Master Thesis

How does water management affect water consumption in the brewery industry? Insights from the cases of Heineken Brewery, the Netherlands, and Zhujiang Brewery, China.

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Master of Environmental and Energy Management Program

University of Twente, The Netherlands

Academic year 2018/2019

Acknowledgement

First of all, I would like to express my gratitude to my parents, for their selfless supports and understanding, providing me with this opportunity to study at the University of Twente.

Then, I would like to express sincere thanks to my supervisors, Dr. Gül Özerol, for her patient and professional instructions and helps throughout my master thesis and entire study life in the Netherlands. When I got in trouble, she always helps me to find the solution and suggests the most effective way for me. In addition, I would also like to express great thanks to my second supervisor Dr. Maia Lordkipanidze for her helpful feedback on my thesis.

Last but not least, I would like to thank all coordinators and classmates of MEEM; you made me feel home.

Yilin Zhao

Abstract

After tea, carbonates, milk and coffee, beer is the fifth most consumed beverage in the world, and it continues to be a popular drink. Water is a major ingredient of beer, composing of 90–95 percent of beer by mass, and used in almost every step of the brewing process. Therefore, global breweries are searching for the best way of water management to lower their costs and improve their performance in both environmental and energy impacts of their water consumption. Water consumption for modern breweries ranges from 4 to 10 hectoliter of water per hectoliter of beer of the beer produced. The aim of this research is to compare the water consumption practices and water managements of breweries in both developed and developing countries. In addition, the best practices of water consumption in global breweries is identified to support the findings. This research gives insights from the cases of Heineken Brewery, the Netherlands, and Zhujiang Brewery, China.

Both Heineken and Zhujiang breweries reduced water consumption in their breweries by making and implementing detailed action plans. From the examination of publicly available and internal documents and the conduction of interviews, several similarities and differences were found between the two companies. Three recommendations were proposed from the examination of the regulations regarding water management and the identification of water consumption practices in both breweries. Firstly, it is recommended to set the goals and conduct practices according to regional characteristics and needs. Secondly, it is recommended to set a measurable and time-bound water consumption target in Chinese breweries. Lastly, it is recommended to conduct technical reform focusing on processes which have relatively higher water consumption, such as fermentation, cooling and packaging processes.

Key words: water management, water consumption, sustainability, brewery, Netherlands, China

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Chapter 1. Introduction

1.1. Background

After tea, carbonates, milk and coffee, beer is the fifth most consumed beverage in the world, and it continues to be a popular drink with an average consumption of 9.6 L/capita by population aged above 15 (OECD, 2005). The brewing process is energy intensive and utilizes large volumes of water. Beer production involves the blending of the extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast (Wainwright, 1998). The brewing industry uses a number of batch-type operations in processing raw materials to the final beer product. In the process, large volumes of water are utilized to produce the beer itself, as well as for washing, cleaning and disinfecting of various units after each batch are completed. The main water use steps of a typical brewery are brewhouse, cellars, packaging and general water use.

Water is the main ingredient of beer, composing of 90-95 percent of beer by mass. Water is used in almost every step of the brewing process. Water scarcity affects more than 40percent of the global population and is projected to rise (Heineken, 2017). Though the payback on reducing water usage is usually longer than recommended using standard financial calculators, the long-term sustainability and growth of a business may depend on the ability to use water efficiently. It is vital for global breweries to design and implement a sustainable way of water management.

1.2. Problem statement

Beer contains about 95percent of water; however, the amount of water used to produce a container of beer is far greater than the amount of water contained in the beer that is actually packaged and shipped out. Since beer is the fifth most consumed beverage in the world besides tea, carbonates, milk and coffee, and water scarcity affects more than 40 percent of the global population and is projected to rise, the current drive towards sustainability and the rising costs of freshwater and wastewater treatment have guided the brewery industry to find new ways in freshwater consumption.

Water consumption for modern breweries typically ranges from 4 to 10 hl/hl (hectoliter of water per hectoliter of beer) of beer produced (Hannover, 2002). The Oxford Companion to Beer definition of hectoliter is a metric unit of volume which equals to 100 liters. Hectoliter is the major unit of volume used in the global brewing industry. Every brewery has its own water management regulations and practices for reducing water use. In addition, the level of the technological development and investment is different in each brewery.

In Heineken, the global average water consumption was lower than 4 hl/hl of beer in 2014, and 3.6 hl/hl in 2017 (Heineken, 2017). However, water consumption in most breweries exceeds 4 hl/hl, especially in some small and medium breweries and in some breweries in developing countries. For example, water consumption in Zhujiang Brewery, China, was 4.06 hl/hl in 2016, and the average water consumption in Chinese breweries is approximately 8 hl/hl (Zhujiang, 2016). China is the largest developing country and one of the countries with the world's poorest per capita water resources. The per capita water resources is 2,200 cubic meter, which is about 25 percent of the world average level (Bingyao Li et al., 2017). However, it is the country with the most water consumption in the world. The number of beer companies which were above the scale of beer industry in China was 468 in 2016 (Yongqi Han, 2017). The total beer production exceeded 440 billion litres in 2017 (CHNCI, 2018).

In terms of water consumption, every brewery makes efforts to reduce it, such as setting regulations and taking practices of water management. Water management regulations can be regarded as a basic instruction on how to minimize the water consumption, because employees need to follow the regulations when working. If regulations and practices are aligned, this can have positive effects on water consumption in breweries. In this research, by describing the water management regulations and comparing practices for minimizing water use in Dutch breweries and Chinese breweries, recommendations can be identified for Chinese breweries that have higher water consumption than Dutch breweries. Such recommendations can have a great significance for improving the water consumption practices of Chinese breweries.

1.3. Research objectives

The objectives of this research are 1) To compare the water management regulations for Heineken and Zhujiang breweries, 2) To compare the current practices for minimizing the water

consumption in Heineken and Zhujiang, and 3) To give recommendations to improve the water consumption practices of Chinese breweries. Heineken from the Netherlands and Zhujiang from China, to compare them in terms of different conditions for water management and water consumption practices. These two breweries have different water consumption practices and they both rank among top-10 brands in their country. This allows to make a comparison analysis between a developing and a developed country.

1.4. Research questions

Main research question: What are the possible ways to improve the water consumption practices in Chinese breweries in comparison to the water consumption practices of the Dutch breweries?

