In: Implementing Data Analytics and Architectures for Next Generation Wireless Communications, pp. 18-26. Hershey, PA: IGI Global, 2022. ISBN: 9781799869894
DOI:10.4018/978-1-7998-6988-7.ch002

Improving water efficiency in the beverage industry with the internet of things

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INTRODUCTION

Background

Out of the total existing water on earth's surface 97% is ocean water, 2.5% is entrapped in glaciers and ice and only 0.5% is accessible as freshwater (Mullen, 2012). From the abstracted freshwater about 70% is used for irrigation, 19% is used for manufacturing purposes and the 11% left is consumed for domestic usage (Luckmann, Grethe, McDonald, Orlov, & Siddig, 2014). With respect to manufacturing, water is extensively used in the food industry (Poretti, 1990). In more detail, it is estimated that food and drink industries consumption of water in 2010 was between 185.5-195.7% (Bromley-Challenor, Kowalski, Barnard, & Lynn, 2013) as shown in Table 1. With the rising world population, which is set to reach 9.7 billion by 2050 (United Nations, 2017), an increasing amount of freshwater will be needed for drinking, food production, hygiene and sanitation. This increases pressure on water resources and exposes the food industry vulnerability to water scarcity.

Problem Overview and Scope of Work

Water is an essential resource for food and drink sector as it is embedded within the food product, is needed for processing or for cleaning purposes (Casani, Rouhany, & Knøchel, 2005). This sector considers water efficiency and sustainability as the topmost priority in decision-making processes for Food Supply Chain (FSC) stakeholders (Jagtap, 2019; Jagtap, & Rahimifard, 2018). To meet both demand and supply for freshwater, a well-aware and responsive water management system is required. Only through communication, collaboration, and collective actions of all the stakeholders within the FSC, water efficient practices can be implemented (Skouteris et al. 2018; Webb, Skouteris, & Rahimifard, 2018). Hence, a real-time water consumption tracking system is needed through which a detailed information on water usage activities can be monitored to identify wastage and find the opportunities to reduce the consumption.

Table 1. Food and drink sector water use

Food and Drink Industry	Total Water Use (million m³/annum)	
	2007	2010
Food and Drink Manufacturing	230.9 (56.1%)	185.5-195.7 (53.4%)
Retail	10.1 (2.5%)	6.9-10.1 (2.0-2.8%)
Wholesale	1.6 (0.4%)	1.1-1.7 (0.3-0.5%)
Hospitality and Food Service	169.0 (41.1%)	153.7-158.8 (44.3 -43.3%)

Source: (Bromley-Challenor et al., 2013)

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The Internet of Things (IoT) is accepted as one of the most important areas of future technology and is gaining careful attention from a wide range of industries (Lee & Lee, 2015). The IoT concept, which aims to support the transparency and visibility, could be utilized to provide detailed information on water consumption in FSC through smart sensors and meters from each machine component to whole of the supply chain (Jagtap et al., 2021a; Jagtap, Garcia-Garcia, & Rahimifard, 2021b). Thus, real-time water consumption data from food manufacturing processes can be gathered seamlessly and then analyzed, to increase water-aware decision-making.

This paper provides an understanding of water efficient practices that are undertaken through the application of IoT and addresses the benefits of adopting such management practices. Furthermore, a framework is introduced to support the incorporation of collected water data into an FSC's planning tools and information technology platforms. The final goal of the framework is to highlight how decision-making processes based on such data could support and enhance water efficiency and thereby increase the effectiveness of FSC. Finally, the case study results back the adoption of IoT in value-based manner and water management practices that are more in line with FSC development.

IOT-BASED WATER MONITORING SYSTEM

IoT based Water Monitoring Architecture

Figure 1 shows a detailed IoT architecture for water management. The bottom right quadrant is termed as Sensing layer and its primary function is to acquire data and information on water flowrate and quality in real-time. This data is collected using a number of sensors, such as pressure transducers, flow meters and water quality sensors. The bottom left quadrant is called as Networking layer which follows certain procedures for reading sensors and devices. It executes basic functions of linking up of sensing layer to database systems and software platforms. It uses short-range wireless networks such as WiFi, Bluetooth, RFID and ZigBee. The upper left quadrant is the Service layer, and it involves management of data and information, software applications and platforms. Service layer is responsible for collecting the data from all IoT-gateways. It processes an excessive amount of data and sorts it before storing it in a data warehouse. The stored data is then made available for data mining and analyzing by applications running in a cloud to extract useful information. The Application layer which is the upper right quadrant generates real-time water data analysis and water trend reports and presents information to user over the Internet via HTTP. The web application is powered by ASP, .NET, HTML5 and supports user-friendly functionalities such as diverting water from certain food production processes to other secondary processes depending upon the water quality, checks the water usage, sends alerts and allows to view historical data.

