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Industrial water demand management and cleaner production potential: a case of beverage industry in Marrakech - Morocco

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Résumé

Gestion de la demande en eau et production propre en industrie : cas d'une industrie de mise en bouteille à Marrakech – Maroc

Au moment où la demande en eau fraîche connaît une croissance forte, les procédés et les systèmes consommateurs d'eau sont soumis aux règlements environnementaux de plus en plus rigoureux quant à la génération de la pollution liquide. Au Maroc, la consommation de l'eau par les industries est estimée en 1994 à 1 milliard de m3, l'eau potable en constitue 4%. L'eau utilisée dans l'industrie agroalimentaire et de boissons est approximativement 24 millions de m3 par an comprenant 14 % d'eau potable.

Cette étude était conduite dans une unité de mise en bouteille. Nous avons étudié la consommation de l'eau et la génération des effluents. Le but de l'étude est d'une part d'identifier tous les points du procédé de fabrication utilisateurs d'eau traitée, puis entamer une étude d'économie et de minimisation de la consommation de l'eau dans ces points. D'autre part, pour développer une gestion globale des ressources en eau au sein de l'industrie, nous avons étudié la possibilité du traitement et réutilisation des rejets.

Pendant l'année 2001-2002, nous avons conduit des campagnes de mesures et de caractérisation du réseau de l'eau dans l'usine pour mesurer les diverses entrées et sortie des processus et pour évaluer le volume et la qualité des rejets liquides. Nous nous sommes également intéressés à l'impact de chaque activité de production sur la qualité des effluents.

Mots-clés : *Boissons gazeuses, procédé de fabrication, consommation d'eau, économie d'eau, caractérisation des rejets*

Abstract

Processes and systems using water today are being subjected to increasingly stringent environmental regulations on effluents and there is growing demand for fresh water. In Morocco, consumption of water by industries is estimated in 1994 at 1 billion m^3, the drinking water constitutes 4%. Water used in the food and drink industry is approximately 24 million m^3 per year including 14 % of drinking water. This study was conducted in bottling plant in Morocco, we have investigated the consumption of water and production of effluents.

The aim of the study is on the one hand to identify all the processes users of fresh water, then make minimisation of consumption and saving of water in these processes, on the other hand to develop a wastewater management by studing the possibility of reuse, recycling and treatment.

During the year of 2001-2002, we conducted campaigns of characterization of the network of water in the factory to measure the various input and output of processes and to evaluate the assessment of the liquid rejections. Initially we were also interested in the impact of each activity of the process on the effluent quality. We made follow-ups of the effluent flows and pollution on the level of each outlet.

Keywords : *Soft drink, industrial processes, water usage, ratio minimisation, Wastewater*

1. Introduction

Water is an essential raw material in soft drink production, with a consumption of 2.5 to 3.5 litres of water per litre of soft drink [1,2]. The wastewater generated in this industry is mainly from bottle washing, filter backwashing, washing of bottling machines, washing of equipment, floors and pipe work during flavour change. The major contaminants in the effluent are the caustic soda and sucrose [3]. An overall water balance drawn for this industry revealed that 76% of the water consumed daily ends up in the biological wastewater treatment plant [4]. Wastewater from bottle washing is almost 50% of the total wastewater generated, which is on the average 1.25 litre of wastewater per litre of soft drink [5]. Bottle washing is performed by washing machines that operate in different cycles: pre-rinse, pre-wash, caustic wash and final rinse. The substances used are detergent, chlorine and a solution of NaOH at 2.5%.

In order to reduce soft water consumption and the volume of wastewater, the bottling plants can introduce the cleaner concept. It is an integrated approach requiring cooperation from all and commitment from the top tier of management to implement and sustain policies that aim to ensure that production is carried out in a manner that is both cost-effective and environmentally sound. Cleaner production in most industrial processes can be applied to different stages of the process, and a project implemented by stages according to a company's needs and possibilities. The concept of water demand management generally refers to initiatives, which have the objective of satisfying existing needs for water with reduced consumption. The general view is that when a series of linked efficiency technologies are implemented in concert with each other, in the right sequence and manner and proportions, there is a new economic benefit to be reaped from the whole that did not exist with the separate technological parts [6].

