Water Recycling / Reuse in Factories Case Study Soft Drink Factory

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ABSTRACT

The aim of the present work is to study water recycling and reuse in a soft drink Factory.

Water is an essential raw material in the soft drink productions with a consumption of 2.5 to 3.5 liter of water per liter of soft drink. The wastewater generated in this industry is mainly from bottle washing, filler backwashing, washing of bottle machines, equipments, floors and pipe work during flavor changing. The major contaminants in this effluent are caustic soda and sucrose

In order to reduce water consumption and volume of wastewater generated in the soft drink plant, Sulave private sector factory was chosen as a case study of the generated wastewater in the plant .The study was carried out between May till October 2010 for measuring and monitoring various pollutants of the generated wastewater in the plant.

Two strategies had been proposed, in the first wastewater out of bottle washing machine and washing columns could be recycled to the units if treated by: Filtration-Adsorption-Reverse Osmosis system, this proposal reduced water consumption in the factory by about 35% and decreased wastewater effluents by 65% of total wastewater effluents. The second strategy was to reuse water out of the bottle washing machine after treating it by: Filtration-Adsorption system to be used in the washing column .The water consumption in this strategy was reduced by about 15% with a reduction of 35% in wastewater effluents

Keywords: Water recycling, Reuse, Soft drink factory.

اعادة تدوير المياة الصناعية المستخدمة في المعامل الكيمياوية (معامل المشروبات الغازية كمثال)

الخلاصة

الهدف من هذا العمل هو دراسة إعادة تدوير المياه وإعادة استخدامها في مصنع المشروبات الغازية. الماء هو المادة الخام الأساسية في إنتاج المشروبات الغازية مع استهلاك 2.5 حتي 3.5 لتر من الماء لكل لتر من المشروبات الغازية.

مصدر المياه الصناعية الملوثة في معامل المشروبات الغازية ينتج عن غسالة القناني الزجاجية وكذلك من غسل المعدات وعلى وجه الخصوص عند تبديل النكهات وابرز الملوثات في المياه الناتجة تكون الصودا الكاويه والسكروز. تم اختيار مصنع سولاف لانتاج المشروبات الغازية لدراسة

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امكانية اعادة تدوير او استخدام المياه الناتجة لتقليل الهدر. الدراسة اجريت للفترة مابين ايار ولغاية تشرين الاول عام 2010. حيث تم دراسة كمية المياه المستهلكة في الوحدات المختلفة بالمصنع وكمية ونوع الملوثات الناتجة من هذه الوحدات. تم تقديم مقترحين المقترح الاول قلل استهلاك المياه بحدود 35% وخفض كمية المياه الصناعية الناتجة الى 65% وذلك بامرار المياه الملوثة على المرشحات الرملية, اعمدة الامتزاز بالفحم, والتناضح العكسي. المقترح الثاني يتم بامرار المياه الصناعية على المرشحات الرملية واعمدة الامتزاز بالفحم فقط وبذلك يتم تقليل استهلاك المياه الى 15% وتنخفض كمية المياه الصناعية الملوثة بمقدار 35% تقريبا.

INTRODUCTION

Soft drink industry forms a large part of the food and beverage industry. Thus it is important to study the nature and amount of wastewater generated by the soft drink plants. The production of soft drinks in Iraq expanded rapidly since 1996, before that time soft drink productions were prohibited as a result to blockade. After 2003 the production increased, although there are different kinds of soft drinks imported from Iraq neighborhood countries.

Water is an essential raw material in the soft drink production with a consumption of 2.5 to 3.5 liter of water per liter of soft drink. The wastewater generated in this industry is mainly from bottle washing, filler backwashing, washing of bottle machine, equipments, floors and pipe work during flavor changing. The major contaminants in this effluent are caustic soda and sucrose [1].

Wastewater from bottle washing is almost 50% of the total waste water generated, which is about 1.25 liter of wastewater per 1 liter of soft drink, bottle washing is performed by washing machines that operate in different cycles [1].

Wastewater reuse is an essential factor in water resources management in industrial activities and development .The high water consumption and demand exceed the local resources, resulting sub regional deficit. The soft drink industry produces constitute of different effluents, therefore reuse or internal recycle should be seriously considered when planning water supply and resource managements [2].

