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Water recycling and reuse in soft drink/beverage industry: A case study for sustainable industrial water management in Turkey

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ABSTRACT

The aim of this study was to investigate water conservation and reuse opportunities in a soft drink/beverage manufacturing company. Water use analysis and benchmarking were carried out to determine the areas and processes where significant water saving potential is present. Based on evaluations, water recycling and reuse practices were realized in cooling systems. As a result of applying these practices, the total specific cooling water demand of the company was reduced from 14.4 to 1.2 m^3/m^3 product or by 91.8%. Moreover, the total specific water intensity of the company was decreased 55.0%. Thus, the achieved total annual water saving was 503,893 m^3. After applications, specific wastewater generation of the company was reduced by 57.4% and hydraulic overload issues in wastewater treatment plant of Kayseri organized industrial zone were resolved. During the implementation of water saving measures/techniques 56,960 $ was spent for equipments. Annual cost saving of the company were 97,000 $. So, the payback period of the implementations was approximately 7 months. This study proved that water recycling and reuse can successfully be implemented in soft drink/beverage industry as a sustainable industrial water management approach. If successfully replicated in other manufacturing sectors besides soft drink/beverage sector, outcomes of this study can be a solution for excessive cooling water consumption in Turkey as well as other parts of the world where similar processes are employed.

1. Introduction

As an emerging economy, Turkey is currently witnessing a rapid industrial development and associated excessive resource consumption. Being among the essential natural resources as well as indispensible inputs of agricultural, industrial and domestic activities, water resources are under increasing pressure. According to "Turkey Water Report", total water consumption in Turkey was increased 50.2% from 30.6 to 46.0 billion m^3 between 1990 and 2008 (MOEF, 2009). Projections indicate that between 2008 and 2030 total water consumption will increase almost threefold and become 112.0 billion m^3 (MOEF, 2008). During the same period (2008–2030), industrial water consumption is expected to increase tremendously or from 5 to 22 billion m^3. In other words, the share of the industrial water consumption will be expected to increase from 10.9 to 19.6% among agricultural and domestic uses in Turkey (MOEF, 2009). This trend reveals that although agricultural water use is by far the highest water consuming sector at present with a share of 70% of total water demand, industrial based development is subject to change it. Thus, serious measures should be taken in order to conserve water resources from depletion due to intensive industrial activities (Ulutas et al., 2011). The drastic changes in water quality and increasing territorial reduction of ground water level in Ergene Basin (in Thrace Region) due to intensive textile manufacturing activities can be given as an example for mismanagement in this area (Kaykıoğlu and Ekmekyapar, 2005). In order to prevent similar cases to happen in other areas of Turkey, the water intensive sectors should be targeted for water conservation.

In Turkey, one of the core industrial sectors relying on continuous and high quality water supply is food/drink industry which has been experiencing a remarkable rate of economic growth. The Federation of Food and Drink Industry Associations of Turkey states that annual added-value created by food/drink companies increased by 53.3% from 7.7 to 11.8 billion Turkish Lira (TL) between 2004 and 2009 (TGDF, 2011). Turkish food/drink industry has continued to grow even with a higher rate after 2009. In 2009–2012 period employment was increased from 338,852 to 406,091, an increase of 19.8%. During the same period export of food/drink products increased 61.0% from 5.9 to 9.5 billion $. In 2010, food/drink industry achieved an annual turnover of

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88.8 billion TL, which corresponds to 16.1% of total annual turnover (552.8 billion TL) generated in Turkish manufacturing industry (MOSIT, 2013).

Although food/drink industry is crucial for Turkish economy, its environmental impacts require particular attention. The primary impact of food/drink industry is on natural water resources. According to Turkish Statistical Institute, with a 131.2 million m^3/year it is responsible for 10.0% of total industrial water consumption (TSI, 2008a). Due to this high rate of water consumption food/drink industry placed in 3rd rank (after basic metals and textile products) among 23 manufacturing sectors in terms of water use. Furthermore, it exerts a great influence on receiving water bodies by discharging 76.3 million m^3 wastewater/year (TSI, 2008b). Besides water and wastewater issues, food/drink industry is among the highest solid and hazardous waste producer industries in Turkey. Producing 1.2 million ton/year of solid waste, it is responsible for 10.0% of total industrial solid waste generation which makes it 2nd biggest solid waste producer (TSI, 2008c). Based on hazardous waste generation quantity, food/drink industry is on 4th rank with a figure of 51.9 thousand tons/year (TSI, 2008d).