The present work was carried out in a factory of carbonated soft drinks in order to increase its performance with respect to water demand management and environment protection. The aim of this study was to introduce a water demand management by carrying out the state of fresh water usage, characterization of wastewater and identify the possibility of treatment recycling and reuse.

2. Material and methods

During of the two years of study, measurements of flows are carried out using flow meters installed on the water canal or simply by a graduated container. The monitoring took place during a production cycle and lasted several days to take into account the variation of the type of products and the maximum number of combination of polluting activities. To assess the wastewater physical-chemical quality pH, temperature and conductivity were measured on-site. Total Chemical Oxygen Demand (COD), Biological Oxygen Demand at 5 days (BOD_5), Suspended Solids (TSS) were measured as described elsewhere [7].

3. Results

3-1. Pre-Treatment of Water On Site

The manufacturing of soft drinks requires large volumes of water. As the vector carrying the activities is water, we began with investigating the water process treatment in site. The water is pre-treated on-site to meet product quality requirements before being used in the manufacturing process. The process of water treatment can be divided into two dies, a softened die produced softening water for bottle washing and for vapour production. The other produced treated water or (fresh water). This process is fed by municipal water.

The water input volume is measured by a flowmeter. Then this water is stored in a tank to avoid any risk of water miss. For the production line of treated water, stored municipal water is pumped to the sand filter, a coagulation/flocculation can take place on line by adding alumin sulfate according to the quality of municipal water. Then water passes through two decarbonator filters before stored. As this water is intended for the manufacture of simple and finished syrup, it must undergo a treatment by activated carbon with of two carbon filters. For more safety water passes finally through a polisher before been sent towards the production (*Figure 1*)

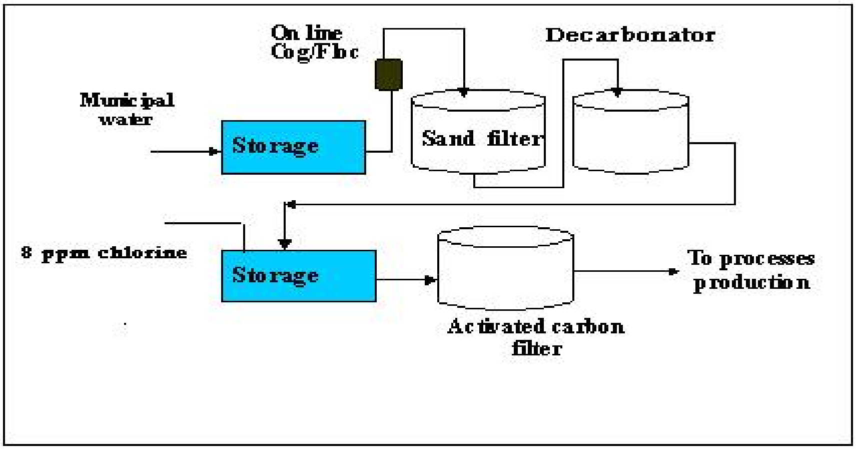

Figure 1: *The on-site system of fresh water pre-treatment*

For softened water, municipal water is filtered on two resin softener. Softened water is stored in a tank before been sent towards the bottle washing and the system of vapour production *(Figure 2).*

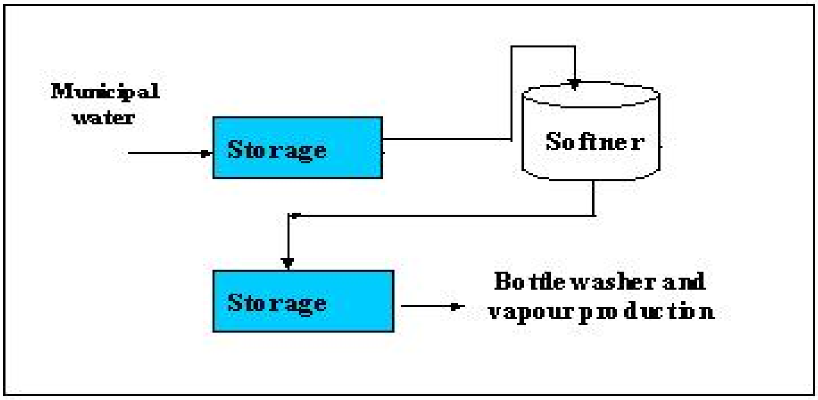

Figure 2: *The on-site softened water system pre-treatment.*

There are potential opportunities for reducing water intake and minimising waste. The plant pre-treats municipal water at an average of 3.7 m^3m^{-3} soft drink produced by using a conventional type. Backwash water is discharged into a sewer. The industry cleans two carbon filter and four sand filters on a daily basis by forcing water back through the filters. The generation of backwash water is dependent on production levels, but is estimated to reach 76 m^3 per day.