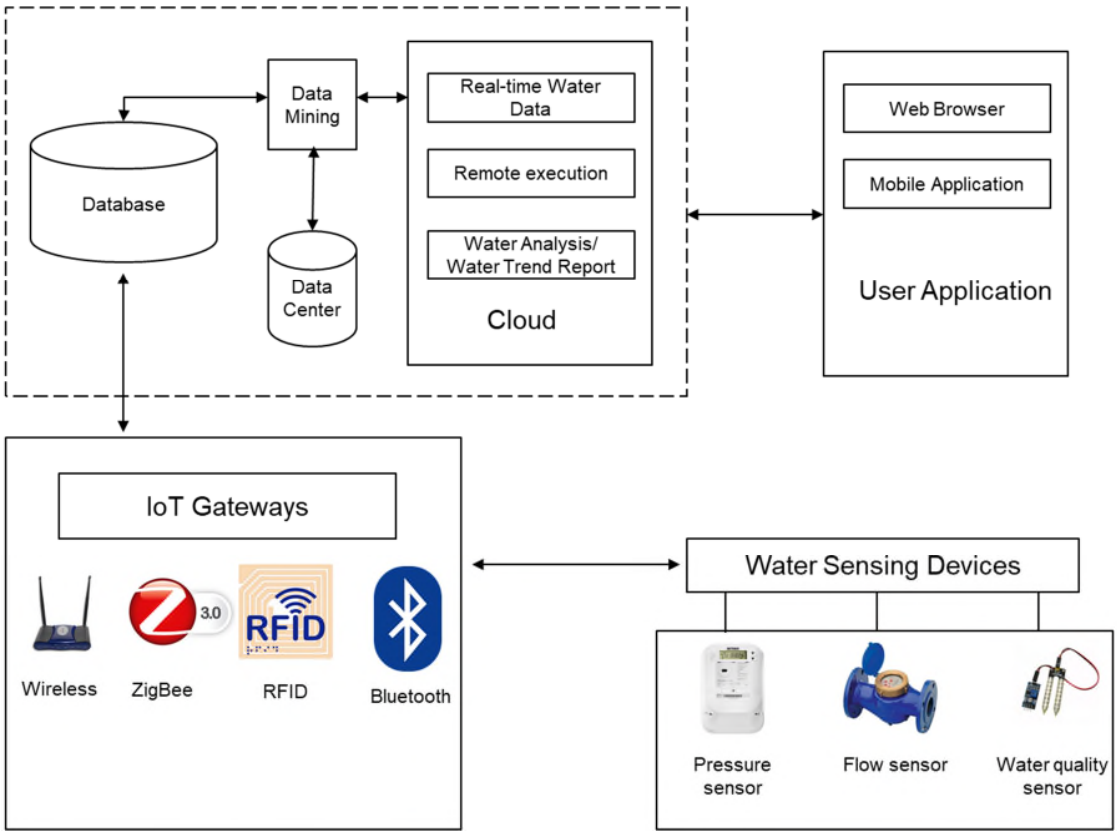


Fig. 1. IoT Architecture for Water Monitoring

IoT-based Water Efficiency System

Figure 1 illustrates the process of IoT-based water monitoring system deployed in the case company. The system consisted of pressure sensors, flowmeters and water quality sensors to sense various water parameters which are crucial for food production. The system recorded data for water flowrate, water pressure for identifying leakages and water quality parameters such as pH, temperature, chlorine, electrical conductivity, dissolved oxygen and oxidation/reduction potential for possible contamination. The data collected is stored on the secured cloud server and is made available in real-time irrespective of their location. It uses a specially designed software suite that mines for the suitable water data and recognizes water usage patterns. It further uses mathematical and statistical algorithms to capture behavioral changes and variations in pressure, flow and quality of water. It distinguishes between abnormal events when compared to the standard operating procedures and statistically filters out false alerts. As shown in Figure 2, the Water monitoring system can identify and measure water loss in real-time and detect leaks in the system as well as detecting contamination. This allows the users to contain the wastage of water immediately as soon as it is detected and reinstate the water usage back to normal.