Sub-research questions:

1. What are the water management regulations in Chinese and Dutch brewery industries?
2. What are the current practices for minimizing water consumption in Chinese and Dutch brewery companies, with empirical focus on Zhujiang and Heineken breweries?
3. What are the differences and similarities on regulations and practices of water management between Heineken and Zhujiang breweries?

Answering those three sub-questions will eventually lead to answer the main research question. At first, the answer to sub-question 1 and 2 together gives the necessary input to answer sub-question 3. In the end, based on the answer to sub-question 3 it is possible to give an answer to the main research question.

Chapter 2. Literature review

This chapter provides the literature review, starting with the beer production process and water consumption in breweries, followed by water management regulations on breweries and best practices for minimizing water consumption in global breweries.

2.1. Beer production process and water consumption in breweries

The brewing process utilizes malted barley and/or cereals, unmalted grains and/or sugar/corn syrups (adjuncts), hops, water, and yeast to produce beer. Most brewers use malted barley as their main raw material. Depending on the location of the brewery and the quality of incoming water, the water is usually pre-treated with a reverse osmosis carbon filtration or other type of filtering system. Incoming water to a brewery can reach 4 to 16 barrels of water per barrel of beer, while wastewater is usually 1.3–2 barrels less than water use per barrel of beer (UNEP, 1996).

2.1.1 Production process

The first step of brewing, milling and carbon filtration, takes place when malt grains are transported from storage facilities and milled in a wet or dry process to ensure that high yields of extracted substances are available (UNEP, 1996). The mixture of milled malt, gelatinized adjunct and water is referred to as mash. Mashing consists of mixing and heating the mash in the mash tun, and occurs through infusion, decoction or a combination of the two. During this process, the starchy content of the mash is hydrolysed to produce liquor called sweet wort. After the mash conversion is completed, the wort is separated from the mash. The most common system in large breweries is a lauter tun or a mash filter (Galitsky et al., 2003; O'Rourke, 1999). The next step is wort boiling, involves the boiling and evaporating the wort (about a 4-12percent evaporation rate) over a 1-1.5h period. During the wort boiling, hops for extracting bitter resins and essential oils can be added. In a process called hop straining, hops can be removed after boiling with different filtering devices. As with the spent mashing grains, breweries use water to spray the spent hops and press to recover wort. To remove the hot break, the boiled wort is clarified by sedimentation, filtration, centrifugation or whirlpool. After clarification, the

clarified hopwort is cooled. Once the wort is cooled, it is oxygenated and blended with yeast on its way to the fermentor. During fermentation, the yeast metabolizes the fermentable sugars in the wort to produce alcohol and carbon dioxide (CO_2) (Olajire, 2012).

Fermentation time will range from a few days for ales to closer to 10 days for lagers. This rate is dependent on the yeast strain, fermentation parameters (like the reduction of unwanted diacetyl levels) and taste profile that the brewer is targeting. Carbonation takes place in fermentation. The final step in beer production is beer aging or conditioning. The beer is cooled and stored in order to settle yeast and other precipitates and to mature and stabilize the beer. Beer is held at conditioning temperature for several days to over a month and then chill proofed and filtered. Finally, all remaining harmful bacteria in the beer must be cleaned before bottling. A typical method to achieve this, especially for beer that is expected to have a long shelf life, is pasteurization, in which the beer is heated to 140 °F (60 °C) to destroy all biological contaminants. Following steps are labelling and packaging, then the beer can be sold. The beer production stages are showed in Table 1 below.

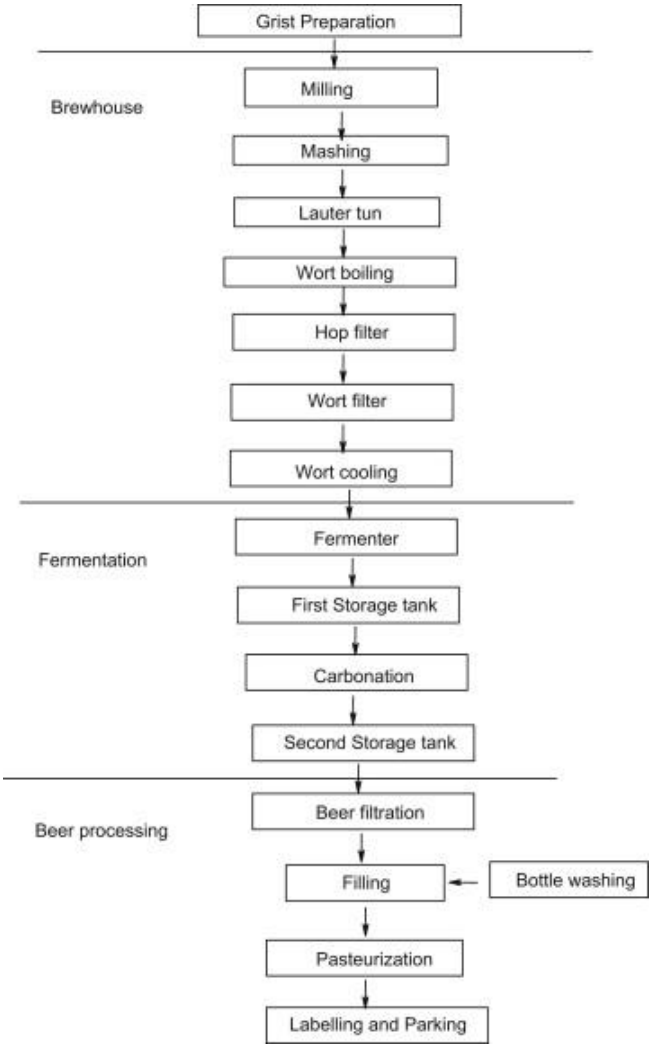

Table 1: Stages of beer production. (Source: Olajire, 2012)

2.1.2 Water consumption

A large volume of water is used for cleaning operations. The water consumption varies depending on the type of beer, the number of beer brands, the size of brews, the existed bottle washer, how the beer is packaged and pasteurized, the age of the installation, the cleaning system and the type of equipment used. Bottling consumes more water than kegging. The level of consumption through cooling systems is high and/or losses due to evaporation in hot climates. An efficient brewery will use between 4 and 7 L of water to produce 1 L of beer (EC, 2006). In addition to water for the product, breweries use water for heating and cooling, production machinery and process areas, cleaning packaging containers, cleaning vehicles, and sanitary water. Through wort boiling water is also lost and with spent grains. Water consumptions of individual process stages are shown in Table 2.

