Journal of Engineering and Technology for Industrial Applications, 2020. Edition. 21.Vol: 06
https://www.itegam-jetia.org
ISSN ONLINE: 2447-0228
DOI: https://dx.doi.org/10.5935/2447-0228.20200006

RESEARCH ARTICLE OPEN ACCESS

WASTEWATER REUSE IN THE CLEAN IN PLACE PROCESS OF A BEVERAGE INDUSTRY

Letícia do Couto Pereira[1] and Éverton Hansen[2]

[1, 2] Ritter dos Reis University Center – UNIRITTER. Teresópolis-Porto Alegre, Brazil.

Email: evertonhansen@gmail.com

Received: Jan 24th, 2020

Accepted: Jan 31th, 2020

Published: February 10th, 2020

ABSTRACT

Clean in Place is a hygiene process widely used in the food industry, as it establishes operational safety, reduces costs of water consumption, chemicals and energy, as well as it ensures safety and quality in the final product for the consumer. The Clean in Place process follows a standard operation, however the application of the system and procedures are individually designed for each process, according to its needs. In general, Clean in Place consists of water and chemical tanks, feed and return pumps, heat exchangers, conductivity sensors and temperature gauges. The present work addresses an industrial scale study using data from a food industry located in southern Brazil. The objective of this work consisted of the minimization of water consumption and effluent disposal by reusing water in process stages. In addition, it was intended to reduce detergent consumption and total process time through adjustments in detergent concentration, and time reduction in some system steps. The proposed wastewater reuse reduced the consumption of water and effluents discharged by 32.75%, detergent consumption by 37.5% and process time by 34%.

Keywords: Clean in Place, Water Reuse, Wastewater, Food Industry, Beverage Industry, Industrial Scale Study.

I. INTRODUCTION

Freshwater is an essential element for the maintenance of life, as well as for human well-being and sustainable development. This is one of the main current reasons for regional and global crises in the world. For many years water was considered an inexhaustible natural resource, however, recent studies show that water is, in fact, a finite resource and its preservation is necessary [1]. Water global demand is expected to increase by about 55% by 2050, due to increased consumption in industries, thermal power generation, and domestic use. In this way, water must become insufficient to meet the demand growth, which is directly related to the population increase and continuous consumption growth related to the world production structure [2].

Faced with this scenario of water resources scarcity, among the alternatives to reduce water consumption are the rationalization of use and the reuse of this limited resource [3]. Water reuse must be implemented with appropriate precautions and technologies, aiming at the adequacy of quality according to its application [4]. In addition, water recovery is performed in order to reduce impacts to the receiving water body, since a smaller volume of effluents is discharged, besides reducing the withdrawal of water from non-renewable sources [5]. The recovery of treated effluents is an economically viable and sustainable alternative for the preservation of water resources. Through proper management, it is possible to achieve savings of up to 30% of total water consumption [6].

One of the fundamental causes of the current water crisis is the increasing scale and intensity of industrial production activities [7]. Industries in general can use water as raw material, incorporated into the final product, as heating or cooling fluid, or even in internal and external cleaning processes of equipment [8]. In the case of the food, beverage or pharmaceutical industry, water must have a high level of purity if it is introduced into the final product. However, the quality requirements are lower if water is used for other purposes, such as heat exchange systems [9].

In the food industry, hygiene aims to eliminate contamination, reducing the chance of future problems in the final product caused by microorganisms or dirt in general. One of the most widely used methods for internal cleaning of equipment and piping is Clean in Place (CIP). This technique consists of a closed system, avoiding major stops of production and disassembly of equipment [10]. Beverage, processed food, pharmaceutical and cosmetic industries are the ones most dependent on this process, as they require frequent internal cleaning to meet high levels of hygiene [11].

The performance of Clean in Place method is usually divided into four operations: pre-washing, cleaning with detergents or chemical agents, rinsing and disinfection. By using chemical reagents, the procedure's contact time is not necessarily related to cleaning efficiency. In CIP, the solutions become saturated with the material originated from the reactions, having a greater efficiency in the initial period of the application process of the products [12]. Additionally, excessive use of resources such as water and energy has negative economic and environmental impacts, resulting in loss of production time [13].

Due to increased environmental awareness, water consumption minimization studies have been conducted in different food industries [14]. As an alternative to reduce water consumption in a fish processing industry, the reuse of effluents generated in the industry was proposed, reducing effluent volume and minimizing water consumption [15]. A study in a dairy industry was developed to check the potential for reuse of cheese whey as water in the Clean in Place process operations, using a combined ultrafiltration and reverse osmosis system [16]. An improvement of CIP in a dairy industry was also developed applying mathematical methods for improvement, using the GAMS algebraic modeling software, as well as the treatment of residual water by means of a reverse osmosis membrane, reducing water consumption and wastewater generation [17].

Thus, the objective of this work is to conduct a study of water consumption in the CIP process of a beverage industry, aiming to reduce wastewater generation, water and detergent consumption, besides reducing the time of this operation. This is a study applied on an industrial scale in a large beverage company located in the south of Brazil. The present study is expected to bring relevant information so that it can be replicated in other food industries using the Clean in Place process.