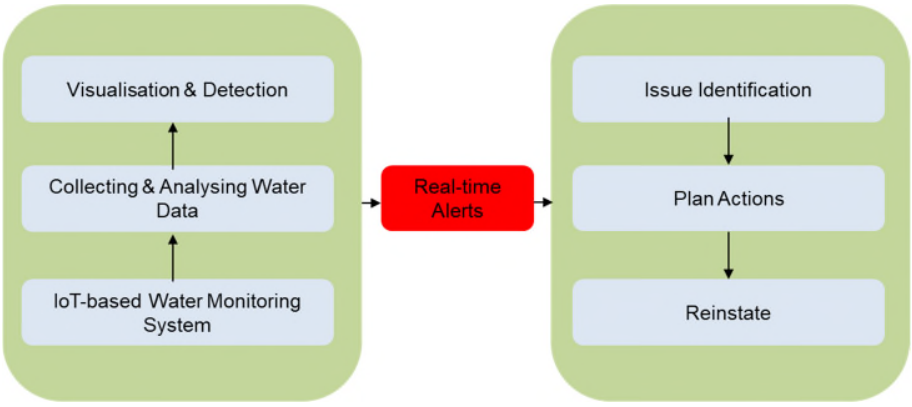


Fig. 2. Pathway for IoT-based Water Efficiency

CASE STUDY

Beverage industry is one of the largest users of water resources and is highly relevant as it consumes between 89-99% of potable water (Beverage Industry Environmental Roundtable, 2011). Traditionally, water usage in the beverage industry has been quantified on a total volume or normalized volume (volume water used per volume product packaged). This ratio is typically well known and has become the standard for measuring water use efficiency in the beverage sector. As per Statista 2018, production volume of aerated and soft drinks across India from 2015 to 2017 (in million litres) has dropped as shown in Figure 3. But, still 2644.56 million liters for the year 2017 is quite significant because every 1 litre of beverage production consume anywhere between 1.7 - 4.2 liters of water and in some cases even more than that (Beverage Industry Environmental Roundtable, 2011).

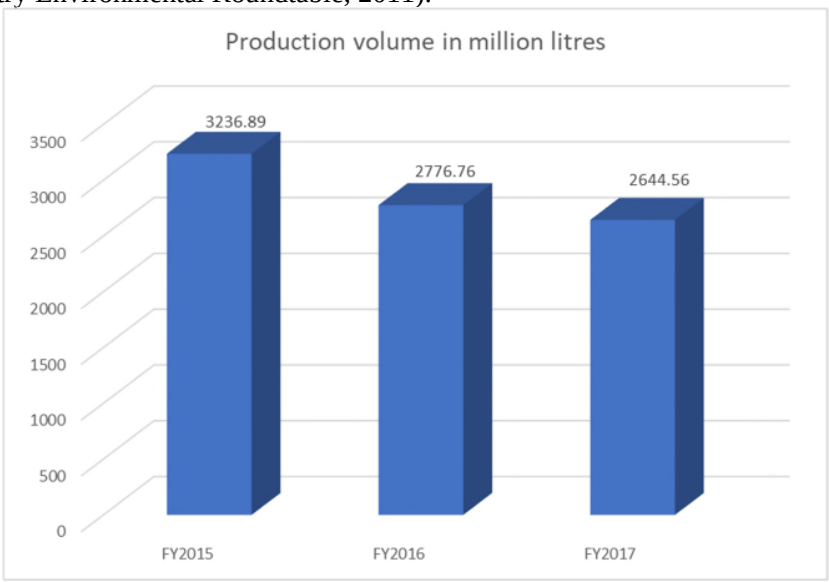


Fig. 3. Production Volume of Aerated & Soft drinks – India (Source: Statista 2018)

Manufacturing Process

Figure 4 shows the soft drink production process. The raw water drawn from the water-wells goes through various purification and filtration processes until it reaches the blenders. Once inside the blenders,

flavorings and sugar are added to the water as per the recipe and mixed thoroughly. The mix is sent to the filling machines wherein CO_2 gas is added while filling the bottles.