In order to reduce water consumption and volume of wastewater in soft drink plants, the sources of wastewater uses should be identified then, measuring and monitoring the various pollutants in the wastewater are to be performed. Many researchers have worked in this field among them:

Camperos, et al. studied treatment systems like: filtration-adsorption-reverse osmosis and filtration-adsorption-ion exchange for wastewater treatment. The installation of these treatment techniques in the soft drink industry would decrease bottle washing water consumption by 50% [1]. Visvanathan , C. and. Hufemia, A. worked on a microfiltration-reverse osmosis system that purified the rinse water for reuse in the bottle washing process, thereby reducing raw water consumption by 58% and the liquid discharge by 81.5%. On the other hand, They used a dual filter media-ion exchange system which reduced raw water input by 57% and the liquid discharge by 80.5% [2]. Miyaki, H. et la studied a water recycling system, where a floating media filtration and nanofiltration (NF) was developed and implemented for the reuse of the water at a soft drink factory. The NF was applied as a mean for removing soluble organics .This treatment system was of 33 m^3/hr in capacity and 85%in water recovery [3].

Case Studies

To attaine the study, the Sulave, a private sector soft drink plant in south of Baghdad was chosen as a case study. The plant produces 10000 boxes of glass returnable bottle per day, 7500 PET (polyethylene terephthalate bottles) family size and carbon dioxide production with 8000 kg per hour.

The study was carried out between May till October 2010 as the soft drink plants are seasonal industries and water consumption in this period is at the maximum levels.

The general soft drink process may be described as: a simple syrup is produced by dissolving refined sugar in treated water. Then it is pasteurized at 85^0C filtered, and cooled, the final syrup is prepared by mixing it with soft drink concentrate at definite proportions. The final solution is refrigerated then carbonated by carbon dioxide gas, transferred to clean bottles at definite volumes and then refrigerated. Finally the containers are capped or sealed and then packaged for distribution [2].

Carbon dioxide is the smallest constituent by weight but is usually the largest by volume, it provides the characteristic sparkle to all carbonated soft drinks Carbon dioxide is produced by burning kerosene, which is burned in a boiler to produce steam. The flue gases containing 10 -18 % CO_2 leave the boiler and passes through the packed tower where they are cooled and cleaned by water. In the absorption tower, monoethanolamin (MEA) solution absorbs CO_2 by countercurrent flows, other gases are forced out of the absorption tower (mainly nitrogen and oxygen), then MEA solution and CO_2 are passed into a stripping column. Steam strips CO_2 in the column and enter cooler steam condensed and return to the tower, carbon dioxide then go through a purification unit then compressed and cooled to be liquefied then stored in a storage tank [4].

One of the most important processes in the soft drink production is bottle washing. The high quality of the product depends largely on how thoroughly the bottles are cleaned immediately before filling. The bottling process starts with the passing of the returnable bottles through a wash and rinse sequence. Then, the cleaned bottles are carefully inspected before they go automatically through consecutive steps of filling, crowning, mixing, labeling, packaging and shipping [3,5].

To produce soft drink, water needed in the boilers and bottle washers use purified water from local municipal water treatment plants.

The plant may be equipped with water treatment systems to meet operation requirements. Tap water stored in storage tanks, is pumped to main treating units which consists of sand filters, activated carbon columns and softeners, then the treated water is stored in storage tanks. This water is consumed in the different units such as bottles washing machines, carbon dioxide washing column, boilers and cooling water,………. etc. Water used in juice preparation goes through further purification processes.

The treating process of the juice water consists of: addition of lime, coagulation, and chlorination followed by filtration through a sand filter and an activated carbon filter finally stored in storage tanks.

The average consumption of water in the different units in the plant is shown in Fig. 1.

Table 1 shows the main characteristics of the process water used in the plant (except that used in juice preparation).

From Fig. 1 it is clear that the bottle washing machine, juice preparation and gas washing column consume about 75% of the total water in the plant.

The consumption of water in the bottle washing units reach 16 m^3/ day for washing and rinsing processes. A steady stream of fresh soft water is supplied for final rinsing. A part of the final rinse is reused as pre-rinse in each bottle wash. The final rinse and the pre-rinse effluent are discharged to the wastewater treatment plant. Therefore the wastewater generated in the plant is essentially from the bottle washing process.