The cleaner production approach, which the industry can implement, involves optimisation of the time and flow of backwashing and regeneration of the softener and decarbonator at the same time to maintain strict quality standards. Process can be reclaimed into a recovery holding tank and then used for services requiring lower quality water e.g. floor washing. An over-capacity water treatment plant can often result in large water wastage due to the backwashing of unnecessary sand and carbon filters. The industry therefore has to optimise on the amount of water for treatment and the backwashing process. Water usage should be included as part of the selection criteria when purchasing major equipment such as bottle washers, sprays and bottling machines

3-2. Water usage in the plant

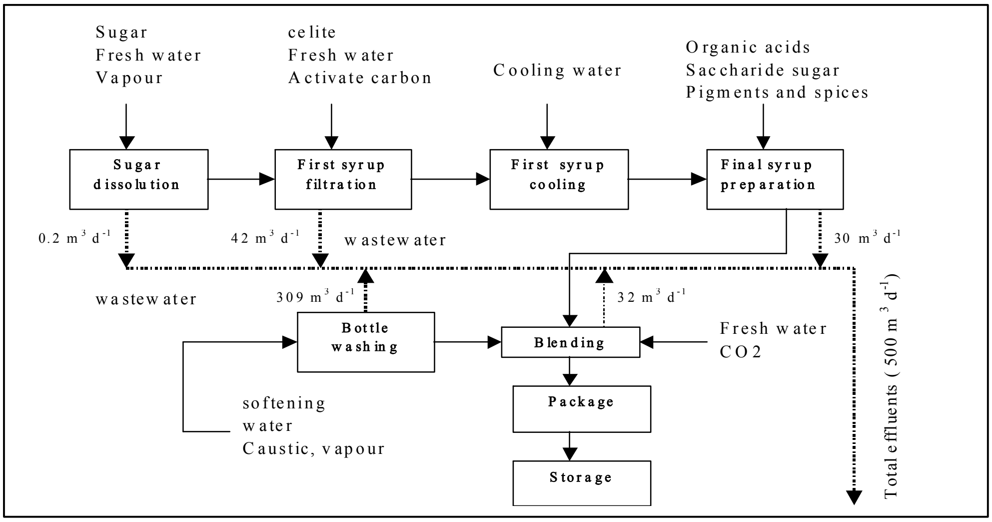

Figure 3: *Simplified diagram for the soft drink manufacturing process and water network*

Figure 3 shows the principal network of water use in the plant, the process of production that use fresh water and generate an important volume of wastewater.
The consumption of fresh water varies between 426 m^3d^{-1} and 917 m^3d^{-1} with an average of 683 m^3d^{-1} (*Figure 4*).