Since food/drink industry holds a water intensive and polluting character in Turkey, it was referred to in various policy and strategy documents to be treated as a priority sector for environmental protection (MOEF, 2010; IDA, 2012; Ulutas et al., 2012). The Ministry of Science Industry and Technology (MOSIT) underlined that steps are to be taken in the short-term to conserve natural resources and encourage waste recycling in the activities associated with the food/drink industry (MOSIT, 2013). Moreover, The Scientific and Technological Research Council of Turkey determined one of its targets as “protecting the environment by converting food/drink industry wastes into high added-value products” within the scope of “National R&D and Innovation Strategy: Food/Drink Sector” (TUBITAK, 2010).

In order to decrease water intensity and related environmental impacts as well as high costs associated with water and wastewater management in food/drink industry various water recycling and reuse techniques/technologies were implemented. According to Haroon et al. (2013) wastewater of soft drink/beverage industry can be reused in bottle washing and as boiler make-up water after treatment through a combination of reverse osmosis and ion-exchange systems. Another water treatment technology which is gaining much interest is ozonation. Owing to its powerful oxidizing and disinfection properties, ozonation is becoming more popular in food/drink industry for treatment and consecutive recovery of wastewaters (Norton et al., 2012). In a mandarin orange canning company, a water reclamation system composed of chlorination, filtration by active carbon and UV-sterilization was installed. The treated water is reused for segmenting, transportation and washing of fruits which led to substantial water saving in the company (Wu and Chu, 2013). In a non-alcoholic drink producer plant on the other hand, water pinch analysis was conducted after a water audit to identify water reuse opportunities. As a result of analyses recycling options were realized and this led to water saving of 83.2 m^3/day (Agana et al., 2013). According to Lozano et al. (2013) a chemical leasing study resulted in the elimination of water use in the lubrication process of a beverage company and the total water consumption of the company was reduced by 1500 m^3 annually. Cook et al. (2014) advocates that 37% of the non-potable demand can be satisfied by harvested rainwater in commercial buildings.

This study is expected to contribute to the efforts devoted to the sustainable exploitation of scarce resources particularly water sources which are under considerable risk due to climate change effects in Turkey (Alkaya and Demirer, 2015). The aim of this study was to investigate water conservation and reuse opportunities in a soft drink/beverage manufacturing company which relies on intensive water consumption in its production processes. For this purpose a walk-through audit was followed by analysis and benchmarking of water consumption of the company with the literature in order to determine processes/practices where significant improvement potential is present. After the diagnosis, the closed-loop water recycling systems and the practice of water reuse for fruit washing were introduced to save water and associated costs in the company. This study is expected to be a model for food/drink industry as well as other manufacturing industries for sustainable industrial water management.

2. Methodology

2.1. General information and production processes of the company

The company was established in 1969 in Kayseri, Turkey. It operates on a covered area of 15,000 m^2 and employs 100–130 workers depending on the season. Located in Kayseri Organized Industrial Zone, it currently produces soft drinks/beverages (Nace code: C.11.0.7 – Manufacture of soft drinks; production of mineral waters and other bottled waters). Major products of the company can be listed as: (i) 100% fruit juice (no additives), (ii) fruit nectar (25–50% fruit juice) and (iii) fruit drink (3–30% fruit juice). The company holds several quality and management certificates including “ISO 9001:2000 – Quality Management System Certificate”, “ISO 22000 – Food Safety Management System Certificate” and “BRC – Certificate for Food Safety”. Annual fruit juice production capacity of the company is 50,000 m^3/year.

Although production procedures/practices of the company change according to type of fruit to be processed and the products to be manufactured, a general process flow diagram could be developed as presented in Fig. 1. In the company, fruits are processed into soft drinks/beverages through two consecutive processing lines: fruit concentrate production and fruit juice production.

In 2008 and 2009 the company processed 14,658 and 10,888 tons of fruits, respectively. In 2009, processed major fruit type was apple with 4834 tons/year production. Grape, sour cherry and plum were other major types among 13 different types of fruits. The annual total soft drink/beverage production of the company was recorded as 36,009 and 38,761 m^3 for 2009 and 2010, respectively (no product information was provided by the company for the year 2008). In 2010, fruit nectars were the primary products of the company in terms of total production amount which was recorded as 30,795 m^3/year. Carbonated drinks (soft drinks with carbon dioxide) and 100% fruit juice drinks were other major products with 4335 and 2218 m^3/year manufactured amounts respectively. Remaining products are fruit juices with varying fruit contents including 50% fruit juice.