II. MATERIALS AND METHODS

This work was carried out in a carbonated and non-carbonated beverage industry, located in the state of Rio Grande do Sul, Brazil. The studied company is present in 10 countries and globally sells 1.7 billion products per day. In Brazil, it is present in 48% of the national territory, has about 20 thousand employees, serving more than 88 million consumers in the country. The productive capacity of the evaluated unit is approximately 240 thousand liters of beverage per hour.

II.1 DESCRIPTION OF THE PRODUCTIVE PROCESS

The first stage of the present study was the analysis and description of the productive process. The description of the process was carried out by consulting the internal procedures of the evaluated company, as well as field technical visits carried out in the factory.

II.2 CONVENTIONAL CIP PROCESS

The study and data collection of the conventional CIP process in the company was carried out by consulting internal procedures with the detailed description of the CIP operation, as well as the field monitoring of the operational procedure, through technical visits. The company uses different CIP procedures; whose choice depends on which is the change of beverage to be produced. In this work, only the hot cleaning and sanitizing process was studied, since this is the most used procedure of the industry.

II.3 IMPROVEMENT OF CIP PROCESS

The improvement of the CIP process was carried out by studying the process flow diagram and proposing amendments with the objective of reducing the water consumption of this system. Technical documentation of the evaluated industry was used for this study, as well as meetings with operators and supervisors of the operational area.

II.4 MASS BALANCE IN THE CIP PROCESS

The mass balance was performed through the compilation of flow measurements recorded by the flow meters installed in the studied industry. Mass flows used by CIP operation prior to improvement were obtained from data collected in May 2018. For the optimized CIP, the results are the average of a typical CIP operation recorded in December 2018 (after the improvements implementation). These measurements were used to compose the total amount of water used in a CIP operation, as well as the total amount of water discharged as effluent or reused in the process (in tonnes). The mass balance was performed using equation 1.

$$\dot{m}\_accumulated = \dot{m}\_in - \dot{m}\_out \tag{1}$$

Where:
$\dot{m}$accumulated – accumulation of water and detergent in the system (t);
$\dot{m}$in – mass of water and detergente entering the system (t);
$\dot{m}$out – mass of water and detergente leaving the system (t).

II.5 COSTS

The costs of the CIP process were obtained considering costs with water consumption, treatment of effluents, and consumption of detergent. Equation 2 was used to obtain the total cost of each operation of the CIP process.

$$Ctotal = m(H2O\ cons.)\times CH2O + meffluent\times Ceffluent + mdetergent\times Cdetergent \tag{2}$$

Where:
Ctotal – total cost with water, effluent and detergent (US$);
mH2Ocons. – mass of water consumed (t);
CH2O – cost of water treatment (US$);
meffluent – mass of effluent generated (t);
Ceffluent – cost of effluent treatment (US$);
mdetergent – mass of detergent consumed (kg);
Cdetergent – cost with the purchase of detergent (US$).

The costs obtained through calculations of water consumption, effluent generation and detergent consumption were used to make an annual comparison between costs generated before and after CIP improvement. The total number of CIPs executed in 2018 was used in order to verify the cost reduction obtained by the company after the improvement of the process.

II.6 MICROBIOLOGICAL ANALYZES

In order to check whether the proposed improvements did not modify the quality of the equipment decontamination, three samples at the final rinse stage and two samples of the recovered water tank were evaluated. Nasco Whirl-Pak bags were used for laboratory sampling. The samples of the final rinse stage were collected in the filling machine, which is the last equipment before water is transferred to the water recovery tank or discharged. Microbiological analyzes were performed in the Microbiology Laboratory of the evaluated industry, using the membrane filtration method. The results obtained were compared with the specifications established by the company for the microbiological parameters (Table 1).

Table 1: Microbiological specifications for CIP samples.

Sample	Test	Specifications (CFU/Volume)
Recovery Tank	Total Bacteria	<25/1 mL
	Yeasts and Molds	<10/100 mL
	Total Coliforms	0/100 mL
Final Rinse (Storage Tank and Filling Machine)	Total Bacteria	<25/1 mL
	Yeasts and Molds	<10/100 mL
	Total Coliforms	0/100 mL

Source: Authors, (2019).

III RESULTS AND DISCUSSION

III.1 DESCRIPTION OF THE PRODUCTIVE PROCESS

The production process of the evaluated industry can be divided according to the product to be manufactured in: "cola soda" process and "various soda" process. As the volume of cola soda produced is higher, compared to other beverages, this division occurs in order to facilitate the manufacture of the product. The water used throughout the company's beverage preparation process is treated internally at the Water Treatment Plant (WTP) in order to ensure a final product quality standard. This water goes through a conventional process of coagulation and flocculation, sand filters and activated carbon filters. In the final beverage production sector, water also passes through polishing filters and deaerating tanks.

All types of products, soft drinks (carbonated) or juices (non-carbonated), have their respective recipes. The industry receives so-called "parts" of concentrate, and this recipe is used to define the quantities needed to prepare each product.