Rates of Wastewater Generated in The Plant

Fig. 2 indicates the main streams of wastewater generated in the plant, which are gathered and directed to the waste water treatment. Table 2 shows the average characteristics of the effluents from the units in the plant through the period of the research, about twenty samples for each parameter was tested at different times of operation. Wastes from the bottle washer are highly alkaline in nature, since the washer consists of a series of alkaline baths. It also may contain large amounts of suspended solids resulting from straws, cigarettes butts, paper and other refuse left in the bottles [8].

The PET wastewater as shown in the table, is the minimum characteristics changes due to that rinse water washed the outside bottles normally had to be some how clean, flow rate of wastewater generated from PET rinse is low about (1 m^3/h).

Wastewater out from the washing column in the carbon dioxide plant appear to have high suspended solids with low pH .Suspended solids in water usually came from the packing material of the tower (Raschig ring or saddle ceramics) and rust due to high temperature inside the column. Soot some time is recognizes especially at start up operation or when the burner faults. Water is used for cooling the flue gases before they enter the absorber and also to clean them.

METHODOLOGY

To accomplish the study, the effluents from the bottle washing machine and from the gas scrubbing column (which present 45% of the total the wastewater) were treated in a pilot plant as shown in Fig 3a and 3b, which consisted of the following [9]:

1- **Filtration unit:** The unit consist of three columns (diam. 80mm) working in series, the first was filled with coarse sand (2- 0.8 mm) with height 250 mm .The second column was packed by 250 mm depth of fine sand (1.2 - .06 mm), and the third column packed with two layers, coarse sand 100 mm depth with (2- 0.08 mm in diam.) and 200 mm depth granulated mineral activated carbon .
2- **Ion exchange column:** Two columns working in series, the first one packed by a strong acid cat ion (macro porous purolite C1455) 250 mm in depth and the second was packed by a strong base anion (macro porous purolite A501 p) 250 mm depth.
3- **Reverse osmosis unit:** Is a Marlin Tm system, which includes replaceable filters, membrane elements and carbon post filter.

RESULTS AND DISCUSSION

The study deals with the management options of wastewaters generated from a soft drinks industry . The segregated wastewater streams are characterized to define possible reuse alternatives, and the pollution effluents subjected to various recovery and reuse practices evaluating their level of contamination. The reuse strategies cover a wide range of applications from reuse of wastewater treatment plant effluents to recover and reuse of certain segregated wastewater streams by employing different technologies.

In planning of wastewater reuse, the intended wastewater reuse applications govern the degree of wastewater treatment required and the reliability of wastewater treatment processing and operation, water can be reuse if it meet the water quality requirements for the intended use [6,7].

Bottle washing machine

From Table 2 the average characteristics of the wastewater generated from the washing machine, shows that turbidity represents the main drawbacks in the water and the presence of sodium ions. Grease and oil shown to be in low concentrations, also elements such calcium, magnesium, iron and manganese (iron and manganese ions in earlier experiments didn’t change significantly so in later experiments had been neglected) are in small concentrations in the water and basically appear in the influents before being used in the washing machine. Only sodium ions has the effective contribution to conductivity.

The wastewater from bottle washing machine gathered with PET rinse wastewater as the later is in small quantities were treated in the pilot plant at 40 l/hr in two routes , first the filtration-Adsorption unit then to Ion exchange .The second route was the filtration-Adsorption and then to Reverse Osmosis.

From Table 3-a the removal efficiency of the filtration –adsorption process was 60% turbidity, 80% TSS, 40% TS, about 30% electrical conductivity, and 20% COD.

Filtration- Adsorption –Reverse Osmosis: This treatment process is the most effective process which is recommended if it is required to recycle the rinse water from the washing machine, as shown in Table 3-b . The treated water from the pilot had good characteristics which could be reused in the bottle washing machine or in any other unit in the plant.

Filtration-Adsorption-Ion exchange: The treated water had medium concentrations of total solids and COD, and this means that the water cannot be recycled unless further treatmentis attended for the removal of the solids that may accumulate in the units of the factory.

Washing column

Filtration-Adsorption: From Table 4- a, the concentration of the suspended matter is high, so the height of the sand column should be increased to obtain higher recovery and to avoid clogging in the latter units (R.O or Ion Exchange).