Department	Specific water consumption (m^3/hl beer produced)
Brewhouse	0.17–0.26
Cold storage	0.11-0.24
Fermentation cellar	0.04–0.08
Storage cellar	0.01–0.06
Filtering cellar	0.01–0.08
Bottling cellar	0.09–0.10
Cask cellar	0.01–0.12
Miscellaneous	0.03–0.40
Total process	0.47–1.33

Table 2: Water consumption for different brewery processes (Source: Olajire, 2012)

2.2. Water management regulations in breweries

Over the past 50 years, demand for water has doubled globally and is expected to increase by another 40percent by 2030. In water-scarce areas this means the competition for water among industries, the general population, agriculture and ecosystems is increasing. Breweries use water in its finished product – beer is 95percent water – and throughout its supply chain and recognize the critical importance of sustainable use and protection of water in order to ensure this valuable resource. Therefore, breweries adopt a series of regulations on water management. Tanzania Breweries (SABMiller) in Tanzania has launched an intensive, on-going, in-house campaign to use less water to brew beer. In addition, they have set themselves a target to use 4.5 hectolitres of water to brew a hectolitre of beer. In addition, this company installed a state-of-the-art, electronic energy-management system and implemented a brewery-wide awareness campaign for its employees. The campaign includes a specially designed comic to bring water-saving information to everyone and designs to engage employees in both water awareness and data collection (WBA, 2011).

On World Water Day, March 22, 2010, AmBev (AB InBev) from Brazil launched a partnership in Brazil called the “Cyan Movement" - “Whoever looks at water sees how much it’s worth” in AB InBev‟s Latin America North zone, a campaign to mobilize awareness around water conservation (WBA, 2011).

2.3. Best practices for minimizing water consumption in breweries

A best practice is defined as a working method or set of working methods that is officially accepted as being the best to use in a particular business or industry in Cambridge dictionary. Best practices can be found throughout the brewing sector. These practices are presented according to the different water-using areas in a brewery or brewpub. Within each area, best practices are organized based on five strategies: adjust flow, adjust current equipment, replace to new equipment, reuse or recycle water and, last, convert to a low-water or waterless process (Brewers Association, n.d.).

Based on the conditions of each brewery, they applied different practices on water consumption. In Accra Brewery (SABMiller), Africa, Ghana, they installed new water meters in all user departments to allow for more accurate monitoring and control of water usage. The brewery Sleeman Breweries Ltd., Americas, Canada, installed automatic shut-off valves on all high-pressure hoses used in floor washing, the diversion of water from the pasteuriser overflow for reuse in keg and floor washing, and they replaced all flexible hosing with permanent lines. In Brewery Timmermans, Europe, Belgium, by closing the water tap on the bottle washer a little more, the water usage of this equipment was reduced from 44 m^3/day to 35 m^3/day, without loss of efficiency. They saved 5percent of total water usage. Foster’s Brewery, Asia, Australia, they collect and recycle processed water. Bottling line efficiency measures, a solid waste recycling programme and minimisation of chemical use are adopted in Foster Brewery as well(WBA, 2011). Specific best practices in each process for water consumption from Brewers Association can be criteria for the comparative study. These practices are summarized below.

2.3.1. Reducing water use, effluent flow and effluent strength

Train employees to add the correct volume of liquor and investigate the costs and possibilities of installing a meter to measure the volume of liquor being added. If new batches are brewed

frequently, store surplus of wort and add it to the next brew. On the other hand, storing the remaining wort with trub can be sold to farmers as animal feed supplement, which it is a sustainable solution for breweries. There is a need to separate fermentable matter to maintain its value as an animal feed and to separate yeast to maintain its value for food manufacturers, because the mixture will start to ferment, and the value of both waste streams will be decreased. Furthermore, there will have a high BOD (Biochemical oxygen demand) concentration if separated grains and discharges to sewer. Excess settleable solids to sewer can cause blockage of pipes and accumulate at manholes. Where possible, use dry methods (brush or rake) to remove grains from the mash tun. There is no need to use water jets and subsequently discharge large amounts of effluent to the drain. Install fine mesh baskets in the floor drains to collect and prevent grains from entering the drainage system.

2.3.2. Heat exchangers

Almost all breweries use compact heat exchangers to recover heat from hot wort. The recovered energy can be used to pre-heat subsequent mash water or for washing purposes. Since fermentation temperatures and cold liquor temperatures may vary among the different brews, automatic temperature control will allow for optimizing flow of wort and cold liquor and will minimize water use.

2.3.3. Fermentation vessels

Single pass cooling of fermenters uses vast volumes of water. Closed loop systems will have pumps and control systems in place to regulate the flow of cooling water through the fermenters cooling system. In addition, overflow is prevented by setting the top-up level in the chilled water tank so that it is not topped-up until the reception tank is full. Install frequency controllers on the pump to fine-tune the water flow according to cooling needs. This also helps to minimize the water flow.

2.3.4. Filtration

Diatomaceous earth, plate and frame, or rotary filters have traditionally been used to filter the beer prior to packaging; however, these technologies' water consumption is high. Alternatives include cross-flow or membrane filtration.

2.3.5. CIP system

The Society of Dairy Technology defines CIP (Clean-in-place) as: “The cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of the surfaces or circulation of cleaning solutions under conditions of increased turbulence and flow velocity”. Using a CIP system is generally more efficient than manual cleaning. The advantages include:

- Increased cleanliness of vessel due to chemicals and high temperatures applied
- High level of automation possible
- Reduced water and chemical consumption

CIP is not a new technology, yet it is often considered as such.

2.3.6. Vacuum pumps

Many vacuum pumps use water for cooling and for forming ‘the seal’ (a liquid ring). By recirculating the seal water via chillers or cooling tower, it can be recovered for reuse instead of using water on a once through basis.

2.3.7. Chase water

When beer is transferred in pipes, the pipes have to be cleaned and rinsed frequently. In the case where pipes are rinsed with water, the operator needs to decide when the cleaning is ready and when the pipes can be filled with beer again. This process relies heavily on the judgment of the operator, which can result in more water use than necessary. A method is using a ‘pigging’ system. This is an engineered plug or ball which fits inside the pipe and is pushed through the pipe either mechanically or hydraulically to remove material ahead of the ‘pig’. This can only be applied where bends have a long radius and valves have bore openings.

