ANALYSE OF THE WATER BALANCE AND TECHNOLOGICAL WASTEWATER DURING BEER PRODUCTION, FOCUSING ON THE PRODUCT SAFETY AND QUALITY

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ABSTRACT

The present study aims to stimulate a complete water balance during processing of beer production. First, the water quantity required for the technological treatment, the equipment cleaning and sanitation, pasteurization and packaging processes, and other purposes as well, were considered. Sensitivity analysis of the brewing process in "Birra Korca" brewery was of great importance at this instance, because it technologically allowed a critical judgment for the feasibility of the entire beer production. The article summarizes a modeling technique and a specific computer's software, providing adequate data about inaccuracies of water and it's handling. This technology was a means to address not only the safety and quality of the beer product, but also a comprehensive engineering concept for the whole process of diagram calculations, providing a new structure of data driven algorithm. Applying smart methods such as the process of modeling techniques, numerical tools and computer simulations for the water and the waste water treatment of beer production, proved to be beneficiary with regard to water usage. There are some analytic methods made up of qualitative character, meanwhile during some analysis, these methods provide quantitative indicators regarding the water handling for the main product and the by-products of beer production. The brewing industry in Albania is obliged to apply the requirements of national legislation for water consumption and wastewater treatment. It is known that the ratio between water amount used and discharged from beer industry to the beer volume varies from 2.5-10-liter water per liter beer produced, i.e. one-liter beer requires a considerable amount of water. As it seems, the respective

cost analysis for the water and energy consumption during beer production is imperative, and the beer production unavoidably requires a new innovative water and energy management procedure, subsequently followed by better economic indicators. Therefore: improving the water management in the brewery during production; recycling and reusing the water; designing a treatment spot of the wastewater discharged from beer production, are necessities.
***Keywords*:** beer production, water usage and handling, wastewater treatment methodology

1. INTRODUCTION

Beer production is associated with these three consequent (successive) biochemical processes: i) enzyme formation during the germination of barley grains, ii) transformation of cellulosic starch into fermentable sugars using these specific enzymes and, iii) fermentation of formed sugar leading to ethyl alcohol formation and CO_2 release.

In terms of quantity, the water used is the most important raw material for beer production. Therefore, the chemical and biological composition of water is of fundamental importance for the beer production. The beer production process is related to water ingredients. The water, either supplied from state entities, or from the wells of the companies, has to be accurately used in these two main directions [1.2]: i) treatment of raw water to fulfill legal criteria, and meet the technological requirements of beer production, ii) selection of the best available technology for industrial wastewater treatment which requires a well-structured and comprehensive methodology for the systematic evaluation of alternative technologies.

The environmental issue is a critical factor for the competitiveness of today's industry. Society and individual consumers need to establish a common framework for companies' commitments in regard of environmental protection, process redesign, by-product recovery or/and reuse, are some of the possible actions directed to an eco-efficient strategy [3].

Based on the above principles, the beer production of "Birra Korça" brewery, carries out a daily monitoring and treatment of water used in the beer production process, along with the monitoring and treatment of wastewaters. This study highlights the best practices used by this plant for the water treatment and analytical monitoring parameters, considering waste according to contemporary best practices. The present study identifies the need for a more efficient approach to water treatment as a raw material, and those that emerge as waste according to the best models that carry out a treatment and monitoring which will provide a control modeled according to a software algorithm. This model guarantees the minimization of the amount of water waste during each beer production step, and the partial reuse of this wastewater, which is of a significant economic benefit under the conditions of

globalization and increased competition atmosphere [4,5].

2. "Birra Korca" brewery: analysis and monitoring of water use and waste water management

2.1*"BirraKorca" brewery water use*

The beer produced in the "Birra Korca" brewery is an alcoholic fermentation product due to the activity of selected yeasts of the genus *Saccharomyces cerevisiae*, on the wort obtained by combining water with milled cereals such as malted barley, corn, etc. Cereals contain complex carbohydrates, which are initially converted into simple sugars by the action of the respective enzymes on them, which are then easily fermented. At the end of fermentation and maturation, beer is obtained as an alcoholic product with a low percentage of alcohol between 4-4.5%.

This process is accompanied by a large use of water consumption, which for the worldwide beer industry goes between 2-10 m^3 of water usage per each m^3 of beer produced. Figure 1depictsthe schematic process of beer production.