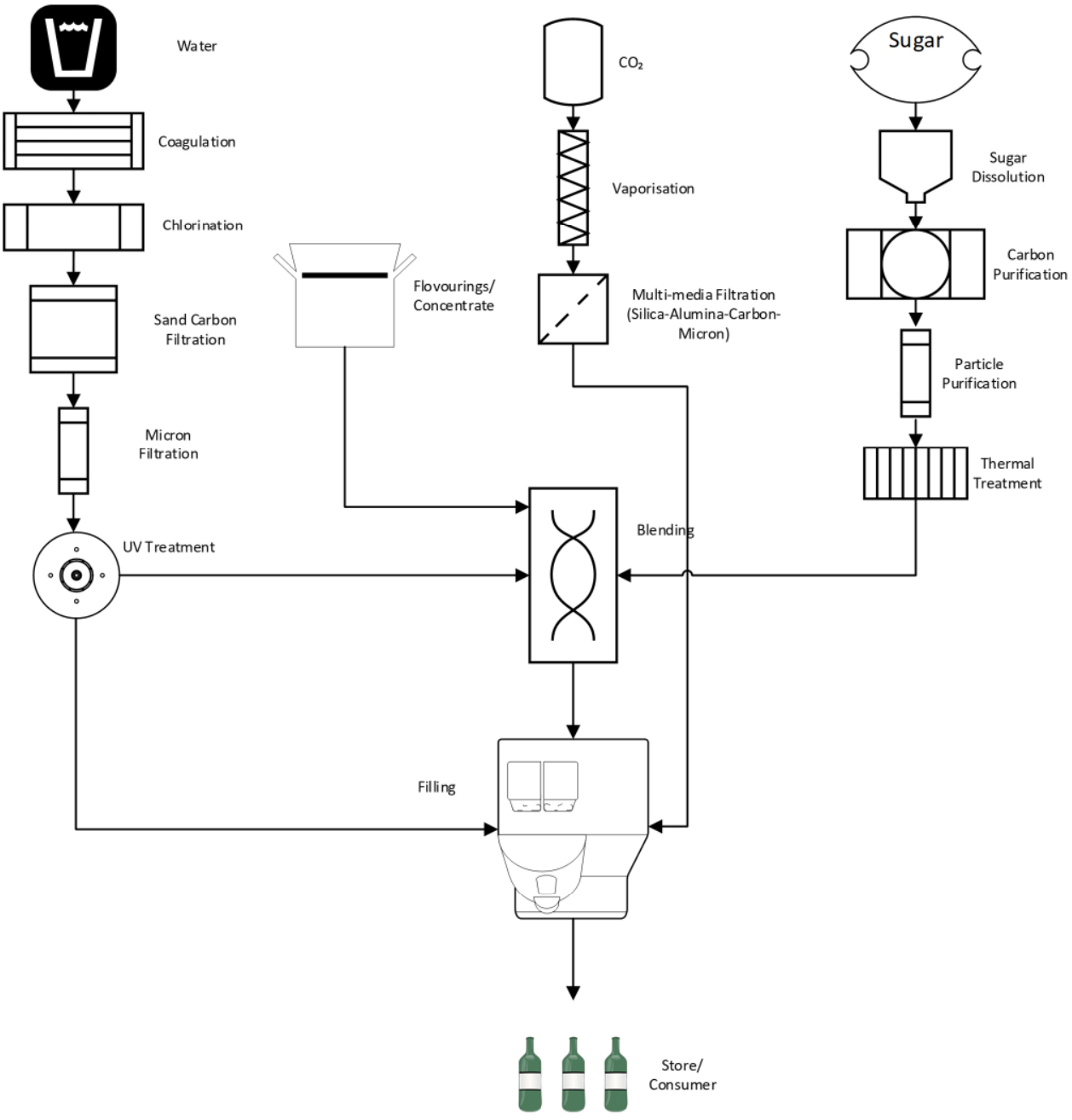


Fig. 4. Beverage Production Flowchart

Water Consumption in factory

The case company consumes 127,500 m^3/month of potable water and through IoT-based water monitoring system identified the five major areas where water is consumed extensively: 1) Cooling, 2) Bottle

cleaning/filling, 3) Plant cleaning, 4) Utilities and 5) Raw material washing. As illustrated in Figure 3, cooling is the largest water consuming water activity taking up 57% of total water which equates to 72,675 m^3/month. The other losses which accounted to 29% was due to evaporation, leaks and due to other reasons.