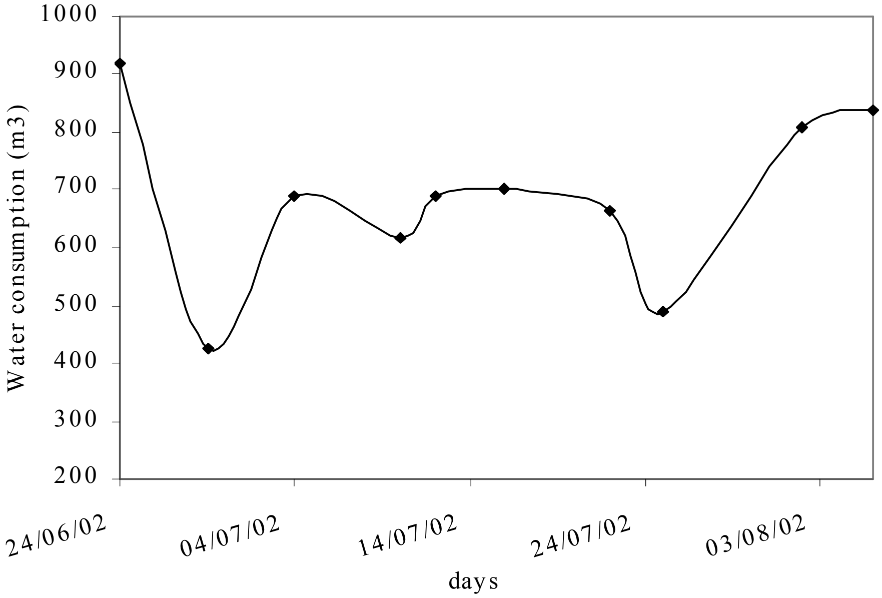

Figure 4: *Evolution of water consumption during the high season of year 2002*

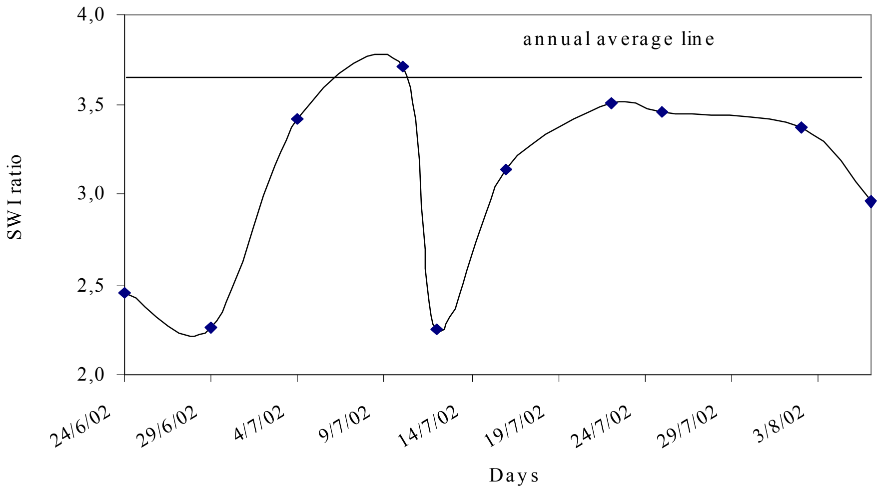

Figure 5 : *Evolution of specific water intake (SWI), (2002).*

The specific water intake ratio vary between 2.2 and 3.7 with an average of 3.1 *(Figure 5)*. The monthly water consumption varies between 7000 and 25000 m^3, over 12 months of the year, five months coincide with the high season of production (April to September), and the seventh month remaining coincide with the low season). Compared to the ratio of the year 2001, the ratio of year 2002 have decreased, some operations lake: Improve plant washing procedures, control flow rates of spray, sealing and cooling water supply, make greater use of cleaning-in-place (CIP) technology, fit meters to measure water use for the whole site individual high-consumption process, have been taken to reduce the consumption of water in the plant.

Analysis has also shown that 70% of the total wastewater disposal costs are caused by the relatively small amount of CIP rinsing water stream that comes from the hot water cleaning processes accomplished after every product change [8].

The bottle cleaning machines causes most of the used water. A new bottle cleaning machine needs 150-200 mL per bottle; an older one up to 600 mL. This corresponds to consumption of 20 000-30 000 m^3y^{-1} for a medium-sized company and much more than 250 000 m^3y^{-1} for a large one [6].

In the case studied, the bottle wash use approximately between 62 % of water daily used with a flow of 21 m^3h^{-1}. The purifying process of a bottle-cleaning machine is shown in *Figure 4*. At the beginning pre-cleaning takes place; normally this zone consists of several baths and rinse stations, which is followed by the main cleaning in a lye-bath which contains 2.0-2.5% NaOH with a temperature of about 80°C. To that a lye-rinse station (post-lye) is connected. After leaving the lye-zone the bottles are cleaned and disinfected. The following part contains in cascades several switched rinse stations that remove the lye from the bottles and cool them step by step. After leaving the cool water at 28 °C bath, the water goes to the pre-cleaning zone and from there to the sewage canal. In these rinse stations, most of the fresh water is used so that a recycling system in this zone could reduce the amount of fresh and wastewater in most effectively (*Figure 6)*.