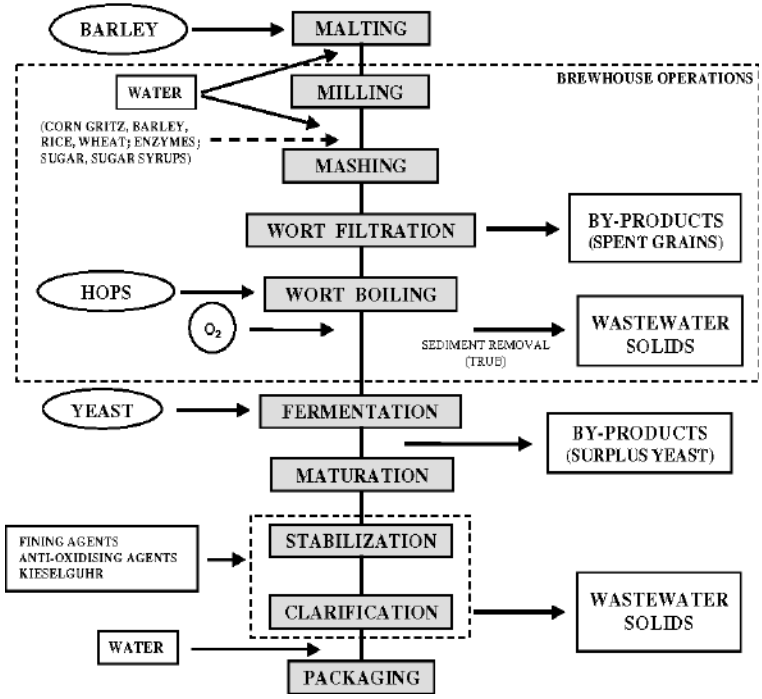

Fig.1: Technological process in breweries (adapted from Unicer SA and Varnam and Sutherland, 1994).

For the beer production in the "Birra Korca" brewery it is required the use of water with salt content in defined parameters. Consequently, the drinking water supplied by the local entity was processed to diminish the salt content by reducing its hardness in the osmosis plant. The method applied is called the Method of Reverse Osmosis. The water that comes out of the treatment has 0^o the German hardness, which once coupled, is brought to the hardness required by the production of PILSEN beer according to the applied technology.

The present study shows the quantities of water used per hl of beer produced during the time period of 2019 and 2020, referring to the efforts to minimize the water quantities used where the best international standards include a water consumption between 2-6 hl of water per hl of beer produced. Water consumption on this brewery generally in the two years taken into consideration varies between 9- 10 $m^3$of water per m^3 of beer produced. Of this amount only 1.8-2.3 hl of water is used to produce beer. The rest of 2.3-10 hl water per hl of beer is the residue generated as a major need for technological water treatment, cleaning and sanitation equipment, for pasteurization and packaging processes and other logistical purposes that accompany this process.

The individual stages of water consumption for each step of the process, as reported for the German beer industry, are shown in the Table 1.

Table 1. Water consumption in a German type of brewing industry

Process step	Water consumption
Gyle (unfermented wort) to whirlpool	2.0 (1.8– 2.2)
Wort cooling	0.0 (0.0– 2.4)
Filter and pressure tank room	0.6 (0.5– 0.8)
Storage cellar	0.3 (0.1– 0.5)
Bottling (70% of beer produced	0.5 (0.3– 0.6)
Barrel filling (30% of beer produced	1.1 (0.9– 2.1)
Wastewater from cleaning of vehicles, sanitary use, etc.	0.1 (0.1– 0.2)
Steam boiler	1.5 (1.0– 3.0
Air compressor	0.2 (0.1– 0.3)
Filter and pressure tank room	0.3 (0.1– 0.5)
Total	6.6 (4.9–12.6)

*(m3/m3 of sold beer; numbers in parentheses are ranges)

The individual phases of water consumption for each step of the process, in the "Birra Korca" brewery for 2019 and 2020 are presented in the Table 2 and 3, respectively:

Table 2. Water consumption in the "Birra Korca" brewery in 2019

Process step	Water consumption
Gyle (unfermented wort) to whirlpool	2.2 (1.8– 2.3)
Wort cooling	1.0 (0.2– 2.4)
Filter and pressure tank room	1.0 (0.8– 1.5)
Storage cellar	0.8 (0.5– 1.5)
Bottling (83% of beer produced	1.1 (0.8– 1.2)
Barrel filling (17% of beer produced	1.1 (0.9– 1.8)
Wastewater from cleaning of vehicles, sanitary use, etc	0.3 (0.1– 0.3)
Steam boiler	2.0 (1.0 – 3.0)
Air compressor	0.2 (0.1– 0.3)
Filter and pressure tank room	0.4 (0.1– 0.5)
Total	**10.1 (6.3–14.8)**