The fruits are first conveyed from storage to sorting/grading unit. The fruits are sorted before being further processed in order to assure that fresh, mature and unspoiled fruits are to be used. In this step fruits that do not meet the required standards are rejected. After sorting, fruits are washed where debris and dirt are removed. Then, the washed fruits are crushed in special mills which creates a type of fruit pulp puree. Crushing is followed by pressing for extracting the juice from the fruit pulps. This is the major solid waste generating operation in the company since spent pulps are rejected at this point. Extracted juice is concentrated in the evaporation step where water is drawn out. Before being sorted as the intermediate product, the concentrated juice is sterilized and filled into barrels through the aseptic process.

Concentrated juice is first fed to the dilution unit (water addition) in the fruit juice production line. Then, the diluted juice is filtered for clarification. After clarification, pasteurization process takes place where juice is subjected to heat. During this process

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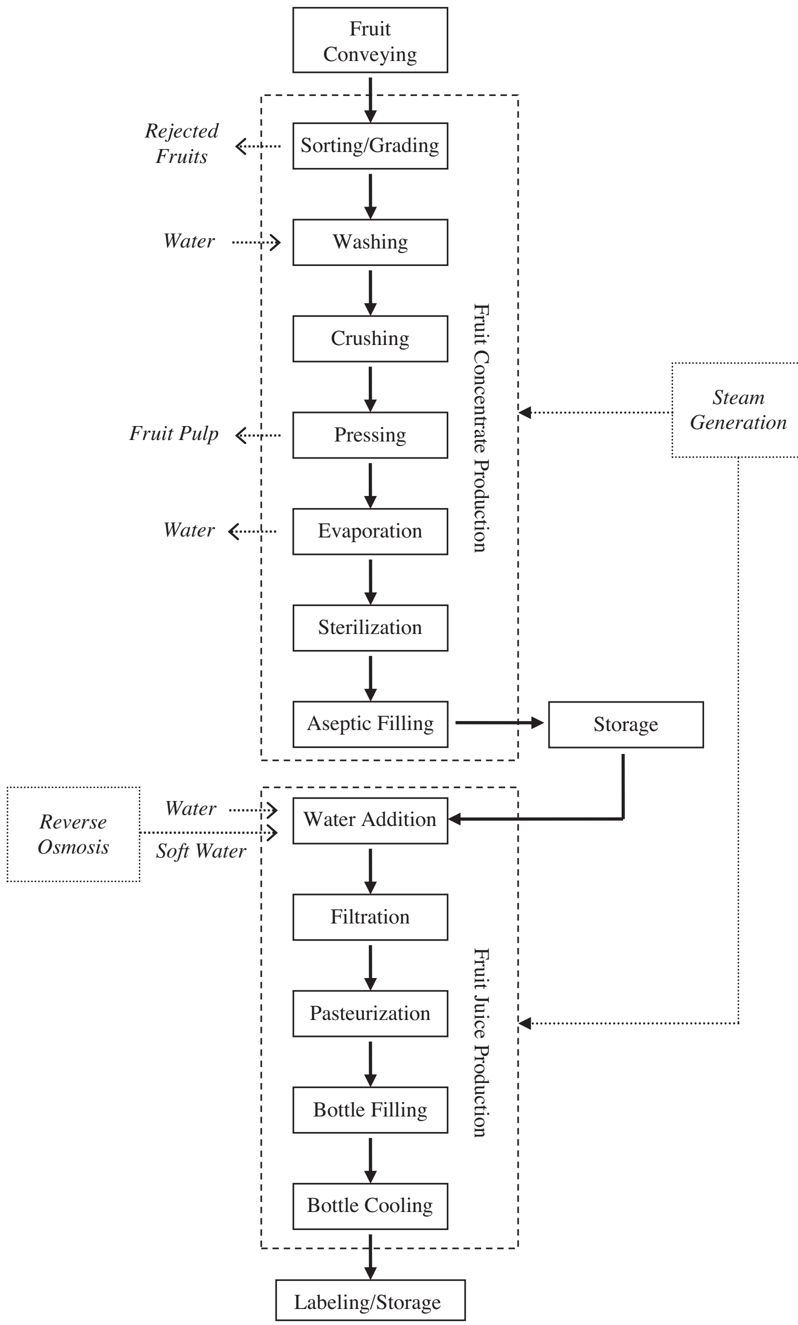

Fig. 1. Process flow diagram of the company.

juice is kept at 100 ± 2 °C for 30 s. Hot fruit juice is cooled during and after bottle filling. Eventually bottled products are labeled and stored before shipment.

2.2. Data collection and water use evaluation/benchmarking

A walk-through audit was carried out together with company officials in order to develop the process flow diagram by getting information on inputs and outputs of major processes (Fig. 1). After the walk-through audit, process-based numerical data were gathered about water consumption in the company. Since the objective of the study was to decrease water consumption and related wastewater generation, only the water consuming processes/practices were investigated in the company. Then, monthly water consumption figures were compiled from different sources provided by the staff of the company. For this purpose, information sources like process-based record sheets as well as water bills were analyzed.