For the production of cola beverage, cola concentrates (part 1 and part 2) are received from the company headquarters. These streams are stored in stirred tanks with temperature control and then they are mixed with a dissolved sugar stream in a multi-component dosing and mixing unit. The concentrate and dissolved sugar mixture are stored in a tank, cooled using a plate exchanger until reaching a temperature between 4 and 8°C, and sent to a carbonation tank. At this stage, the drink is ready and goes to the filling machine, where it is properly packed.

For the production of "various sodas", the concentrate parts (liquids and solids) are first diluted and homogenized in BatchMix tanks, according to the recipe of each product, thus forming the syrup. The following steps are the same as the production of the cola soft drinks: the syrup is mixed with the water and the dissolved sugar, the beverage is stored and then refrigerated, carbonated and packaged in the production line.

III.2 CONVENTIONAL PROCESS OF CIP

The CIP presented in this work is the hot cleaning and sanitizing process, the most used in the studied company. This procedure is performed for the beginning of the production of soft drinks, as well as between product and flavor changes. It is responsible for cleaning and sanitizing from the finished beverage storage tank to the end of the packaging system, and contains three cycles: initial rinse, hot detergent and final rinse. Figure 1 shows the CIP process performed in the final stages of preparation of the beverages, as well as their connection with the production process.

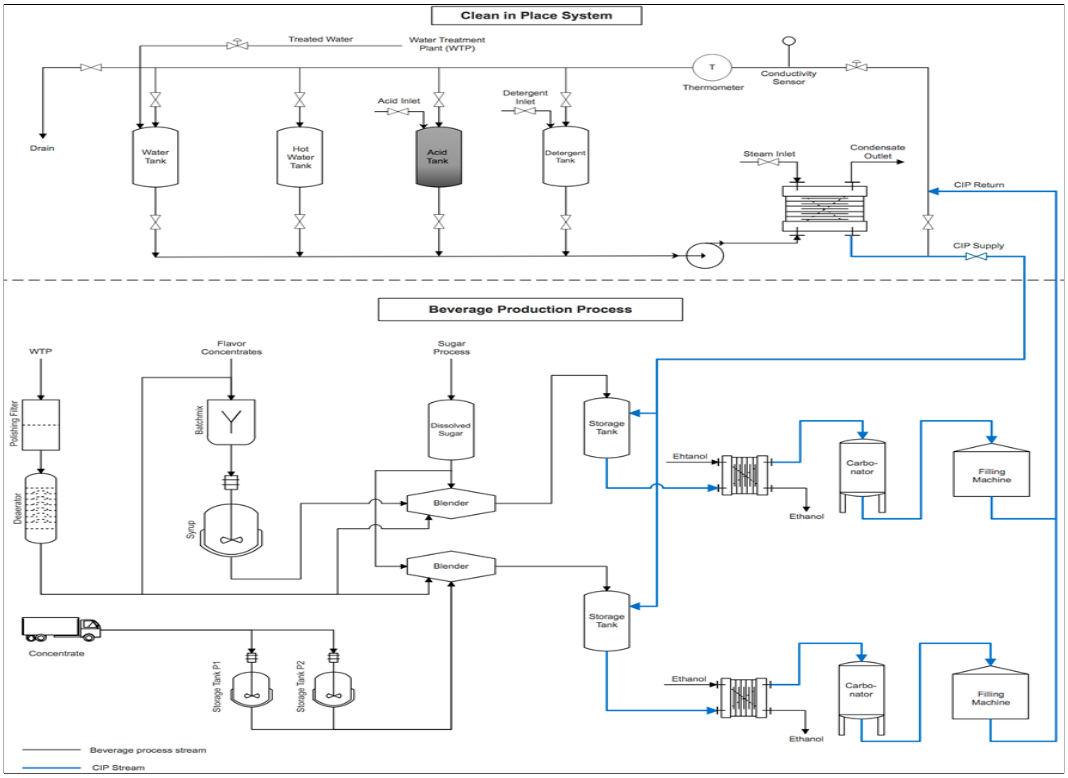

Figure 1: Conventional process of CIP and its operation in the process.
Source: Authors, (2019).

During the initial rinse, only water from the water tank is used, aiming at eliminating the residues present on the surface of the equipment. The complete system rinse occurs for 15 minutes. The second step in the process is the sanitization through the passage of hot detergent, which removes dirt adhered to the surface. At this stage, the detergent tank level must be adjusted to 90% of its capacity, which corresponds to 9 m3. Subsequently, there is a temperature (85°C) and conductivity (38 mS/cm) adjustment of the alkaline descaling detergent, composed of sodium hydroxide. Upon reaching the desired conductivity and temperature, the solution is directed to the beverage processing system, operating this cleaning cycle for 30 minutes. The third and final cycle of CIP is the final rinse. This step aims to eliminate hot water and detergent residues from pipes and equipment for 10 minutes. The final rinse water initially pushes the concentrated detergent into the detergent tank while the conductivity is between 20 and 38 mS/cm, performing a recycle of the detergent. For values below 20 mS/cm, water with diluted detergent begins to be discharged for the effluent treatment system.