2.3.8. Packaging

Traditionally, canning and bottling lines have used water as a lubricant to reduce friction on conveyer belts and reduce static between cans or bottles, with water sprayed directly onto the lines through jets. Several ways to save water:

- Good maintenance of the conveyer belt system can reduce water consumption of a water-based lubrication system by up to 45percent.
- Transition from water spray lubrication to a dry-lube system.
- Deploy plastic belts instead of standard steel belts.

- Large volumes of water are also lost if the water continues to spray when the conveyor belts stop. Installing a solenoid valve to isolate the flow when the conveyor is switched off is a low-cost measure that can save significant water use and effluent costs.
- Optimize conveyor rinse jet pressures. Replace nozzles to increase the pressure and nozzle diameter.

2.3.9. Cask and keg washing

A general measure for cask and keg washers is the effective design of the spray nozzles. High-efficiency spray nozzles use water at a lower pressure and the improved spraying action safeguards better water contact with the cask.

2.3.10. Glass bottle washing and pasteurizing

Re-use of the final rinse water of the washers for the pre-rinse stage (or any other stage or application). For single-use bottles, the rinse water used before the filling can be reused for many applications. Optimize the caustic dosing to the minimum quality standards to allow minimum water use during rinsing. Finally, it is a good idea to check the valves and the pipes of the washers and the pasteurizers regularly to detect leaks.

2.3.11. Cooling towers

Cooling towers and evaporative condensers require a large amount of 'make-up' water to compensate for losses associated with evaporation, drift (or mist) and blowdown (or purge). A key parameter used to evaluate cooling tower operation is "cycles of concentration" (sometimes referred to as cycles or concentration ratio). Water use can be reduced by:

- Maximizing the cycles of concentration. Many systems operate at two to four cycles of concentration, while six cycles or more may be possible. Increasing the cycles from three to six will reduce cooling tower make-up water by 20percent, and cooling tower blowdown by 50percent.
- Performing routine inspections of cooling towers and evaporative condensers for leaks and losses, and taking remedial action as soon as possible.
- Repairing or replacing poorly operating blowdown valves in time.
- Checking overflows (e.g., make-up water tank) and guarantying they are not overflowing.

2.3.12. Steam generation

Boilers and steam generators consume varying volumes of water depending on the size of the system, the amount of steam used, and the amount of condensate returned. Recovering condensate for re-use will reduce water usage.

2.3.13. Compressors

Refrigeration compressors usually need cooling water. A closed-loop system with a cooling tower, or combining the compressor cooling with another chilled water loop, like fermenting cooling are best practices for minimizing water use in compressors.

2.3.14. Restrooms

Post signs in restrooms/lavatories to remind employees to not dispose any non-flushable items in toilet. Any material other than toilet paper will force the septic tank to use more water to flush the material down the drain. Replace existing toilets and urinals with plumbing-code-conforming high-efficiency toilet (HET) or ultra-low flush (ULF) models. Provide additional urinals in men's restrooms and reduce the number of toilets.

Chapter 3. Methodology

This chapter describes the research approach taken to achieve the research objective and answer research questions formulated above. As such, activities to make recommendations to Chinese breweries on water consumption practices.

3.1. Research framework

The framework of this research is showed in Table 3. This research started from collecting documents from two selected breweries. After studying (A) the existing water management regulations and existing best practices for minimization of water consumption in the two breweries, the conceptual design is developed based on the relevant concepts of the research, and used in (B) the case studies, interviews and desk research are used in this step. Case studies are then compared (C) and results and recommendations are provided (D).

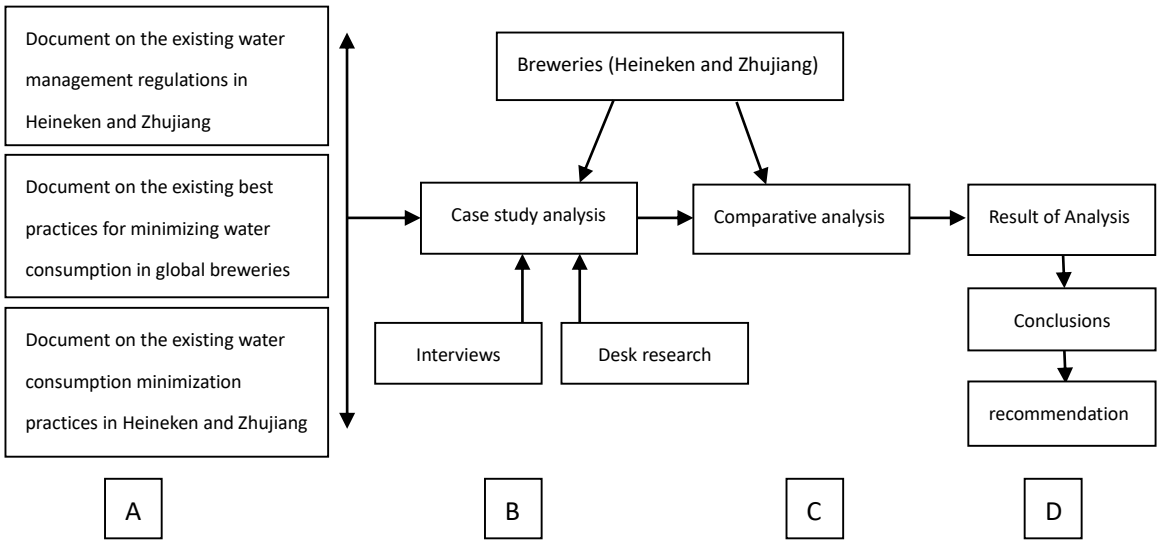

Table 3: Research framework

3.2. Research strategy

The research uses the comparative case study approach as its strategy. This qualitative approach is utilized on two cases of different conditions. The research objects in this research are Heineken Brewery and Zhujiang Brewery.

3.2.1. Research unit

The research unit focused on the water management and water consumption in two breweries from two countries: one from China and one from the Netherlands.

3.2.2. Selection of research unit

Two breweries, Heineken from the Netherlands and Zhujiang from China, are selected to compare them in terms of different conditions for water management and water consumption practices. This allows to compare and contrast adaptation approaches between a developing and a developed country. These two breweries have different water consumption practices and they are all ranked in top-10 brands in their country. Focusing on these breweries highlights the importance of water consumption in breweries and helps to give recommendations to other breweries to minimize their water consumption.

3.2.3. Research boundary

Due to time limitations and the scarce literature in this field, this research restricts its focus to:

- Best practices for minimizing water consumption in global breweries in general.
- Two chosen breweries in particular.