Filtration- Adsorption –Reverse Osmosis: Table 4-b show that the average characteristics of the treated water are good and the water can be safely recycled to the column except temperature was relatively high (as shown in Table 2) and must be considered when using R .O to avoid membrane damages.

Filtration-Adsorption-Ion exchange: Calcium and Magnesium in the wastewater from the washing column are higher than of the washing machine due to water evaporation inside the column .The Ion Exchange column has the ability to remove such ions better than the R.O unit, but economically Ion Exchange is more costly than R.O due to the cost of chemicals.

CONCLUSIONS

Designing a scheme for reduce water consumption and wastewater generation for a specific plant often required a compromise among water quality, wastewater constituent, operating costs and capital equipment costs. The system introduced hereafter is being used in a soft drink bottling factory to minimize its use of tap water and to recover as much water as possible from wastewater, whose organic concentration is relatively low. The treatment flow at this factory has been worked out to match the requirement of water in the plant.

First Proposal Recycle Strategy

Fig. 4 shows the first proposal recycle strategy of water in the plant .It is proposed that waste water of the final rinse water from the washing machine and from PET rinse can be recycled to the washing machine after treatment in the Filtration- Adsorption -RO unit.

Water out of these units had a quality close to the water used. Only a small quantity of soft water required as make-up water (due to leakage evaporation and spillage) to accomplish the flow rate required, the over all water recovery in this unit is about 90 %.

To recycle water out of the washing column in CO_2 plant, cooling is needed first because the water temperature is relatively high about 55C ^{o}. Water should be at 25 to 3 ^{o} C where it could be safely treated in RO unit and could be recycled to the column for cooling flue gases. Water treated in the Filtration- Adsorption- RO unit as shown in Table 3-b, 4-b is of good quality compaired with the Filtration –Adsorption – Ion exchange unit that may have extra cost for regeneration of risen (hydrochloric acid and caustic soda). Make-up water added to the recycled water, may cause about 80% in water recovery.

In this proposed strategy the total water recovery is about 20 m^3 / h and water consumption in the plant may drop to 40 m^3/h that means a reduction of 35%, wastewater generated in the plant is reduced to 9-10 m^3/h rather than 30 m^3/h (65% reduction).

Second Proposed Strategy

Fig. 5 shows the second proposed strategy of water recycling, the water out of the washing machine and PET rinse was gathered and treated in the Filtration – Adsorption unit then reused in the washing column. Water out of the washing machine is alkaline in nature (presence of sodium ions) this gives a benefit in this strategy because alkaline reacts with the sulfur compounds in the flue gases, this will reduce the impurities of the final products of CO_2.

In this proposal wastewater is decreased to about 35% of total wastewater and water consumption may be reduced by 15%.

In the first strategy high concentrated pollutants may be obtained in the waste water stream and cost more expenditure on waste treatment before disposal to the nearby drainage system.
Table shows the investment cost and saving for suggest proposals from the table it is obvious that both suggest can reduce cost needed in the factory.

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Table (1) Average characteristics of the process water used in the plant

Parameter	Concentration Value
pH	7-8
Temperature C ^{o}	25-30
Turbidity NTU	1.0-1.2
Total dissolved solid mg/l	230-250
Total suspended solids mg/l	10-50
TS mg/l	400-420
Total hardness as $CaCO_3$ mg/l	20
Conductivity µms/cm	500
Cl mg/l	50
SO_4 mg/l	74
Na mg/l	58
Ca mg/l	42
Mg mg/l	23

Table (2) Average characteristics of wastewater generated in the plant

Characteristics	PET rinse	Washing machine	Washing column	Other uses
pH	7-8	8-10	5-6	4-5
Temperature C ^{o}	25	30-40	40-50	30
Turbidity NTU	1.4	4	6	10
Total Solids mg/l	35	500	740	1120
Total Suspended solids mg/l	16	120	240	260
Conductivity µms/cm	400	780	630	
COD mg/l	14	50	43	1100
BOD mg/l		175		720
Oil and grease mg/l				5.2
Na mg/l	50	146	150	
Ca mg/l	45		56	
Mg mg/l	28		34	
Cl mg/l	68			
SO4 mg/l	80		140	140

Table (3) Average water characteristics after treatment (water out of washing machine)