In order to ensure a dependable baseline before water saving applications, the monthly water consumption data was averaged for 2009. Then, the average monthly water consumption in 2009 was regarded as the baseline situation throughout the study for comparison purposes. As part of the analyses, water use evaluation/benchmarking was carried out by using Environmental Performance Indicators (EPIs) (Alkaya and Demirer, 2013a) which are specific water consumption and wastewater generation data collected from relevant literature.

As described by the International Organization for Standardization (ISO) "environmental performance evaluation is a process to facilitate management decisions regarding an organization's environmental performance by selecting indicators, collecting and analyzing data and assessing information against environmental performance criteria" (Dias-Sardinha and Reijnders, 2001). Thus, in order to identify the processes/practices which need to be improved in manufacturing enterprises environmental performance evaluation methodologies are being developed and widely used in various sectors (Jiang et al., 2012). According to Thoresen (1999) EPIs can be used by industrial enterprises to control performance of processes and set goals as well as benchmark with competitors' performance. In this study, water performance EPI was calculated by dividing water consumption data by 1 ton of manufactured product. Then, specific water consumption data (m^3/m^3 product) was used for evaluation/benchmarking of water consumption. In other words, the water intensive processes/practices were comparatively evaluated with environmentally friendly alternatives referred to in the literature including Best Available Techniques – BATs (European Commission, 2001, 2006).

Based on the water use evaluation/benchmarking, processes/practices which need to be improved in terms of water consumption and wastewater generation were determined. Moreover, four objectives were set for improving water efficiency and decreasing production costs associated with determined processes/practices (Table 1). To achieve these objectives, 17 different techniques/measures were developed.

Among the techniques/measures listed in Table 1, based on evaluations carried out together with company officials two practices were applied in 2010 to decrease water consumption and associated wastewater generation:

- Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines.
- Reuse cooling water blow-down in fruit washing process.

The implementation of proposed techniques/measures were finalized in June 2010 (6th month) after an implementation period of 90 days. Monitoring of the results of water saving techniques/measures lasted 9 months.

The study was carried out within the framework of "National Eco-efficiency (Cleaner Production) Programme" which was coordinated by United Nations Industrial Development Organisation (UNIDO) and implemented by Technology Development Foundation of Turkey (TTGV). The technical consultancy was provided by the Middle East Technical University. The program was implemented as a sub-program of the United Nations Joint Programme "MDG-F 1680: Enhancing the Capacity of Turkey to Adapt to Climate Change" (Alkaya and Demirer, 2013a, 2013b). More information about the "National Eco-efficiency (Cleaner Production) Programme" can be retrieved from its web page (http://www.ecoefficiency-tr.org/).

3. Results and discussions

3.1. Water use evaluation/benchmarking

The company is the single most water consuming plant within the Kayseri Organized Industrial Zone by consuming 70,959 m^3/month of water. There are five major areas where water is used extensively: (i) cooling, (ii) bottle preparation/filling, (iii) facility cleaning, (iv) utility operations and (v) fruit washing (Fig. 2). Apart from these water intensive areas, water is either consumed or lost during other activities including domestic use and transmission between processes. Groundwater is the major water source of the company. It is used in all processes except bottle preparation/filling where mains water is used either unprocessed or after softened by reverse osmosis (RO) system. Groundwater is withdrawn from two wells of the company by four pumps with 30 kW electrical powers each. Since company processes fresh fruits picked up in summer periods operational activities of the company increase during summer and autumn (6 months between June and November). In this period water consumption is also increased.

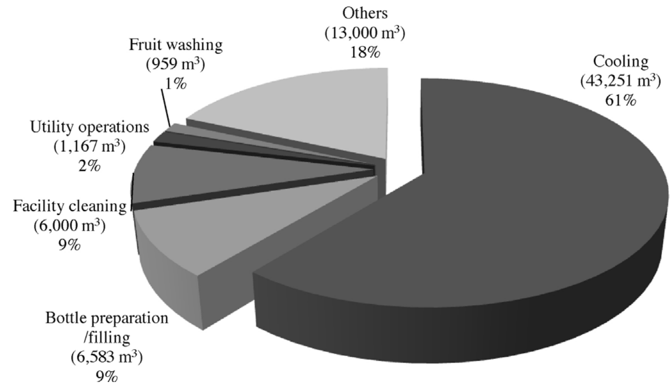

Fig. 2. Breakdown of water consumption in production processes as the baseline situation.