In addition, this research aimed to interview some related staff and collect data from Heineken Brewery and Zhujiang Brewery at the beginning, but it was not able to do interviews with Heineken staff or collect internal data about Heineken. Therefore, only publicly available reportd and data from Heineken was collected and analysed.

3.3. Data collection methods

Table 4 shows data collection methods, including research questions, required data, sources and methods of access to data. Interviews were only available in Zhujiang Brewery in this research. The interviews were conducted as semi-structured interviews. There are two interviewees from Zhujiang Brewery involved in this research. Interviews were conducted at the same day with two employees from the Safety and Environmental Protection Department in Zhujiang Brewery. They are responsible for environmental management in the company and their main job is managing all environmental related documents and analyzing water consumption data in Zhujiang Brewery. Here I prepared a questionnaire with the questions of water management regulations and/or rules and water consumption practices in their company (Appendix 1). In

terms of those questions, they shared some internal documents for water regulations and water consumption practices. The list of interviewees is showed in Table 5.

Research questions	**Data required to answer the question**	**Source of data**	**Method to access the data**
What are the possible ways to improve the water consumption practices in Chinese breweries in comparison to the water consumption practices of the Dutch breweries?	Identification of gaps in each aspect Identification of potentials for improvements	- Secondary data Documents - transcripts of interviews based on exploration of each case	- Desk research - Interviews
What are the water management regulations in Chinese and Dutch brewery industries?	Identified the water management regulations in each of Heineken and Zhujiang	- Secondary data Documents	- Desk research
What are the current practices for minimizing water consumption in Chinese and Dutch brewery companies, with empirical focus on Zhujiang and Heineken breweries?	Identified the practices in each of Heineken and Zhujiang	- Secondary data Documents - transcripts of interviews based on exploration of each case	- Desk research - Interviews
What are the differences and similarities on fermentation, cooling and packaging processes between Heineken and Zhujiang breweries?	Identified the data from each steps of beer production in Heineken and Zhujiang	- Secondary data Documents - transcripts of interviews based on exploration of each case	- Desk research - Interviews

Table 4: Research questions, required data, sources and methods of access to data

Interviewees	Date	Department	Duration
1	14/06/2019	Safety and Environmental Protection Department	30 min
2	14/06/2019	Safety and Environmental Protection Department	15 min

Table 5: List of interviewees

3.4. Comparison framework

The comparison framework is showed in Table 6. This research did a comparison analysis which focused on regulations and practices in Heineken and Zhujiang breweries. Differences and similarities are identified and discussed in chapter 5.

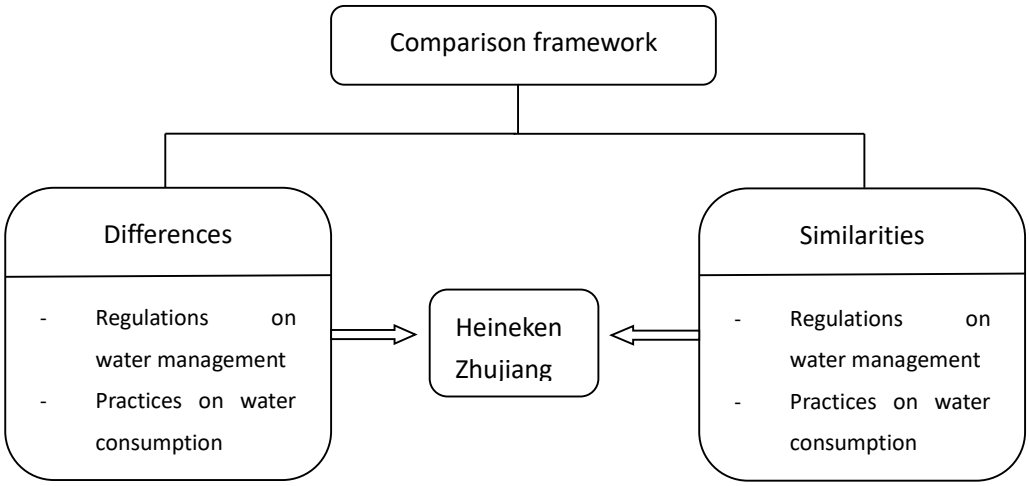

Table 6: Comparison framework

This section conveys the materials needed to answer the main research question and it brings to light the sub-questions and identifies the required data. Furthermore, it recognizes the source of these data and the method of access to the necessary information.

As previously mentioned, this research looks in depth to each of selected breweries as case studies, thus each of sub-questions is answered in each of selected context.

The research framework describes the differences of water management in each brewery to better understand how those managements affect the water consumption in each brewery. Desk

research is used to access the data available in scientific literature, databases and other accessible literature and documents. The research focuses on the latest practices in the two selected breweries.

Based on the best practices identified in global breweries (section 2.3), the study compared the current water consumption minimization practices adopted in the selected breweries. After the comparison, conclusions were made based on cases analysis supported with desk research and interviews. Finally, recommendations were made for improving the water consumption practices of Chinese breweries.

3.5. Research ethics

There are some ethical issues to be considered in my research. First one is privacy, which may be seen as the core ethical issue that confronts those who undertake research. Before the interviews, I sent the official consent form to interviewees and they signed it before the interviews started (Appendix 2). In my interviews, I did not ask the participants to fill their name and I kept all the information I have got from the interviews as confidentiality. No matter during the design and initial access stage, the data collection stage or the analysis stage, the confidentiality and anonymity are always important, the only use of collected data and information for the purpose of research. I did not attempt to apply any pressure on intended participants to grant access. I remained within the aims of my research project that I shared and agreed with my intended participants when access had been granted. Moreover, the research did not harm the safe or health of the participants in the research.

Chapter 4. Results

This chapter presents the research findings based on the data collected through desk research in the two breweries and the interviews with the representative staff in Zhujiang Brewery. This chapter answers two sub-questions: 1) What are the water management regulations in Chinese and Dutch brewery industries? and 2) What are the current practices for minimizing water consumption in Chinese and Dutch brewery companies, with empirical focus on Zhujiang and Heineken breweries?