Since juices are more sensitive and consequently more susceptible to contamination, it is necessary that the method of cleaning and sanitizing the equipment for this beverage be more rigorous. The juice CIP consists of five steps: initial rinse, hot detergent, intermediate rinse, chemical sanitizer and final rinse. The step that differentiates the other CIP procedure is basically the use of chemical sanitizers, such as peracetic acid, which ensures the sterilization of process equipment. Thus, for the juice CIP, the sanitizer is stored in the acid tank, rarely used in the evaluated industry, due to the low production of juice compared to other products.

III.3 IMPROVEMENT OF THE CIP PROCESS

The improvements proposed in this work were tested and implemented in stages. The first improvement consisted of using the acid tank to store recovered water. This tank receives the water discarded in the final rinse, the third cycle of the process, so that it can be used in the next CIP for the initial rinse step. This change does not affect the CIP process of juices as the chemical sanitizers are currently stored in an IBC tank container.

The second improvement consisted of reducing the initial rinse time from 15 minutes to 10 minutes and preparing the detergent tank by heating the detergent at 85°C before the start of each CIP process. Subsequently, a preheating of the water to complete the level of the detergent tank was also adopted, reducing the time required to reach the specified temperature and initiating the CIP process, causing the production lines to be stopped for a shorter time.

Another improvement was to change the minimum contact time of the hot detergent step. The time of this step was set to 15 minutes, reducing the stage time by half than before the improvement (30 minutes).

The conductivity of the detergent solution was also reduced from 38 mS/cm to 36 mS/cm (since internal company documentation determined a minimum conductivity of the detergent solution of 35 mS/cm). This improvement led to a five minutes reduction of the final rinse time, totaling 30 minutes for this step. That is because a lower time is required for the final rinse water to eliminate detergent solution from the process with a lower conductivity.

Finally, an adjustment was made in programming the process software, defining the detergent recovery in the detergent tank only with values above 30 mS/cm (before improvement the software was programmed to recover detergent with conductivity above 20 mS/cm). This action aimed to avoid sending diluted detergent to the tank, reducing the demand for detergent needed for each CIP cycle. After improvement, detergent with conductivity below 30 mS/cm is directed to the recovered water tank, to be used in the initial rinsing of the next CIP.

Through the adjustments made, the total CIP time went from one hour and thirty-four minutes to one hour and two minutes, representing a 34% reduction in process time. For the validation of the proposed improvements, microbiological tests were performed. The different implementation steps are presented in chronological order in Figure 2 and Figure 3 shows a CIP flowchart after the proposed improvements.

III.4 MASS BALANCE OF CIP PROCESS

III.4.1 MASS BALANCE BEFORE IMPROVEMENT

Figure 4 shows the inputs and outputs of water and detergent in the CIP prior to improvement, indicating a consumption of 7.5 t of water in the initial rinse and 1 t of water in the hot detergent step. To perform this step, there is also an input of 0.32 t of detergent (required to reach the conductivity of 38 mS/cm). In the final rinse, the mass of water consumed for the complete elimination of the detergent in the pipes and equipment is 17.5 t.

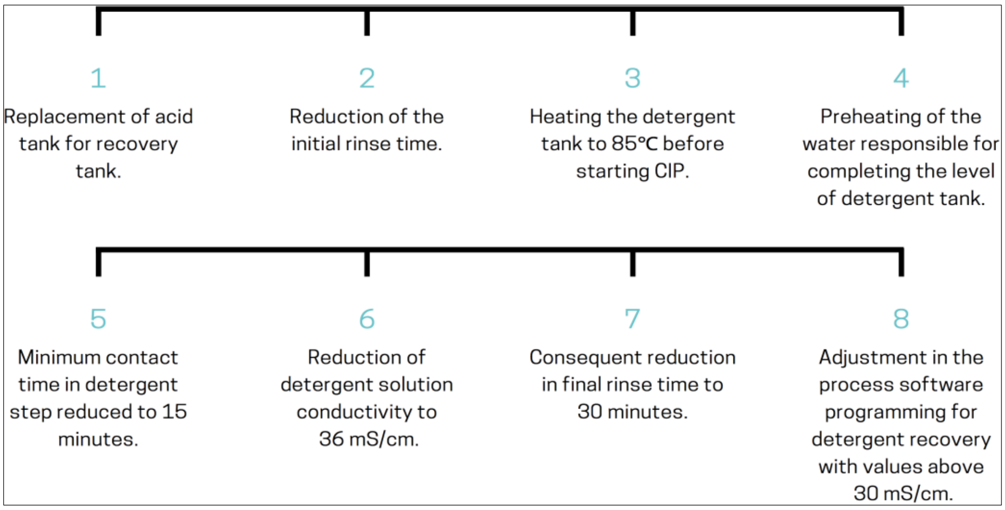

Figure 2: Steps for implementing improvements.
Source: Authors, (2019).