As demonstrated in Fig. 2, cooling is the largest water consuming activity with 43,251 m^3/month water demand. In other words, 61.0% of total water consumption is recorded for cooling purposes only. Cooling water is used in both fruit concentrate production and fruit juice production lines as once-through practice which relies on single use of water and discharge without any reuse or recycle. According to the calculations, 18.3% of total water consumption could not be attributed to any specific process and regarded as the domestic use and unaccounted losses (e.g. evaporation, leaks) by company officials. In Fig. 2, "utility operations" includes boilers and water softening while "others" includes domestic use, unaccounted losses during transmission, evaporation, etc.

In Table 2, water consumption breakdown of the company in comparison with the related literature was presented. According to the literature, in soft drink production, the major water consuming processes are washing/cleaning (25.0–55.0%) and bottle filling (23.0–60.0%). On the other hand, cooling practices are only responsible for 2.0–8.1% of total water consumption (ETBPP, 1998; Pagan et al., 2004; Geçer, 2007). However, in this company, cooling is the highest water consuming activity with a share of 61.0% while washing/cleaning and bottle filling account for 9.8 and 9.3% of total water consumption, respectively. This initial analysis indicates that cooling water consumption of the company is significantly higher than the reported values in the literature. Besides cooling water, percent sum (18.3%) of other uses (e.g. domestic use) and unaccounted losses are also considerably higher than the reported values in the literature (3.7–13.0%). In addition to the benchmarking of water consumption breakdown of the company, the specific water consumption was comparatively evaluated by referring to the literature (Table 3). According to the literature it is possible to produce 1 m^3 of soft drink/beverage by consuming 2.3–6.5 m^3 of water. However, in this study specific water consumption of the company was calculated as 23.6 m^3/m^3 product. Based on this evaluation it can be claimed that between 72.5 and 90.2% of water saving potential is present in the company. This huge water saving potential is mainly due to excessive cooling water consumption and unaccounted losses as compared to the literature as discussed previously in this paragraph and Table 2.

3.2. Recycle and reuse of cooling water

Based on water use evaluation/benchmarking, it was determined that cooling water consumption should be reduced in order to decrease overall water intensity of the company. It is stated

Table 1
Developed techniques/measures.

Objectives	Techniques/measures to achieve the objectives
Reducing, recycling and reusing cooling water	1. Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines (Casani and Knøchel, 2002; European Commission, 2006; WRAP, 2013a). 2. Recycle bottle rinsing water to be used as cooling water (Envirowise, 2002). 3. Separate spent cooling water from waste water streams (IFC, 2007). 4. Reuse cooling water blow-down in other processes including fruit washing and facility cleaning (Envirowise, 2002; European Commission, 2001; NCDENR, 2009).
Reducing, recycling and reusing washing/cleaning water	5. Segregate, treat and reuse wastewaters originating from filter cleaning operations through membrane processes (Oktay et al., 2007). 6. Recycle bottle rinsing water to be used as cleaning water (Casani and Knøchel, 2002). 7. Introduce automatic shut-off valves for water taps (IFC, 2007). 8. Introduce auto-cut off nozzles for the hoses used in facility cleaning (European Commission, 2006; Pagan and Prasad, 2007). 9. Prevent water losses from hoses left turned on during non-production times (AFGC, 2006; Envirowise, 2002). 10. Install high-pressure and low-volume jet/spray cleaning systems equipped with optimized nozzles (Envirowise, 2002; IFC, 2007; NCDENR, 2009).
Reducing unaccounted water losses	11. Introduce regular maintenance programs for water transmission systems to check damages and prevent leaks (Envirowise, 2002; European Commission, 2006; WRAP, 2013a).
Introducing water recycling and reuse between other processes	12. Treat wastewater through a combination of reverse osmosis and ion-exchange systems to be used for washing/cleaning purposes (European Commission, 2006; Haroon et al., 2013). 13. Recycle and reuse bottle cleaning overflows after sedimentation and filtration (European Commission, 2006). 14. Recycle and reuse final rinses from tank cleaning operations (NCDENR, 2009). 15. Reincorporate product condensate into food product or reuse in other processes except disinfection purposes (Casani and Knøchel, 2002). 16. Reuse condensate water as the boiler make-up (IFC, 2007). 17. Install chlorination system for treatment and recycle of transport/flume water (NCDENR, 2009).

Table 2
Benchmarking of water consumption breakdown of the company.

Processes	This Study (%)	ETBPP (1998) (%)	Geçer (2007) (%)	Pagan et al. (2004) (%)	Seneviratne (2007) (%)
Cooling	61.0	2.0	8.1	2.0	4.0
Washing/cleaning	9.8	55.0	36.1	25.0	54.0[a]
Bottle filling (in product)	9.3	23.0	35.1	60.0	27.0
Utility operations[b]	1.6	7.0	17.0	8.0	11.0
Others[c]	18.3	13.0	3.7	5.0	4.0
Total	100.0	100.0	100.0	100.0	100.0

[a] Includes equipment preparation.
[b] Includes boilers and water softening.
[c] Includes domestic use, unaccounted losses, etc.