It was considered treating the rinse waters at 28°C to determine if recycling could be performed. To know whether the membrane performance is sufficient, a definition of the cleaning aims is necessary, which is given by the water quality for the bottles for each considered rinse station. The recycling system strives to save water by 50%. It is not possible to replace the all the fresh water by recycled water because the law demand using drinking water for the very last step in cleaning processes of the food industry. Water conservation potential according to research carried out, the average ratio for soft drinks manufacturing industries should be set at 2.3 m^3m^{-3} of soft drink produced [9].

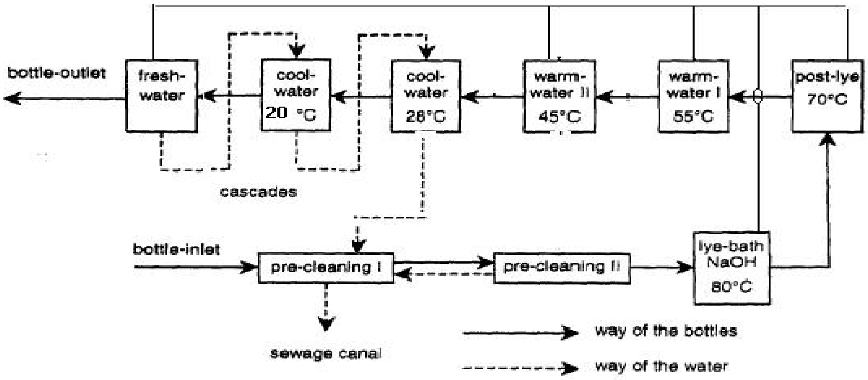

Figure 6 : *Scheme of the process of a bottle-cleaning machine*

Automatic shut-off, valves and high pressure, low-volume jets for hosepipes could also prove to be effective in helping reduce water intake. Attention should also be paid to future developments such as varying heat transfer systems and waste minimisation; the resource use potential efforts could also be made to reduce the amount of material that contributes to the high Chemical Oxygen Demand (COD) levels entering the effluent stream.

3-3. Wastewater production by processes

The volume of wastewater generated by the processes varies between 238 $m^3d^{-1}$and 567 m^3d^{-1}. The effluent represents approximately 56% to 71% of the total water used *(Figure 7)*. The bottle washing generate the important part of effluent, approximately 62 % of the wastewater or 336 m^3d^{-1} with an average of 21 m^3h^{-1} and 16 hours of work a day *(Figure 8)*. The CIP operation and equipment of bottling and blending, even if, didn't generate a lot of flow, but contribute to the increasing of carbon pollution.

Figure 8 represents two cases of wastewater flow generated by the bottle cleaner and rinse during a period of production. The flow cans reach 23 m^3h^{-1} and cans work in the summer season more than 16 hd^{-1}.

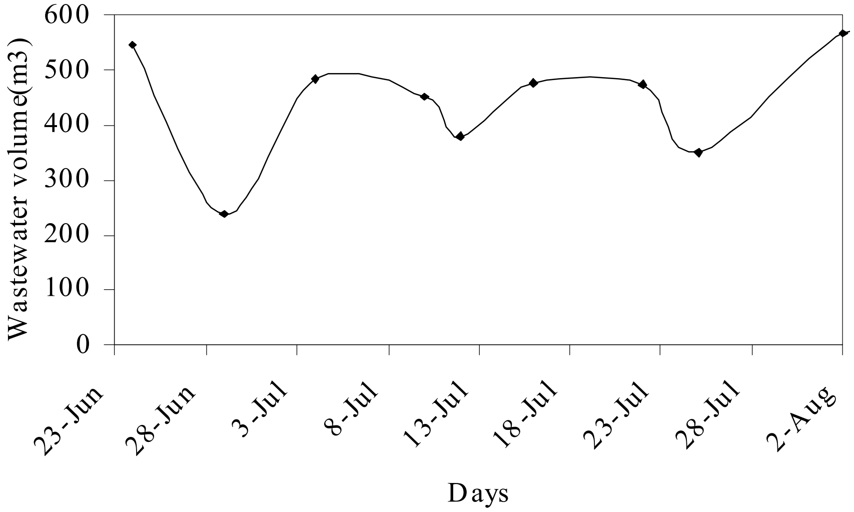

Figure 7: *Evolution of wastewater generated during the high season of year 2002*