Characteristics	Filt.-Adsor. a	Filt.-Adsor.-R.O b	Filt.-Adsor-Ion Exch. c
pH	8.0	6.5	8.0
Turbidity NTU	2.4	1.0	1.2
TS mg/l	200	70	110
TSS mg/l	30	10	12
COD mg/l	30	10	10
Electrical conductivity µms/cm	500	5	110
Na mg/l	120	40	90

Table (4) Characteristics of the wastewater out of the washing column after treatment

Characteristics	Filt.-Adsor. a	Filt.- Adsor.-R.O b	Filt.- Adsor- Ion Exch. c
pH	7	6	7
Turbidity NTU	3.6	1.0	1.0
TS mg/l	360	80	70
TSS mg/l	50	40	40
COD mg/l	20	20	15

Table (5) Investment costs and saving of the suggested combination

Parameter	1st suggestion	2nd suggestion
	Wastewater regeneration and recycle (Reverse osmosis)	Waste water regeneration and reuse (sand &active carbon)
No. of units required	Two units .consist complete reverse osmosis units.	One unit consist sand filter, activated carbon
Investment cost (us. Dollar)	50000	6000
Cost of raw water (us dollar/m^3)	1	1
Cost of soft water (us dollar/m^3)	1.1	1.1
Cost of water recycle /reuse. (us dollar/m^3)	0.6	0.4
Saving (us dollar/m^3)	0.5	0.7