Table 3
Benchmarking of specific water consumption of the company.

Specific water consumption (m^3/m^3 product)	Reference
1.5	AFGC (2006)
1.5–4.5	UNIDO (2014)
1.95[a]	FHC (2012)
2.29[a]	WRAP (2013b)
2.3	Binnie and Partners (1987)
2.3–6.1	ETBPP (1998)
2.5–3.5	Ait Hsine and Benhammou (2005)
3.0–4.0	Haroon et al. (2013)
3.5	Gumbo et al. (2003)
4.5	UNEP (2010)
6.5	IFC (2007)
3.3 ± 1.4	Average of the above references
23.6 ± 2.1	This Study

[a] Excluding that in product.

in various studies that once-through cooling practice should be replaced by closed-circuit cooling in soft drink/beverage industry (Casani and Knøchel, 2002; European Commission, 2006; WRAP, 2013a). According to European Commission (2006), up to 80% of water can be saved by eliminating once-through cooling practice and introducing closed-circuit cooling. Moreover, cooling water blow-down can be reused in other processes including fruit washing and facility cleaning (European Commission, 2001; Envirowise, 2002; NCDENR, 2009). Therefore, once-through cooling systems both in fruit concentrate and fruit juice production units were replaced in the company by separate closed-circuit cooling systems (Fig. 3). Each closed-circuit cooling system composed of a cooling tower, stainless steel water pumps, stainless steel pipes/fittings, variable speed drivers (inverters) and a control panel. Technical specifications of the implemented systems are provided in Table 4.

Fig. 4 shows the monthly specific water consumption of the company before and after the applications. It covers the period between January 2009 (1st month) and March 2011 (27th month). It is observed from the figure that specific cooling water consumption of the company increases during June–November 2009 (6th–11th month) and reaches 26.3 m^3/m^3 product. This observation can be explained with the fact that fruit concentrate production line of the company operates seasonally during June–November period when fruits are received. Thus, cooling water demand increases due to cooling needs of evaporation, sterilization and aseptic filling processes employed in fruit concentrate production line. Although fruit concentrate (intermediate product) is produced seasonally, fruit juice (final product) is produced all year long from the concentrate. In other words, monthly amount of product does not change considerably while water demand of the company increases during June-November period, which is reflected as an increase to specific

Table 4
Technical specifications of implemented cooling water recycle and reuse systems.

Components of the system	Technical specifications
Cooling towers	Tower casings are made of stainless steel sheets. Connections between casing components are sealed with silicone. Polyvinyl chloride (PVC) filing materials are used to enable maximum contact surface between the air and water. The drift eliminators are manufactured from PVC and designed in a way that minimizes the water carried out with air flow. The fans, motors and belts are protected from the surroundings with wire mesh and sheet casing. Inspection doors are mounted on both of the cooling towers, which enable tower maintenance and floater adjustment. Designed inlet and outlet temperatures of cooling waters are 50 and 28 °C respectively.
Water pumps (for pumping to the cooling tower)	Six mechanical centrifugal pumps made of American Iron and Steel Institute (AISI) 304 grade stainless steel were installed. They are of a horizontal shaft monoblock type end suction pumps. By the help of these pumps cooling water (spent cooling water) is recirculated to the cooling tower. Electrical power of each pump is 7.5 kW while pumping capacity is 30–70 m^3/h. Working head of the pumps are 20–30 m and maximum allowable working pressures are 8 bars.
Water pumps (for pumping from the cooling tower)	Six mechanical centrifugal pumps made of AISI 304 grade stainless steel were installed. They are of a horizontal shaft monoblock type end suction pumps. By the help of these pumps cooling water (spent cooling water) is recirculated to the cooling tower. Electrical power of each pump is 3 kW while pumping capacity is 10–40 m^3/h. Working head of the pumps are 15–25 m and maximum allowable working pressures are 8 bars.
Pipes and fittings	AISI 304 stainless steel water pipes and connectors were installed for water transmission between cooling tower and process units.
Variable speed drivers (inverters)	Each pump is supplemented by an inverter for their speed control. Maximum applicable motor outputs of inverters are 7.5 kW.
Control panels	The installed control panels are in compliance with the standards set by Turkish Standards Institute (TSE). Panels are suitable for 3–7 kW pumps.