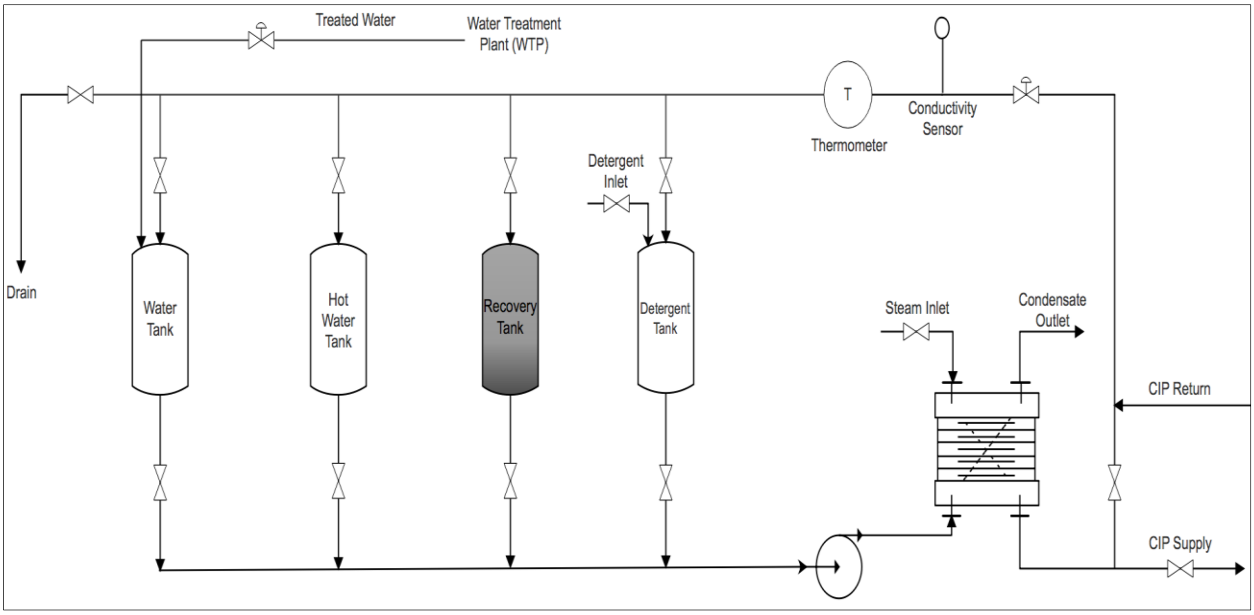

Figure 3: Clean in place process after improvement.
Source: Authors, (2019).

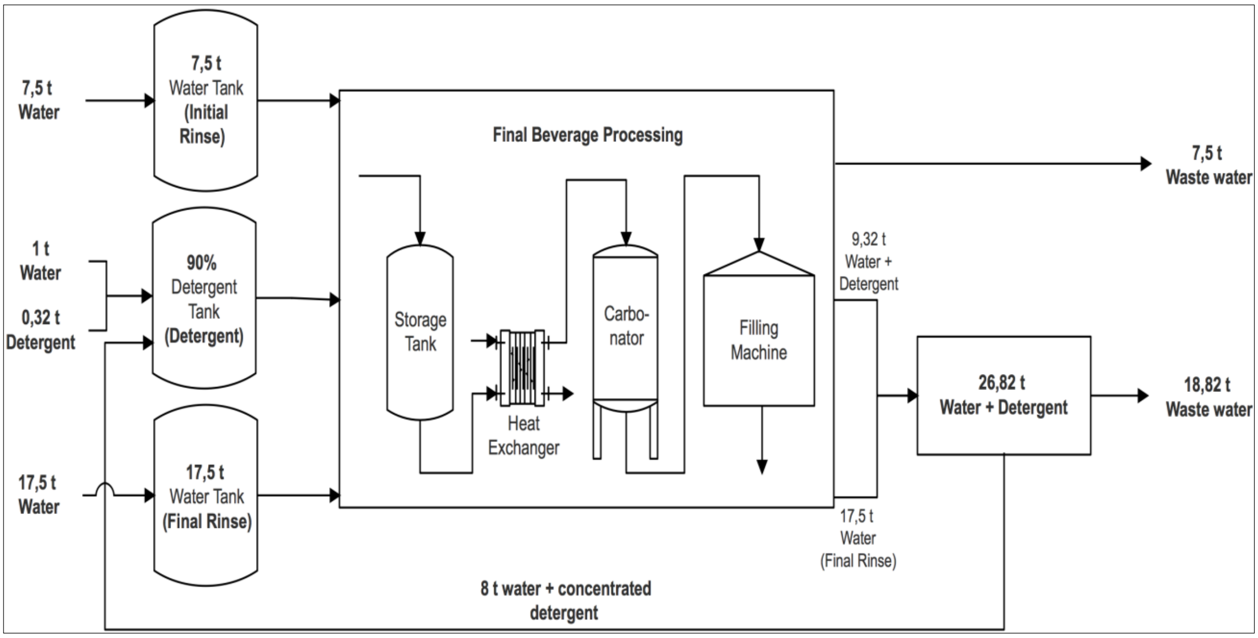

Figure 4: Mass balance of the Clean in Place process prior to improvement.
Source: Authors, (2019).