4.1. Case 1: Heineken Brewery, the Netherlands

4.1.1. Water management regulations in Heineken Brewery

Water is a prime raw material and indispensable for cleaning purposes for Heineken Company. However, sufficient quantities of water with good quality will become scarce in the world. The Heineken Company is aware of this and wants to demonstrate its responsibility towards this subject by the publication and implementation of their Water Policy Statement (Heineken, 1999). The statement is composed of two sections: “general” regulations and “use” regulations. The “general” regulations can be summarized as these six parts. First, various of sources can supply the Heineken Company water like wells or public supplies, which is in accordance with the prevailing regulations and make sure of the necessary permits. Second, the water survey regularly assessed the Company’s water supply sources, which analyze every parameter in water according to the standards of drinking water legislation. In order to make sure of the sustainable relationship between the Company and its surrounding environment, the water survey evaluates the impact from the Company’s operations on the natural surroundings and vice versa, and then the surveyor will take according actions on it. Third, through setting several water usage targets and taking certain actions, the Heineken Company and Breweries are working hard at saving its water and achieving these targets to reduce its water use. Fourth, in accordance with the operations in prevailing regulations, the Heineken Company discharges its wastewater. If those regulations do not exist, the company will take responsibility and set its own wastewater discharge standards. Breweries conduct plans to reduce the pollution load and

meet the standards set at the same time. Fifth, efforts to continuously improve water use and wastewater discharges will be monitored through the Brewery Comparison System and will be published in the company's Environmental Report. Sixth, the Water Policy and related activities will inform all employees and provide support through other means of communication to keep a high level of awareness.

In the “use” section, there are two main regulations. First, high quality brewing water is essential for beer. Heineken strictly adheres to high water quality standards and monitors them regularly. Second, water conservation is an important part of company policy. However, reducing water use is a priority without compromising the safety and quality of the final product and the health of its consumer.

4.1.2. Current practices for minimizing water consumption in Heineken Brewery

Heineken has outlined progress towards achieving its ‘Brewing a Better World 2020’ commitments including reducing specific water consumption in its breweries to 3.5 hl/hl (Heineken, 2017). The figures were released in the Heineken’s 2017 Sustainability Report. Water consumption in its breweries worldwide reduced to 3.6 hl/hl–a 28 percent decrease since 2008 (Heineken, 2017). Their approach is to make detailed action plans for reduction of water use in their breweries, embedded within the Total Productive Management (TPM) framework. The Heineken Company prioritizes improvement projects based on impact and improvement potential. For example, they reduced water consumption at their brewery in Ijebu-Ode (Nigeria) by nearly 0.8 hl/hl in just six months by reducing the losses in the pasteuriser and by solving leakage problems. They invested in technology for reclaiming and recycling water in production processes, especially in water-stressed areas. The Heineken Company realize that there is more to do, and their next step is to look beyond 2020, defining their water strategy and related targets for 2030: ‘Every Drop’ (Heineken, 2017). "The world needs to pay more attention to water," said Jean-François van Boxmeer, Chairman of the Executive Board (CEO) of Heineken (Heineken, 2019). Under Heineken’s 'Every Drop' water ambition for 2030, the Dutch brewer commits to the following goals (Heineken, 2019):

- To fully balance within the local watershed, every litre of water used in their products in areas that are water stressed. The brewer also commits to work collaboratively with other

users of the watershed so that its health is protected, which is essential for the communities around it to thrive.

- To maximise water circularity in water stressed areas through recovery, reuse and recycling and to treat 100 percent of their wastewater worldwide.
- To reduce water usage to an average of 2.8 hectolitres of water per hectolitre of beer (from 3.2 hl/hl) for breweries in water stressed areas and to 3.2 hectolitres of water per hectolitre of beer (from 3.5 hl/hl) on average for all breweries worldwide.

4.2. Case 2: Zhujiang Brewery, China

4.2.1. Water management regulations in Zhujiang Brewery

Zhujiang Brewery formulated water management regulations in order to save water and guide employees to develop good habits for saving water which will also improve the level of water management and corporate competitiveness. Furthermore, those regulations are used for maintaining high efficiency and sustainable development of the company (Zhujiang, 2018a). The water management regulations of Zhujiang can be categorized under four main topics. First, Zhujiang formulates water use plans for each department according to the annual plan and then reward or punish based on water use plans and final water use statistics at the end of every month. Second, Zhujiang organizes a water conservation publicity campaign every year, mobilize employees to participate in it, use the internal newspaper, propaganda window, banner and other carriers to expand publicity. Third, Zhujiang formulates a water-saving management team to participate in water-saving management and implement various water-saving measures and follow up funds, personnel, progress. Fourth, Zhujiang will further optimize production process and introduce advanced cleaning and water use technologies to reduce the water consumption as much as possible.

4.2.2. Current practices for minimizing water consumption in Zhujiang Brewery

Zhujiang Brewery promoted cleaner production very early. In 2003, it became the first industrial enterprise in China that officially passed the clean production inspection and acceptance in Guangdong province, won the highest honor in China's environmental protection field in 2005, the National Environment Friendly Enterprise, and received the honorary title of Guangzhou Water-saving Enterprise in 2006. For reducing the water consumption, they took a

series of actions during the whole production process, which can be summarized as follows (Zhujiang, 2018a):

- Recycling of condensed water: Beer production requires a large amount of steam. The condensed water produced after the used steam can be directly entered into the boiler as soft water, and the heat can be recovered while recovering the water. After collecting steam condensate water, it can be used for boiler water directly.
- Recovery of hot water from mash: The brewhouse uses ice water to cool the hot wort, and the heat exchange of ice water and the hot wort will make the water become hot water (around 80℃), except for part of the brewhouse itself, washing and cleaning of the equipment, the hot water also used as the CIP cleaning water in the fermentation cellar.
- Reduce the hot water use for CIP cleaning: Subdivide the fermentation tank and yeast tank cleaning procedures into two modes: pre-use and post-use. The cleaning procedure before use remains unchanged, and the cleaning procedure after use cancels the cooling step and let it natural cooling.
- Recycling of the wastewater: After the treatment from their own wastewater treatment plant, the water is used for rinsing the sludge equipment and greening in the whole company.
- Operation control: Control the water consumption of the equipment sanitary and ground sanitation; Adopts the middle and night shifts to rinse the pipes coherently to reduce the water consumption; Keep daily inspections to eliminate leaks.

Chapter 5. Comparative Analysis

In this chapter, differences and similarities of the above regulations and current practices in selected breweries are summarized. This chapter gives an answer to the third sub-question of this research: What are the differences and similarities on regulations and practices of water management between Heineken and Zhujiang breweries?