* (m3/m3 of sold beer; numbers in parentheses are ranges)

Table 3. Water Consumption in the "Birra Korca" brewery in 2020

Process step	Water consumption
Gyle (unfermented wort) to whirlpool	2.2 (1.8– 2.3)
Wort cooling	1.0 (0.2– 2.4)
Filter and pressure tank room	1.0 (0.8– 1.5)
Storage cellar	0.8 (0.5– 1.5)
Bottling (83% of beer produced)	1.1 (0.8– 1.2)
Barrel filling (17% of beer produced	1.1 (0.9– 1.8)
Wastewater from cleaning of vehicles, sanitary use, etc	0.3 (0.1– 0.3)
Steam boiler	1.6 (1.0 – 3.0)
Air compressor	0.2 (0.1– 0.3)
Filter and pressure tank room	0.4 (0.1– 0.5)
Total	**9.7 (6.3–14.8)**

*(m3/m3 of sold beer; numbers in parentheses are ranges)

The steam condensate used in its steam production system was recovered in 2020 as recommended by the authors. Consequently, the amount of hl of water used for hl of beer produced in 2020 compared to 2019 was reduced by 4%.

Comparing the amount of water being consumed in a standard German Brewery, with our consumption in the **"Birra Korca"** brewery, during the last two years (2019-2020), it is shown clearly in the graph of figure 2.

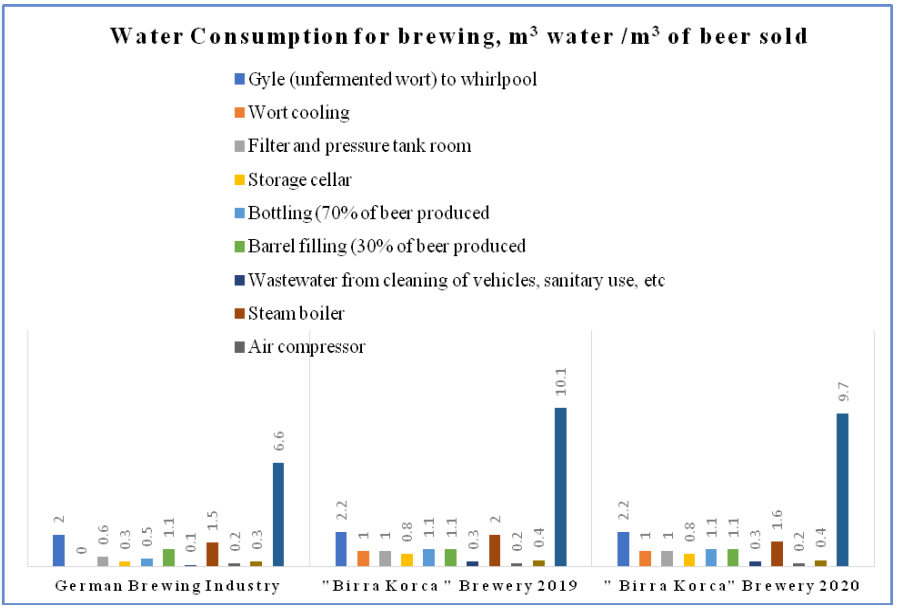

Fig. 2: Different style of the graphical presentation of the water used in German breweries' standards, comparing to the consumption of the "Birra Korca" brewery throughout 2019 and 2020.

2.2. Characterization and management of waste water

Untreated wastewater in breweries usually contains: i) suspended solids in the range of 10–60 milligrams per liter (mg / l), ii) biochemical oxygen demand (BOD_5) in the range of 1,000–1,500 mg / l, iii) chemical oxygen demand (COD) in the range of 1,800-3,000 mg / l, iv) nitrogen in the range of 30–100 mg / l, v) phosphorus may also be present in concentrations of the range of 10-30 mg / l.

The parameters above are variable depending on the individual steps of the process. For example, bottle washing produces the largest volume of wastewater, but contains only a small fraction of the total organic compounds discharged from the brewery. Wastewater compounds resulting from the fermentation and filtration process have a high content of organic compounds and BOD_5, but are low in volume. They account for about 3% of the total volume of wastewater, but 97% of the BOD_5.