Without accumulation, the input mass is equal to the output mass. Thus, the 7.5 t of water consumed in the initial rinse is discharged as effluent. The water and detergent consumed in the hot detergent stage and the final rinse water come out in a single mixed stream. This occurs once the final rinse water pushes the detergent solution as a return to the detergent tank until the conductivity reaches 20 mS/cm (below that, detergent residue water is discharged as liquid effluent). Thus, 26.82 t of water with detergent leave the stages of hot detergent and final rinse, with 8 t of concentrated detergent returning to the detergent tank and 18.82 t of water with dilute detergent discharged as effluent.

III.4.2 MASS BALANCE AFTER IMPROVEMENT

Figure 5 shows the consumption of water and detergent and the generation of effluents after the improvement. The water used in the initial rinse is the recouvered water of the the previous CIP final rinse and corresponds to a mass of 5 t. This mass of water is discharged as an effluent after the initial rinse procedure, generating 5 t of liquid effluents.

The detergent tank receives 2.5 t of water and 0.2 t of detergent to achieve the conductivity of 36 mS/cm. It should be noted that a lower mass of detergent is required because of the higher concentration of detergent present in the tank, which corresponds to a conductivity of 30 mS/cm after improvement. In the final rinse, due to the reduction of time, the water usage was reduced to 15 t. At the completion of the hot detergent step, the final rinse water pushes the detergent into the detergent tank, returning 6.5 t of water with concentrated detergent. For the recovered water tank, there is a return of 5 t of water with diluted detergent (conductivity below 30 mS/cm). The remaining mass (12.7 t) is discharged as liquid effluent.

Comparing the masses of water and effluents discharged before and after improvement, there was a reduction of 32.75% per CIP.

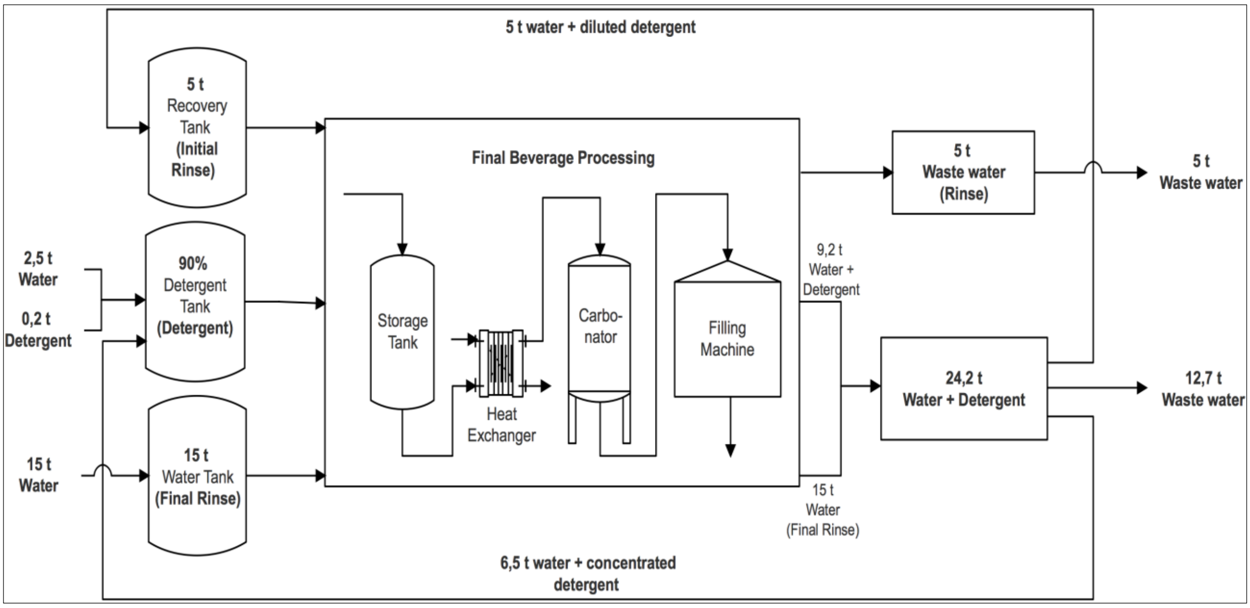

Figure 5: Mass balance of the Clean in Place process after improvement.
Source: Authors, (2019).

A total of 1,614 CIPs were conducted in 2018. Thus, it is verified that approximately 13,912.68 t of water per year are saved after the proposed improvements were implemented. Considering the average water consumption of 153.6 liters per inhabitant per day in Brazil [18], about 248 inhabitants could be supplied for one year with the savings obtained.