5.1. Differences and similarities of regulations

5.1.1. Differences

Heineken Brewery focuses not only on the internal water management but also on the external environment when setting the water management regulations. For example, they regularly assess water supply sources by water survey which includes water analysis of all parameters especially in the drinking water legislation. Assess the impact of their operations on the environment and vice versa and take action to ensure a sustainable relationship with its natural environment(Heineken, 1999).Furthermore, Heineken believes that it is not enough to focus on reducing water consumption. In order to ensure the health of the watershed and the prosperity of the community, users in the watershed should pay more attention to supplementing the water they use. This can be achieved by investing more time and effort on some activities, such as reforestation, landscape restoration, desalination and water capture, and by working closely with other water users to protect this shared asset (Heineken, 2019). This way showed a strong sense of responsibility for the whole world. In contrast, Zhujiang Brewery pays attention mainly on their internal sustainable development. They formulated water use plans for different departments according to the annual plan. For example, reusing the condensed water in the equipment power department and recycling the cans washing water to sterilizer machine in the Packaging department (Zhujiang, 2018b). There are some rewarding or punishing measures taken based on water use plans and final water use statistics at the end of every month (Zhujiang, 2018a). For example, if the water consumption of one department is lower than in the last month, then some bonus will be given by cash or by card to every staff in this department or if the water consumption of one department is higher than in the last month, some fine will be given

for employees in this department (Zhujiang, 2018a). Indeed, rewarding or punishment is an effective way for regulating water use.

5.1.2. Similarities

Both Heineken Brewery and Zhujiang Brewery realized that the employees' high awareness for saving water is essential for water management. Therefore, they conduct many activities to mobilize employees every year, such as organizing a water conservation publicity campaign in Zhujiang Brewery. In addition, Zhujiang Brewery will organize routine training for employees to educate them about the latest water related knowledge (Interviewee 2, 2019).

5.2. Differences and similarities of current practices

5.2.1. Differences

Heineken is committed to water protection and has set measurable targets. For example, reducing average water consumption in their breweries to 3.5 hl/hl and in their breweries in water-stressed areas to 3.3 hl/hl before 2020 (Heineken, 2017) and 'Every Drop' water ambition for 2030 which says: To reduce water usage to an average of 2.8 hl/hl (from 3.2 hl/hl) for breweries in water stressed areas and to 3.2 hl/hl (from 3.5 hl/hl) on average for all breweries worldwide (Heineken, 2019). To reach the goal, their approach is to make detailed action plans for reduction of water use in their breweries, embedded within the Total Productive Management (TPM) framework. Furthermore, Heineken has realized that protecting water resources requires a highly contextual approach to the specific watershed in question, so they are developing individual targets for each brewery in water-stressed areas and prioritising the most relevant actions for each local watershed (Heineken, 2019). However, for reducing the water consumption, Zhujiang Brewery took a series actions during the whole production process, such as recovery of hot water from mash and reducing the hot water use for CIP cleaning, but they do not set a measurable goal. The company requires the decrease of water consumption every year, but they never have a short term or long term "clear goal" to guide their practices (Interviewee 1, 2019). In terms of this aspect, Heineken follow "result to processes" approach, setting a measurable goal and then taking actions to reach it. While Zhujiang, on the other hand, follows "processes to results", implying that they take a series of actions for a lower water consumption without setting a measurable goal.

5.2.2. **Similarities**

The two companies focus on lowering their usage of water by improving water efficiency in their operations, focusing more on water circularity (the reuse and recovery of water) and technical reform. For example, in Heineken, a programme called “Upgraded Osmosis Facilities” was launched in 2009 to discover where additional water savings could be made. As a result, the brewery’s two osmosis facilities were upgraded to allow 10percent more water to flow through the system and be used in the production process, rather than being released into the sewers. The project has increased the amount of water coming out of the reverse osmosis installation reducing the water used from the wells (WBA, 2011). For the Zhujiang Brewery, they recycled condensed water for boiler water use and recycled the wastewater for rinsing the sludge equipment and greening in the whole company (Zhujiang, 2018b).

Chapter 6. Conclusions and Recommendations

This chapter brings together the conclusions of the research and makes recommendations based on the results.

6.1. Conclusions

This research focused on water management and water consumption in two breweries, one from China and one from the Netherlands, comparing the regulations and current water consumption practices in the selected breweries. The comparative analysis demonstrated the results of the two case studies regarding the differences and similarities on water management regulations and on current practices for minimizing the water consumption in the two breweries. The case studies were selected to demonstrate these contrasting aspects and to formulate recommendations to improve the water consumption practice in Chinese breweries.

The water consumption of modern breweries ranges from 4 to 10 hl/hl of the beer produced, and the water consumption in Heineken Brewery was 3.6 hl/hl in 2017, but 4.06 hl/hl in Zhujiang Brewery in the same year. Therefore, there is still a huge gap on water consumption between developed countries' breweries and developing countries' breweries, which also indicates there is room to improve the water consumption practices in developing countries' breweries. To address the main research question on the possible ways to improve the water consumption practices in Chinese breweries in comparison to the water consumption practices of Dutch breweries, three sub-questions were answered.

In the first sub-question, the research sought to identify the water management regulations in Chinese and Dutch brewery industries, and as can be found in Heineken Brewery and Zhujiang Brewery. In Heineken, the water management regulations contain two sections: "general" regulations and "use" regulations. "General" regulations are composed of six aspects. First, ensuring the necessary permits for various water sources for Heineken Brewery. Second, ensuring the sustainable relationship between the company and its surrounding environment by assessing Heineken's water supply sources. Third, setting several water usage targets and taking certain actions to reduce its water use. Fourth, in accordance with the operations in prevailing

regulation. The Heineken is required to conduct plans to reduce the pollution load and meet the standards set at the same time. Fifth, efforts to continuously improve water use and wastewater discharges will be monitored through the Brewery Comparison System and will be published in the company's Environmental Report. Sixth, the water policy and related activities will inform all employees and provide support through other means of communication to keep a high level of awareness. In the “use” section, there are two main regulations. First, Heineken adheres to high water quality standards and monitors them regularly. Second, water conservation is an important part of company’s policy. In Zhujiang Brewery, the water management regulations can be categorized under four main topics. First, Zhujiang formulates water use plans for each department in the company according to the annual plan and then reward or punish based on water use plans and final water use statistics at the end of every month. Second, Zhujiang organizes a water conservation publicity campaign every year to mobilize employees to participate in it and they use their internal newspaper, propaganda window, banner and other carriers to expand publicity. Third, Zhujiang formulates a water-saving management team to participate in water-saving management and implement various water-saving measures and follow up funds, personnel, progress. Fourth, Zhujiang aims to further optimize the production process and introduce advanced cleaning and water use technologies to reduce the water consumption as much as possible.