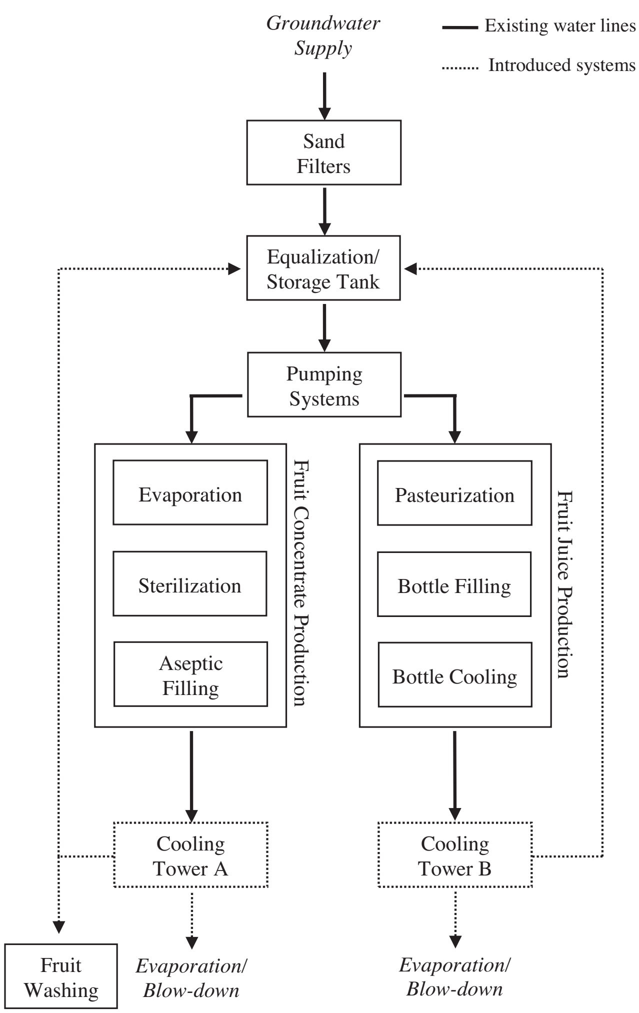

Fig. 3. Recycle and reuse scheme of cooling water after applications.

cooling water consumption of the company. Before applications average cooling water consumption of the company was calculated as 14.4 m^3/m^3. After implementation of cooling water recycle and reuse systems, the total cooling water consumption of the company was decreased by 91.8% and became 1.2 m^3/m^3 product. In addition to this application a part of cooling water blow-down (959 m^3/month) is reused in fruit washing process which decreased fresh water withdrawal in washing/cleaning operations. During the same period water consumption in facility cleaning, utility operations, bottle preparation/filling, fruit washing and other processes did not change considerably. Owing to the decrease in cooling water consumption, the total specific water consumption of the company was decreased from 23.6 to 10.6 m^3/m^3 product a percent decrease of 55.0%.

European Commission (2006) advocates that discharge of spent once-through cooling waters causes dilution and increase energy consumption in wastewater treatment plants thus should be avoided. Before applications, seasonal increase in total water consumption of the company due to increased cooling water demand was creating a hydraulic overload in wastewater treatment plant of the Kayseri organized industrial zone since the company was the major wastewater producer of the zone with 67.411 m^3/month of discharge. After applications specific wastewater generation of the company was reduced by 57.4% and hydraulic overload issues in wastewater treatment plant were resolved.

Major motivation of the company managers for taking part in this study was to secure economic benefits in addition to conservation of water resources. Since companies are not charged for groundwater use in Turkey, cost saving in the company was due to the reduced wastewater disposal cost which is paid to Kayseri organized industrial zone. The company is charged by 0.19 dollar per m^3 of wastewater. So, annual cost saving of the company was calculated as 97,003 $. During the implementation of water saving measures/techniques 56,960 $ was spent for the equipments. The equipments were partly financed by UNIDO as a grant of 28,609 $ while the remaining share (28,351 $) was invested by the company. The payback period of the implementations was approximately 7 months.