A similar work has been developed in a dairy industry, where the potential of cheese whey reuse as water in the Clean in Place process operations was studied. The results indicated that after using a combined ultrafiltration and reverse osmosis system, 47% of the water could be recovered without compromising the safety and quality of the final product [16]. Buabeng-Baidoo et al. (2017)[17] also studied an improvement of CIP in a dairy company through the reuse of the initial rinsing water. Mathematical methods were used for improvement using GAMS algebraic modeling software, as well as the treatment of residual water by reverse osmosis, in order to maximize the opportunities of reuse in the process. The results showed a reduction in water consumption, wastewater generation and a total annual cost of up to 33%. Another study carried out at Ohio State University [18] designed a pilot scale CIP and analyzed the effectiveness of the initial rinse water to remove a film of milk residue on the surface of pipes. It was verified that, by adjusting the contact time and the level of turbulence, there was a 72% reduction in water consumption in the initial rinse, with only a small loss in the removal of microorganisms.

III.5 COSTS

One of the factors that influences CIP costs are the treating water and effluents costs, as well as the purchase value of the detergent. In this way, by reducing the consumption of water, detergent and discharged effluents, there should consequently be a reduction in process costs.

The cost for water treatment and effluent treatment is 1.05 US$/t and the cost of detergent is 0.58 US$/kg. Table 2 shows the costs of the water and detergent consumed and effluent discharged before and after the improvement, applying equation 2. The total cost per CIP before the improvement was US$ 240.76, being reduced to US$ 153.08 after improvement, which corresponds to a reduction of 36.4%.

Table 2: Costs per CIP with water and detergent consumption and effluent treatment before and after the improvement.

	Cost before improvement (US$)	Cost after improvement (US$)	Reduction (%)
Water consumption	27,23	18,32	32,72%
Detergent consumption	185,97	116,23	37,5%
Wastewater effluents	27,56	18,53	32,76%
Total	240,76	153,08	36,4%

Source: Authors, (2019).

Considering the number of CIPs carried out in 2018 (1,614), the cost of the CIP process in 2018 prior to the improvement would be US$ 388,576.84, and it was reduced to US$ 247,085.65 after the improvement, showing an economy of US$ 141,491.19 (Figure 6).

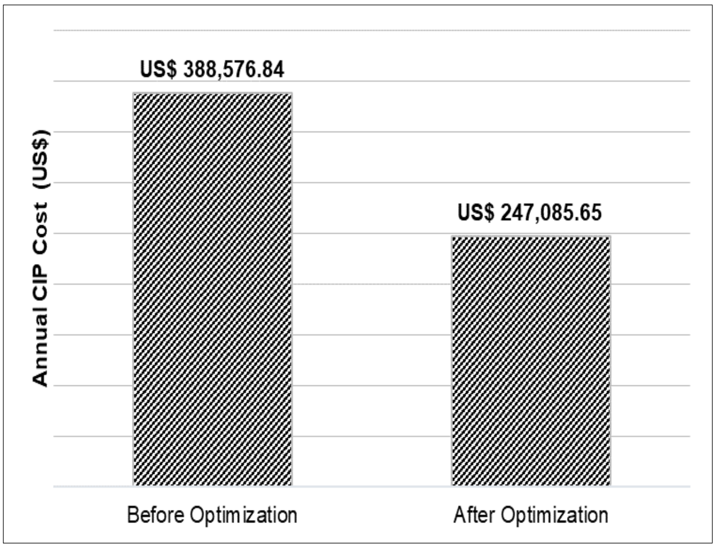

Figure 6: Comparison between costs before and after improvement.
Source: Authors, (2019).

III.6 MICROBIOLOGICAL ANALYZES

The effectiveness of the cleaning and sanitizing process is determined by the results of the microbiological monitoring of the final rinsing water. Detection of microbiological counts outside specified standards indicates the need to review established sanitation procedures.

The results obtained through the analyzes in the company's Microbiology Laboratory are described in Table 3. It is possible to observe that all the results are within the parameters and specifications, ensuring that the improvement can be performed safely, without affecting the quality and integrity of the products.

Table 3: Results of microbiological analyzes.

Samples	Test	Specifications (CFU/Volume)	Results (CFU/Volume)
Final Rinse (Sample 1)	Total Bacteria	<25/1 mL	9/1 mL
	Yeasts and Molds	<10/100 mL	4/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Final Rinse (Sample 2)	Total Bacteria	<25/1 mL	12/1mL
	Yeasts and Molds	<10/100 mL	6/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Final Rinse (Sample 3)	Total Bacteria	<25/1 mL	13/100 mL
	Yeasts and Molds	<10/100 mL	5/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Recovery Tank (Sample 1)	Total Bacteria	<25/1 mL	9/1 mL
	Yeasts and Molds	<10/100 mL	4/100 mL
	Total Coliforms	0/100 mL	0/100 mL
Recovery Tank (Sample 2)	Total Bacteria	<25/1 mL	12/1 mL
	Yeasts and Molds	<10/100 mL	7/100 mL
	Total Coliforms	0/100 mL	0/100 mL

Source: Authors, (2019).