The second sub-question aimed at identifying the current practices for minimizing water consumption in Heineken Brewery and Zhujiang Brewery. Heineken achieved to reduce specific water consumption in its breweries by making and implementing detailed action plans. For example, reducing water usage to an average of 2.8 hl/hl (from 3.2 hl/hl) for breweries in water stressed areas and to 3.2 hl/hl (from 3.5 hl/hl) on average for all breweries worldwide and maximising water circularity in water stressed areas through recovery, reuse and recycling and to treat 100 percent of their wastewater worldwide.

Similarly, for reducing the water consumption, Zhujiang Brewery conducted a series of actions. Recycling the condensed water, reducing the hot water use for CIP cleaning and recycling the wastewater are parts of the practices for minimizing water consumption in Zhujiang Brewery.

From the examination of publicly available and internal documents and the conduction of interviews, several similarities and differences were found between the two companies. Results

from comparing the regulations revealed Heineken Brewery focuses not only on the internal water management but also on the external environment when setting the water management regulations. In contrast, Zhujiang Brewery pays attention mainly on their internal sustainable development. For similarities of regulations, both Heineken Brewery and Zhujiang Brewery realized that the employees' high awareness for saving water is essential for water management and organize many activities to mobilize employees every year.

Results from comparing the current practices on reducing water consumption in the breweries revealed Heineken is committed to water protection and has set measurable targets. Furthermore, they are developing individual targets for each brewery in water-stressed areas and prioritising the most relevant actions for each local watershed (Heineken, 2019). On the other hand, Zhujiang Brewery took a series of actions during the whole production process, such as recovery of hot water from mash and reducing the hot water use for CIP cleaning for reducing the water consumption, but they do not set a measurable goal. Those are the main differences on current practices. For similarities of practices, they all focus on lowering their usage of water by improving water efficiency in their operations, focusing more on water cycling (the reuse and recovery of water) and technical reform. Those findings answered the third sub-question about the similarities and differences on water management regulations and water consumption practices between Chinese breweries and Dutch breweries.

6.2. Recommendations

Based on the findings presented in chapter 5 regarding the Heineken and Zhujiang breweries, it can be argued that the Heineken Brewery is a best practice compared to the Zhujiang Brewery. Therefore, this research makes three recommendations to Chinese breweries, which answer the main question on the possible ways to improve the water consumption practices in Chinese breweries in comparison to the water consumption practices of the Dutch breweries.

Firstly, the goals and practices can be developed according to regional characteristics and needs. For instance, whereas Zhujiang breweries are located throughout China, most of the breweries of the company are in the southern part of the country and several breweries in the north. The water is scarcer in the north than in the south, and therefore more attention is needed to water consumption practices of the breweries that are located in the north. It is recommended for

Zhujiang Brewery to learn from Heineken setting goals and practices to apply for different water availability. For example, Heineken Brewery plan to reduce water usage to an average of 2.8 hl/hl (from 3.2 hl/hl) for breweries in water stressed areas, and to 3.2 hl/hl (from 3.5 hl/hl) on average for all breweries worldwide (Heineken, 2019).

Secondly, it is recommended to set a measurable and time-bound, water consumption target in Chinese breweries. The Cleaner Production Technology Implementation Plan in the beer industry stipulates that under the premise of keeping an average annual growth rate of 5 percent in beer production, the main consumption indicators of the beer industry are reduced at least 2 percent per year in China (National Ministry of Industry and Information, 2010). For example, Zhujiang Brewery can set the water consumption for 3.8 hl/hl as a three-year goal. Such an approach can also be helpful for changing employees' behavior and finally reaching the goal, because the employees will have a specific target and time frame in their mind.

Lastly, it is recommended to conduct technical reform focusing on processes which have relatively higher water consumption, such as fermentation, cooling and packaging processes. Among the water consumption for different brewery processes, above mentioned three processes belong to brewhouse, cold storage, bottling cellar department respectively. Those processes are the main water consumption processes, and therefore they carry significant potential to improve operations to achieve lower water consumption than other processes.

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Appendix 1: Interview guide

The research questionnaire for Zhujiang Brewery

Dear <name of respondent>,

Thank you on your willingness to participate in my research. My name is Yilin Zhao. I am a student at the Master of Environmental and Energy Management (MEEM) at the University of Twente. Currently I am conducting my thesis research, which is entitled "How does water management affect water consumption in the brewery industry? Insights from the cases of Heineken Brewery, the Netherlands, and Zhujiang Brewery, China".

The purpose of this questionnaire: Water is the main ingredient of beer, composing of 90-95 percent of beer by mass and water is used in almost every step of the brewing process. Since water scarcity affects more than 40percent of the global population and is projected to rise, it is vital for global breweries to design and implement a sustainable way of water management. My thesis research will compare the water management and consumption practices of breweries in both developed and developing countries. Based on this comparison, I will propose recommendations for minimizing water use in breweries. The data that I collect through this questionnaire will be used as the basis for the comparison.

An informed consent form is included in the attachment. I would very much appreciate if you could sign and send it back to me.

Informed consent MEEM.pdf

If possible, I would like to have following documents and data from your company:

1. **Water management regulations and/or rules**
2. **Water consumption practices**

Appendix 2: Informed consent

Informed consent form for individual interviews for thesis studies in MSc MEEM

Title research or acronym: How does water management affect water consumption in the brewery industry? Insights from the cases of Heineken Brewery, the Netherlands, and Zhujiang Brewery, China.

I declare to be informed about the nature, method and purpose of the investigation. I voluntarily agree to take part in this study. I keep the right to terminate my participation in this study without giving a reason at any time.

My responses may be used solely for the purposes of this study. In its publications, they may *(please tick one of the options):*
O be cited with my name or function revealed
O be cited anonymously, thus without identifying context
O only used as information source
During the course of the interview, I keep the right to restrict the use of (some of) my answers further than indicated above.

Name
participant: …..……
……..

Date: ……..…… Signature
participant: …...……

I declare to fully adhere to the above.

Name
researcher: ……
……..……..

Date: ……..…… Signature
researcher: ……....…….