The pH of the wastewater remains on average around 7 for the total combined volume, but can vary between 3 to 12, depending on the use of soda-based washing agents and neutralizing acids. The wastewater flow temperatures into the aquifer system take an average of about 30° C. Monitoring the environment influence of contaminated water, includes all the

legal elements that condition the treatment and processing of wastewater prior to discharge into the public system of their collection [6]. Discharges of wastewater from the technological process include wastewaters which are arranged through the sewer manhole and discharged into the main pipeline. Prior to discharge into this receiving aquatic environment these waters are treated and neutralized so they don`t contain contaminating components. The sewerage network is constantly monitored and their periodic cleaning is ensured [7]

The monitoring of discharges in wastewater must be within the national legal norms as reported in Table 4.

Table 4. Legal wastewater discharge norms

Waste water discharges		
Contaminant		**Method**
No.2 appendix	**Name**	**Method used**
	pH	ISO10523:2008
7439-97-6	BOD_5	SSHISO5815-1:2003
7439-92-1	COD	SSHISO15705:2013
	Suspended solids	EN872:2005
	Oils and vegetable fats	
	Ammonium nitrate	SSHISO7890-3:2000
	Total phosphorus	SSHENISO6878:2004
	Increased temperature in receiving waters	T:+3^{0}C

Table 5. The analytical norms of waste water discharges applied by the "Birra Korca" brewery

Processing section	**Parameters**	**Permitted value (mg/l)**
Beer and yeast production	pH	6-9
	Suspended solids	50
	BOD_5	40
	COD	160
	Oils and vegetable fats	10mg/I
	Ammonium nitrate	10mg/I
	Total phosphorus	5mg/I
	Increased temperature in receiving waters	T:+3^{0}C

During 2020, the measurements of the parameters above were carried out, resulting in conformity with the standards set by the legislation which is reported in Table 6.

Table 6. Values of wastewater analyzed in discharges from the "Birra Korca" brewery

Waste Water discharges					
Contaminant		**Method**		**Value**	
No.2 appendix	**Name**	**M/L/V**	**Method used**	**T (Total) (kg/year)**	**A (accidental)**
	pH	Measured	ISO 10523:2008	7.8	No
	COD	Measured	S SH ISO 15705:2013	105 mg/l	No
	BOD_5	Measured	S SH ISO 5815-1:2003 Oxitop method	23 mg/l	No
	Oils and vegetable fats	Measured	Barium chloride	3.2 mg/l	No
	Ammonium nitrate	Measured	ISO 15705	5.1 mg/l	No
	Total phosphorus	Measured	ISO 6059	1.0 mg/l	No

The monitoring shows that “Birra Korca” brewery operates within the allowed parameters for legal content of contaminants in the discharged wastewaters.

Given the complexities of keeping the legal parameters of pollution the study here reports fostering technologic system that offers accurate water management throughout the process of beer production and what comes out as wastewater in a more controlled and automated way what is needed.

The best world experiences in this industry prove that accurate forecasting of water quantity needed for each step of the beer production process and the results of wastewater treatment is of great benefit for the companies. This process also unavoidably considers the partial reuse of this water quantity, e.g. the return of part of the steam condensate used for heating towards the hot water storage tanks which are used for steam production, thus leading directly to the saving of usage quantities and economic optimization of the final product obtained. Therefore, the use of modern technology remains a permanent task of the engineering-technological staff of “Birra Korca” brewery.

3. CONCLUSIONS

The conclusions to be drawn are: i) beer production remains a complicated process which needs continuous improvements related to technological processes in order to improve product quality in parallel with the reduction of production costs associated with the adaptation of modern technologies, ii) environmental protection remains challenging as the beer production process uses water and agricultural products in great quantities and energy for heating, cooling, boiling and chilling, iii) water demand need optimization of the process. So, these quantities of water used for the units of beer produced should be further reduced in order to approximate the best modern standards, thus giving the opportunity to increase competition in the market, iv) sensitivity analysis of the brewing process in "Birra Korca" brewery in a practical optic software usage and its handling addresses not only the safety and quality of the beer product, but contributes to create a complete engineering concept that maybe necessary for the entire process diagram calculations in a new structure of data driven algorithm, v) technologic development is beneficiary for the industry. There are some analytic methods with qualitative character, but during some analysis, they consist also on quantitative indicators regarding the water handling for performing the main product and the by-products of beer production, vi) water consumption referring to the water used versus the respective hectoliters of beer produced decreased by 4%. Consequently, the cost of the final product obtained was reduced, and at the same time brought to the fore the need to apply advanced engineering methods for further improvements and economic benefits for this brewery and, vii) process optimization and the provision of more productive technologies are being used to realize the economizing of water use and also the implementation of permitted standards for wastewater discharge.

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