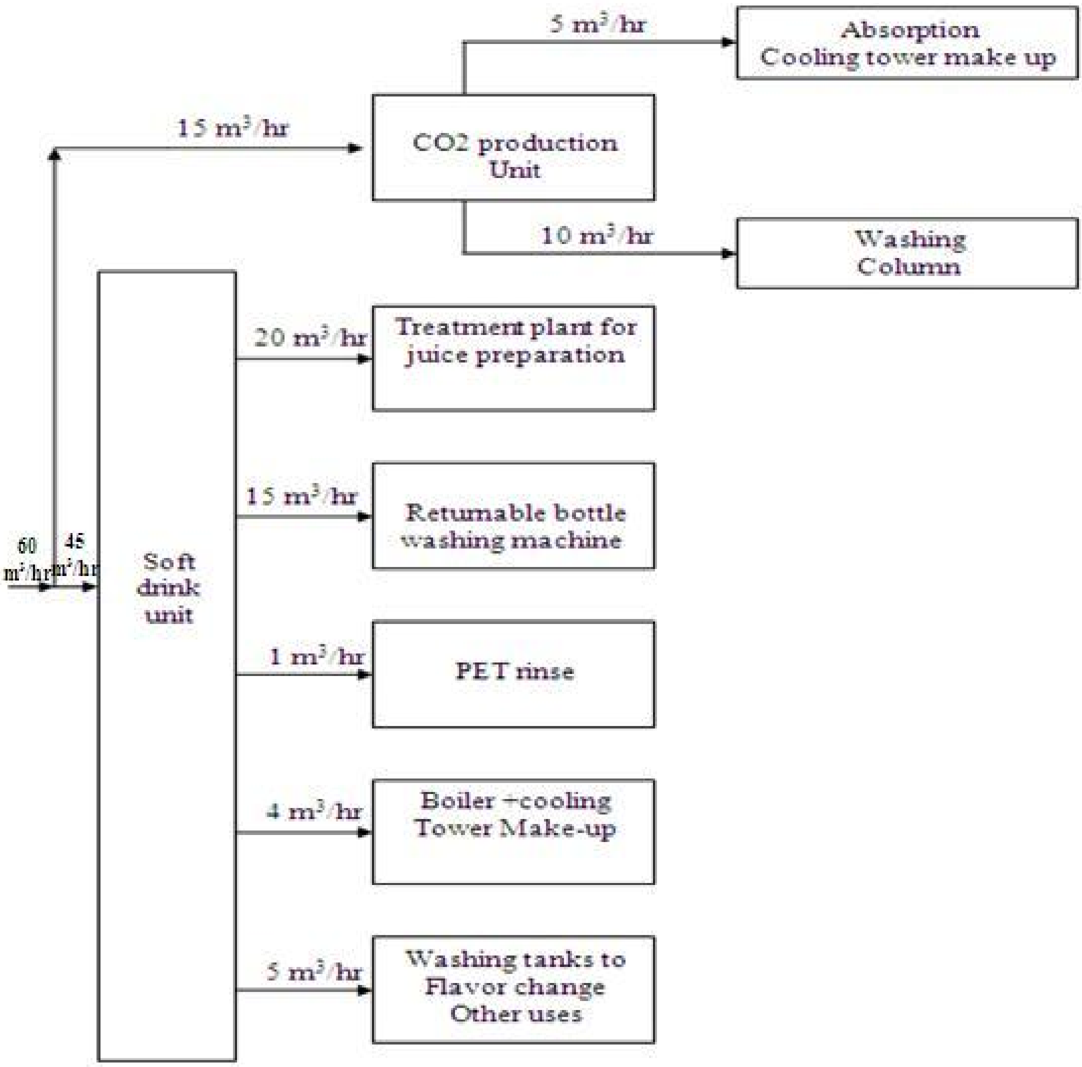

Fig . 1 Average water consumption in Sulave factory

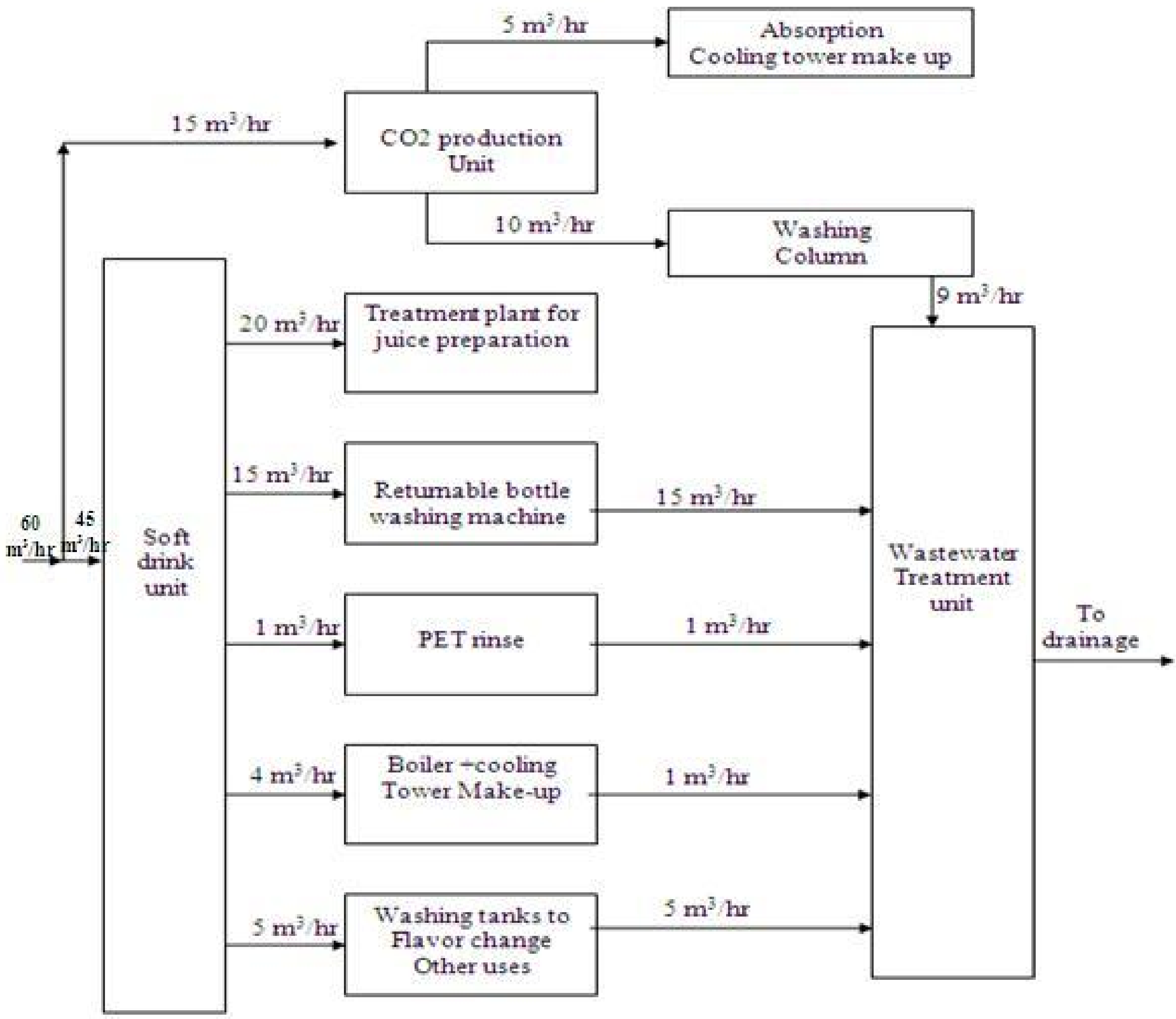