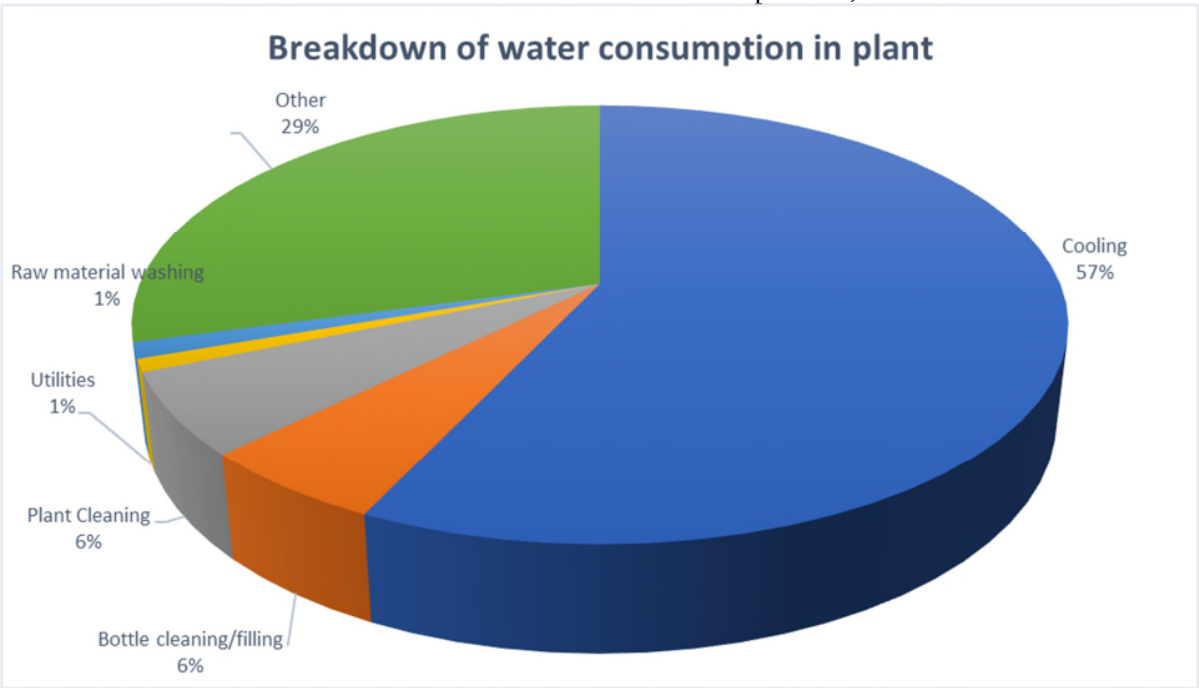


Fig. 5. Breakdown of Water Consumption in Plant

IoT-System Implementation

The beverage company before installation of the IoT system were not aware of their in-detail water usage and its breakdown. For the year 2017, the water usage was not uniform (as shown in Table 2) and the company used mass-balance calculations to estimate the water consumption. The company was aware of the raw water intake, the volume (in litres) of finished beverages and the amount of water discharged to the effluent treatment plant (ETP) and by working out them they estimated the water losses. This practice never allowed them to look for the root cause or reasons behind the water losses.

The company undertook the project to install the real-time IoT-based water monitoring system by the end of December 2017 and started monitoring water consumption from January 2018 onwards. They realized the various water saving opportunities and focused on the issues which did not require extra investments and can be addressed with the resources at their disposal (as shown in Table 3). The outcome of that was a continuous reduction in the water usage from January 2018 to June 2018.

Table 2. Total water in litres to make one liter of finished beverage

2018	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**
Total Water Lt/ Lt beverage	2.03	2.01	1.99	1.98	1.92	1.90
2017	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**
Total Water Lt/ Lt beverage	1.74	2.11	2.19	1.99	2.14	2.49

CONCLUSION

The objective of this case study was to analyze water-intensive processes and identify opportunities to reduce the water consumption of the beverage company. Through IoT-based water monitoring system, processes and areas where significant amount of potential water savings was achieved are listed in the Table 3.

Table 3 Water-saving opportunities

1. Filler bowl gasket damage leading to water leakage
2. Filler valve vent tube issue, dispensing liquid even when bottle is absent
3. Rinser auto system not working properly leading to excessive water usage
4. Recovery tank overflowing pump, float and pipe line changing for water losses
5. Filler room, ozone tester, rinse water diversion to recovery tank
6. CIP system validation for water reduction
7. Final syrup room water recovery system to be install
8. Production line vacuum water to be circulated or diverted to raw water tank

Due to the adoption of the IoT-based water monitoring system, the total water (in liters) required to make one liter of beverage was reduced from 2.10 liters to 1.96 liters on an average. They managed to reduce the overall annual consumption of water by 6.66% which was equivalent to reducing 8491.5 m^3 per month of total water intake. The company also realized that by utilizing the water used for cooling towers can be reutilized and diverted to recovery tank with some adjustments in the piping designs.

The results from this case study shows that there is a tremendous potential with the real-time IoT-based monitoring system to measure and reduce the water consumption of various processes and this can be replicated into other food factories.

ACKNOWLEDGMENT

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) Centre for Innovative Manufacturing in Food [Reference: EP/K030957/1].

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2021-08-31
IGI Global
https://doi.org/10.4018/978-1-7998-6988-7.ch002
Jagtap S, Skouteris G, Choudhari V, Rahimifard S. (2022) Improving water efficiency in the beverage industry with the Internet of Things. In: Implementing Data Analytics and Architectures for Next Generation Wireless Communications, IGI Global, 2022, pp. 18-26

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