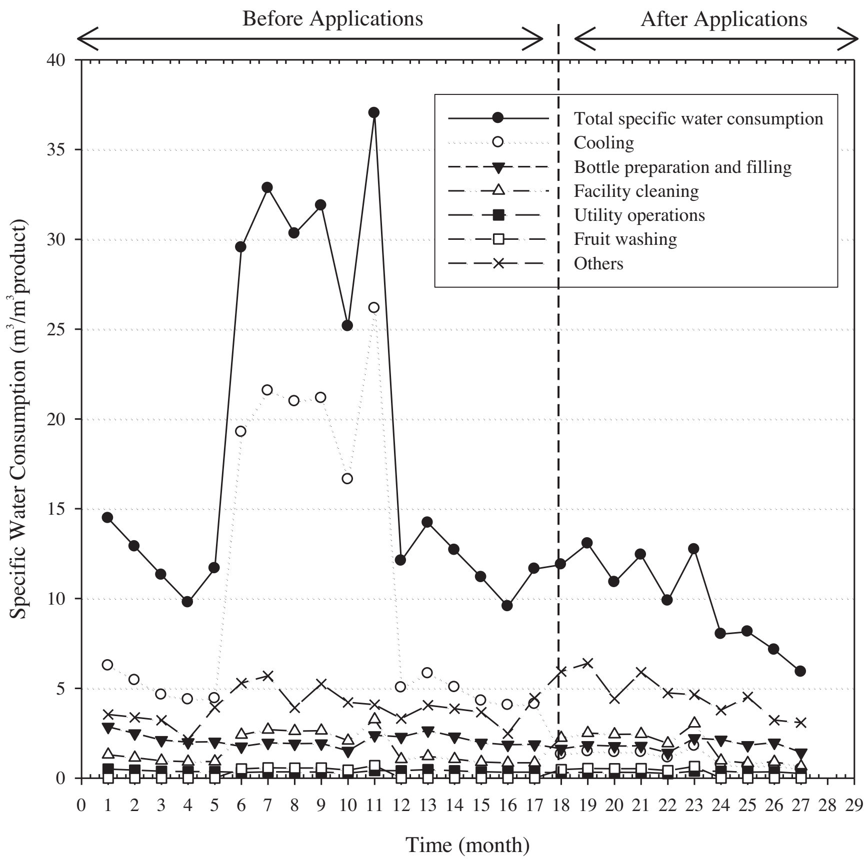

Fig. 4. Specific water consumption before and after applications.

Table 5
Summary of water consumption and wastewater generation of the company before and after applications.

Resources/wastes	Specific consumption/emission values		
	Before applications	After applications	Change (%)
Water consumption (m^3/m^3 product)			
Cooling water: fruit concentrate production	9.6	0.5	−95.2
Cooling water: fruit juice production	4.8	0.7	−85.2
Total cooling water consumption	14.4	1.2	−91.8
Total water consumption	23.6	10.6	−55.0
Wastewater generation (m^3/m^3 product)			
Total wastewater generation	22.5	9.6	−57.4

4. Conclusions

The major objective of this study was to investigate measures/techniques that can substantially reduce water intensity of a manufacturing company in soft drink/beverage industry which rely on continuous supply of high quality water resources. Water use evaluation/benchmarking was carried out, in order to determine areas/processes where significant water saving potential is present. Based on the evaluations, cooling water is targeted in the company for decreasing overall water demand. Below listed applications were realized in the company.

- Replace once-through cooling with closed-circuit cooling system in fruit concentrate and fruit juice production lines.
- Reuse cooling water blow-down in fruit washing process.

As a result of the applications specific cooling water consumption was reduced by 95.2% in fruit concentrate production line from 9.6 to 0.5 m^3/m^3 product (Table 5). Moreover specific cooling water consumption was reduced from 4.8 to 0.7 m^3/m^3 product which corresponds to a decrease of 85.2%. Therefore, the total cooling water demand of the company was reduced by 91.8%. Recycle and reuse of spent cooling water enabled the company to conserve 55.0% of total water consumption. Thus, the total annual water saving was calculated to be 503,893 m^3 by multiplying specific total water saving (13.0 m^3/m^3 product) with annual production of 38,761 m^3 product. After applications specific wastewater generation of the company was reduced by 57.4% and hydraulic overload issues in wastewater treatment plant of Kayseri organized industrial zone were resolved. During the implementation of water saving measures/techniques 56,960 $ was spent for the equipments while annual cost saving of the company was realized as 97,003 $. So the payback period of the implementations was approximately 7 months.

Cakmak et al. (2007) states that measures should be taken for widespread uptake of effective and sustainable water resource utilization practices. According to “National R&D and Innovation Strategy for Water” prepared by The Scientific and Technological Research Council of Turkey prevention of water pollution, sustainable utilization of water resources and increased water recycling are among major objectives of Turkey government (TUBITAK, 2011). This study proved that water recycling and reuse can successfully be realized in soft drink/beverage industry as a sustainable industrial water management approach.

Water cooling is a very common practice in many sectors and is by far the largest (59.5% of total) water consuming activity within whole manufacturing industry in Turkey (TSI, 2010). If successfully replicated in other manufacturing sectors apart from soft drink/beverage sector, outcomes of this study can be a solution for excessive cooling water consumption in Turkey as well as other parts of the world where similar processes are employed.

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