Fig . 2 The main streams of wastewater generated in Sulave factory

Figure (3) a Pilot plant schematic

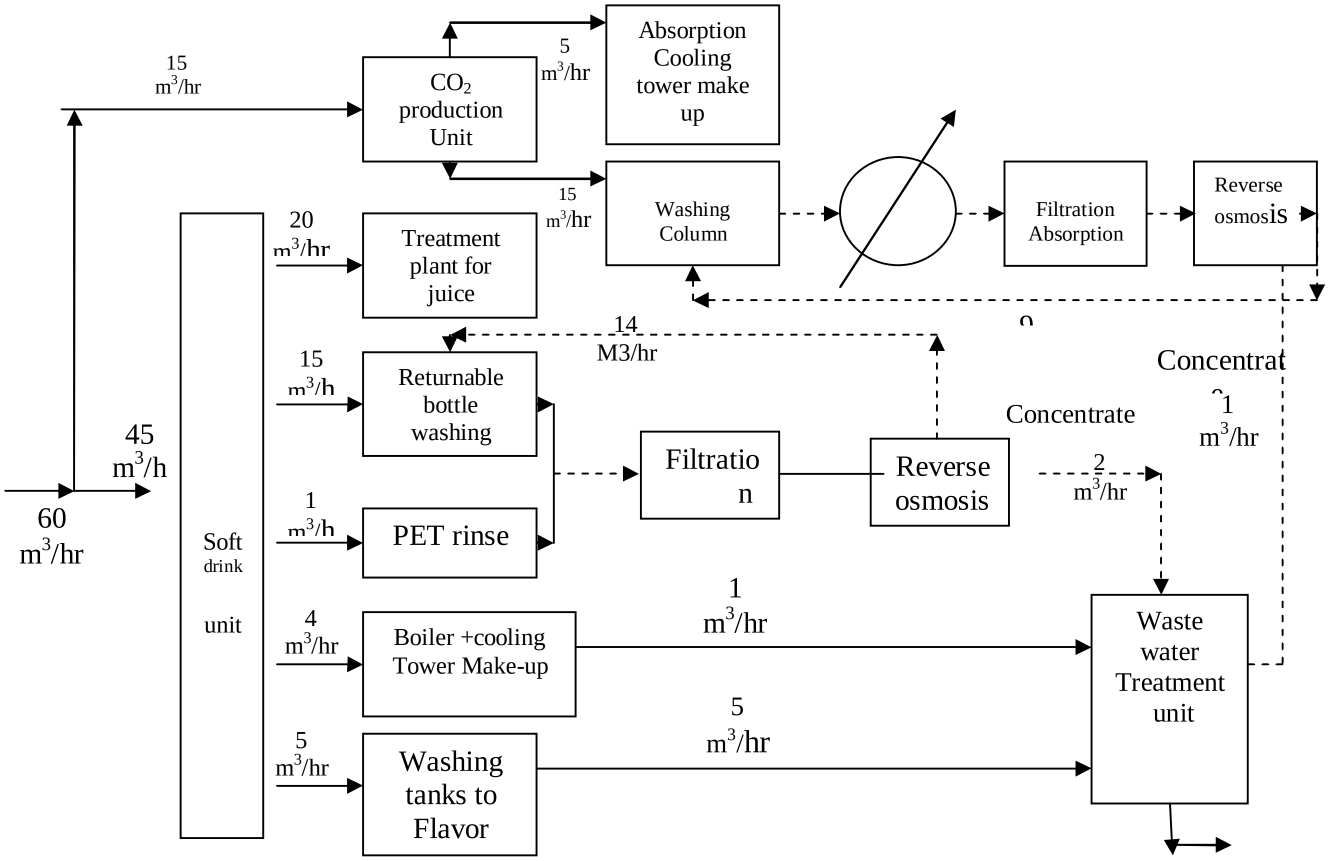