IV. CONCLUSIONS

The improvement study of the Clean in Place process presented in this work demonstrated that it is possible to reduce water consumption, using as an alternative a recovered water tank in order to recycle the final rinse water. In addition, the reduction of the time of the initial rinsing stage, anticipation of water heating for the detergent cleaning stage and reduction of the final rinse time were factors that influenced the reduction of water consumption, detergent, process time and effluents generated in CIP. Through the mass balance, a reduction of 8.62 t was observed in the mass of water consumed and the same mass of effluent is no longer discharged after the improvement of the process. This represents a reduction of 13,912.68 t of water consumed and the same mass of effluents generated in one year (reduction of 32.75%). Regarding the consumption of detergent, there was a decrease from 320 kg to 200 kg, which represents a reduction of 37.5% in detergent consumption per CIP performed. With respect to the costs, the present study generated savings of US$ 141,491.19 per year, representing a reduction of 36.4%. The improvement provided several benefits for the company, minimizing the environmental impacts and the costs associated with this stage the production process hygiene. In addition, a 34% reduction in CIP time was achieved, which represents a significant number, taking into account that the shorter the downtime of the production lines, the greater the efficiency of the industry.

V. ACKNOWLEDGMENTS

The authors would like to thank the beverage industry for providing all the data, and the Ritter dos Reis University Center for offering the infrastructure for this research.

VI. REFERENCES

[1] Guimarães, Jonas T. et al. Quantification and characterization of effluents from the seafood processing industry aiming at water reuse: A pilot study. Journal Of Water Process Engineering. 26, p. 138-145. dez. 2018.

[2] Un Water. Water and Energy, v. 1, 2014. The United Nations World Water Development Report, 2014.

[3] Chen, Zhuo et al. Centralized water reuse system with multiple applications in urban areas: Lessons from China's experience. Resources, Conservation And Recycling. 117, Part B, p. 125-136. fev. 2017.

[4] Mancuso, Pedro Caetano Sanches; Santos, Hilton Felício dos. Reúso de Água. São Paulo: Manole, 2003.

[5] Capocelli, M. et al. A technical-economical approach to promote the water treatment & reuse processes. Journal Of Cleaner Production. 207. p. 85-96. 10 jan. 2019.

[6] Ribeiro, Fábio Henriquede Melo; Naval, Liliana Pena. Reuse alternatives for effluents from the fish processing industry through multi-criteria analysis. Journal Of Cleaner Production. 227, p. 336-345. 01 ago. 2019.

[7] Xu, Meng et al. Optimal water utilization and allocation in industrial sectors based on water footprint accounting in Dalian City, China. Journal Of Cleaner Production. 176, p. 1283-1291. 01 mar. 2018.

[8] Walsh, Brendan P.; Bruton, Ken; O'Sullivan, D.t.j.. The true value of water: A case-study in manufacturing process water-management. Journal Of Cleaner Production. 141, p. 551-567. 10 jan. 2017.

[9] Mierzwa, José Carlos; Hespanhol, Ivanildo. Água na indústria: uso racional e reúso. São Paulo: Oficina de Textos, 2005.

[10] Bansal, Bipan; Chen, Xiao Dong. A Critical Revier of Milk Fouling in Heat Exchangers. In: Comprehensive Reviews in Food Science and Food Safety. 2006.

[11] Li, Guozhen et al. A review of factors affecting the efficiency of clean-in-place procedures in closed processing systems. Energy. 178, p. 57-71. 01 jul. 2019.

[12] Germano, Pedro Manuel Leal; Germano, Maria Izabel Simões. Higiene e vigilância sanitária de alimentos. 5ª Edição. São Paulo: Manole, 2014.

[13] Escrig, J. et al. Clean-in-Place monitoring of different food fouling materials using ultrasonic measurements. Food Control. 104, p. 358-366. out. 2019.

[14] Compton, Marc et al. Food processing industry energy and water consumption in the Pacific Northwest. Innovative Food Science And Emerging Technologies. 47, p. 371-383. jun. 2018.

[15] Almeida, Tamyres Siglya Sousa; Naval, Liliana Pena. Minimização de consumo de água para a indústria do pescado. In: Seminário Integrado De Ensino, Pesquisa, Extensão E Cultura, 3. 2016, Tocantins. Programa de iniciação científica. Tocantins: UFT, 2016.

[16] Meneses, Yulie E.; Flores, Rolando A.. Feasibility, safety, and economic implications of whey-recovered water in cleaning-in-place systems: A case study on water conservation for the dairy industry. American Dairy Science Association. Nebraska, Lincoln, p. 3396-3407. 13 jan. 2016.

[17] Buabeng-Baidoo, Esther et al. Study of water reuse opportunities in a large-scale milk processing plant through process integration. Chemical Engineering Research And Design. Ahmedabad, Índia, p. 81-91. mar. 2017.

[18] SNIS - Sistema Nacional De Informações Sobre Saneamento. Diagnóstico dos Serviços de Água e Esgotos - 20173. Brasília: [s.n.], 2019.

[19] Fan, Mengyuan; Phinney, David M.; Heldman, Dennis R.. The impact of clean-in-place parameters on rinse water effectiveness and efficiency. Journal Of Food Engineering. Columbus, Ohio, p. 276-283. abr. 2018.