hose connectors and fittings	– Repairing identified leaks
WCC4	Cleaning floors and equipment	– Using detergents to dissolve fat, – Applying automated water gun for cleaning oily floor, – Promoting mop cleaning instead of wet cleaning always
WCC4	Unnecessary water wastage during vessels cleaning	– Replacing manual taps with push-button taps, – Proper awareness of rational water use
WCC4	CIP process	– Using ozonised CIP instead of conventional CIP, – Club flushing hot air along with ozonised water to achieve removal of loose fats, scaling and disinfection
WCC1, WCC2	Cooling tower water overflows	– Installing float valves, – Running tower on higher cycles using better cooling tower treatment chemicals.
WCC5	No purge control at the steam boiler (the concentration cycle was lower than ideal)	– Providing appropriate purge control

Some of the proposed measures are technical entirely, while some of them belong to the group of good housekeeping measures. Minimization of water usage is emphasized to management and employees.
All proposed measures and organizational activities were implemented in the process until 20th March 2016. Comparing the values of monthly specific water consumptions for two consecutive years (*Figure* 5), it can be concluded that specific water consumption was reduced by 59.23%, which presents a more then serious cut cost for a company. Beside, level of water consumption reached a level of 0.71 m3/t of produced margarine, which is even lower than values presented in *Table 1*.

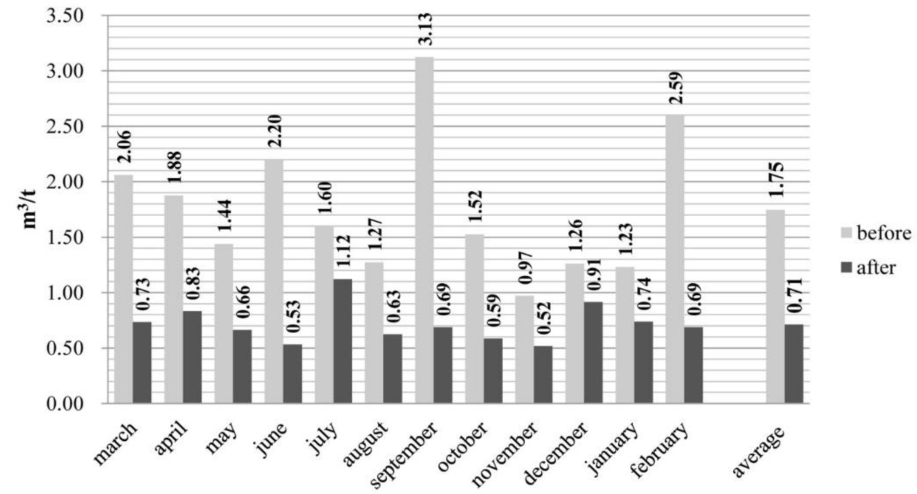

Figure 5 Specific water consumption [m^3/t] for two-year period

Values of daily water demand measured at each WCC see in *Table 4*, had a different values then those presented in *Table 2*.

Table 4 Water demand of each WCC after implementing water management program

WCC	**WCC No**	**Water demand (m3/day)**	**Percentage**
Raw water	WCC1	3.48	29.72%
Steam production	WCC5	3.46	29.55%
Cleaning	WCC4	2.45	20.92%
Hot water production	WCC3	2.10	17.93%
Pasteurization process	WCC1	0.12	1.02%
Cooling system	WCC2	0.10	0.85%

Implementing water management practice completely modified the appearance of the ABC curve is showed in *Figure 6*. Now, two WCCs with highest water consumption (that are in “A” range) are raw water (water used in the process as a raw material) and steam production. In future development of the water management program should be more focused on those two WCCs. Pasteurization process and cooling system are in “C” range as lowest water consumption WCCs.

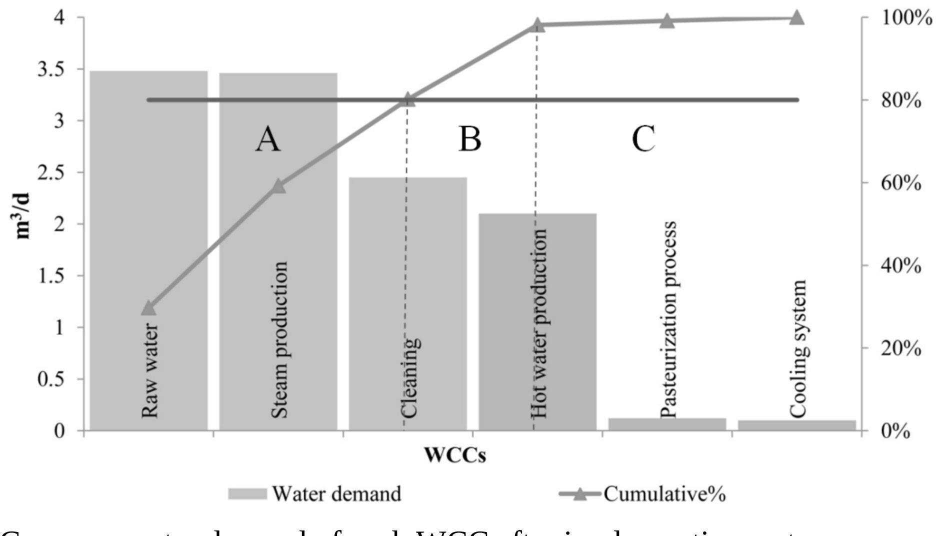

Figure 6 ABC curve - water demand of each WCC after implementing water management program

Considering that cost of non-treated industrial water for the company was 0.911 €/m^3, for the production level of 4554.81 tonnes in 2016. , annual savings was around 8600 €.

CONCLUSIONS

This study shows that water management activities (as a comprehensive and systematic approach for reducing water consumption, increasing water reuse and reducing wastewater creation) are environmentally and economically feasible in a margarine production company. As a result of introduction of different water management activities, specific water consumption in the analysed company was decreased from 2.71 m^3/t to 0.71 m^3/t of produced margarine in two-year period. Taking into account total investment costs, annual operating costs and annual savings, payback period for implemented measures in analysed company is less than 1.5 year. Water consumption reduction in food processes can be a significant cut costs for a company.

Further developments of water management practice in the company should include continual monitoring of water consumption and analysing of additional technical opportunities for reducing water consumption with allocating more significant financial resources for implementation of the opportunities.

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