Figure (4) First suggestion for water management in the factory

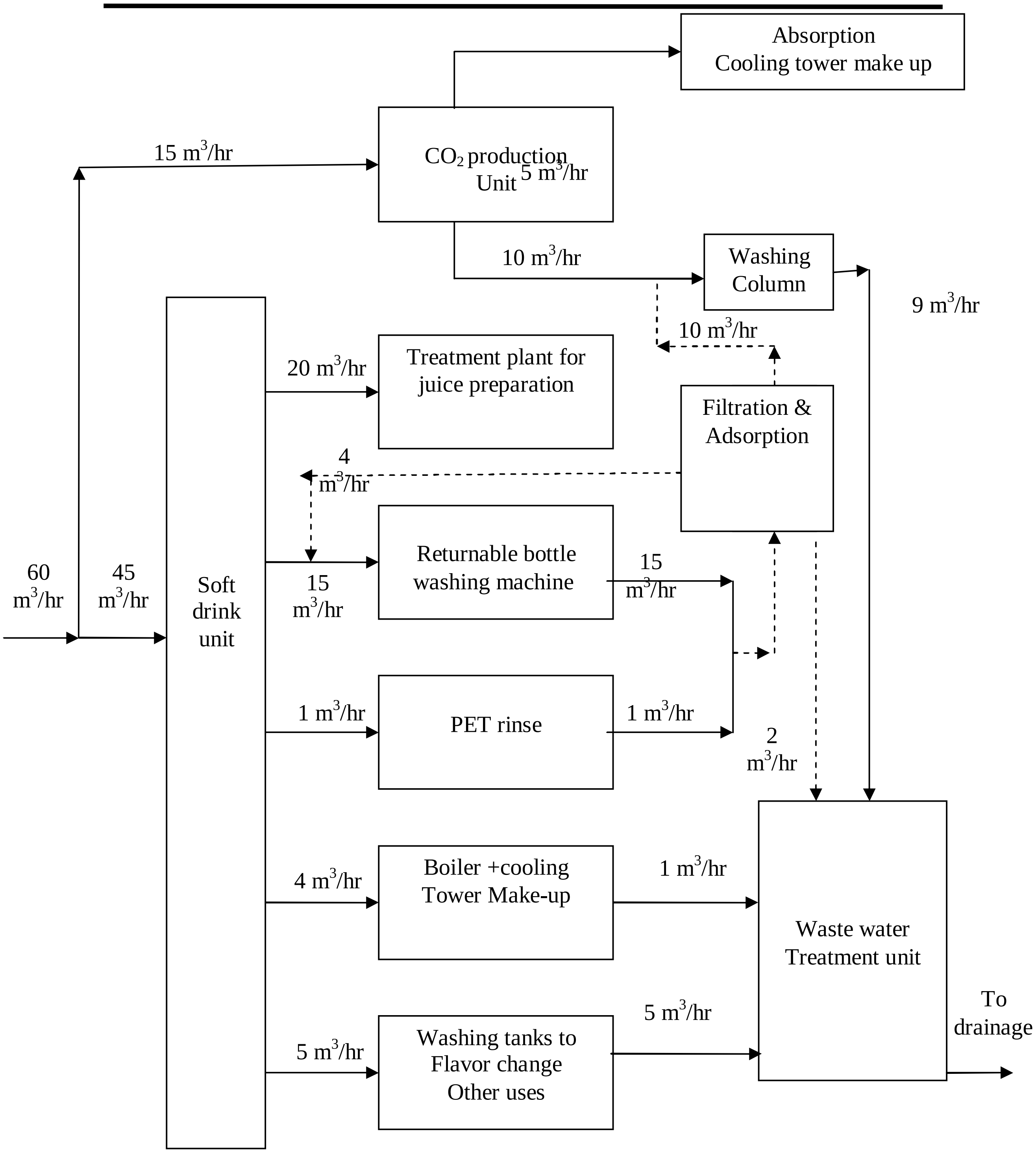

Figure (5) Second Suggestion for water management in the factory