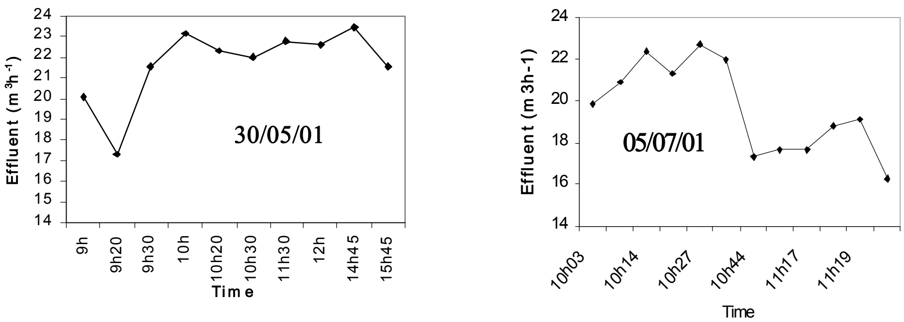

Figure 8: *Evolution of effluent generated by the bottle washer versus time*

The second activity which contributes to the increase of water use and pollution generating is the CIP system. The clean and rinse of syrup tank preparation and the bottling machines, use hot water with 2.5% of caustic and hot water at 80°C, flowed by cool water. This operation takes place at the beginning and end of each production for several times a day.

The CIP of a syrup tank started by a rinsing with treated cool water, then a washing with 2.5% NaOH and 80°C. Soda can be returned to the soda tank according to an automatic program. A conductivity-meter was installed on the line of return and control the destination according to the percentage of soda either in the tank or rejected. After this operation, the tank is washed with hot water at 80°C, hot water can also be returned to the tank according to its temperature, a temperature gauge allows control the destination either the tank or as wastewater. At the end the tank must be rinsed with cool treated water, which is fully rejected.

Different treatment technologies have been implemented for recycling water within the industry. The use floating media filtration and nano-filtration system help to achieve a reduction in tap water consumption of more than 60% [10]. Two strategies have been proposed by [11]: A micro-filtration-reverse osmosis system will purify the rinse water for reuse in the bottle washing process, thereby reducing water consumption further to 58%; and a dual filter media - ion exchange system can reduce water input to 57%. The most wastewater generated by the CIP comes from the hot water and cool water.

Figure 9, illustrate two case of CIP measurement of effluent flow during the 2001 year. The flow can reach 30 m^3h^{-1}, more than three tank can be cleaned for a days. After the automation of the CIP in 2002, we have marked saving of water and energy. The washing of syrup preparation and filing equipment, even if it represents only 6.40 %, it contributes to the most pollution by COD (*Table 2).*

For the food and drink industry, a proportion of the water used often becomes part of the product. However, even in the soft drinks industries, where water is a major component of the product, only 20–30% of the total water consumed leaves in the product [12], with the rest being accounted for in atmospheric emissions or effluent.

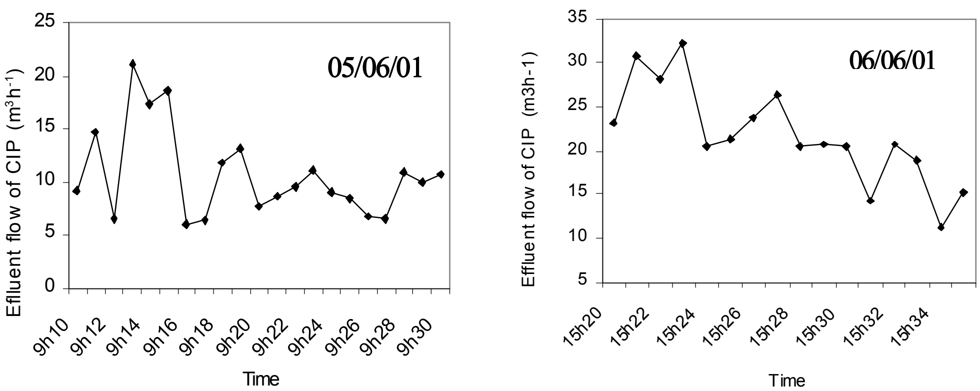

Figure 9: *Evolution of effluent generated by CIP versus time*

Table 1, illustrate the wastewater flow rate rejected by each activity in the site.

Table 1: *Various outlets of activities and their rejection flow*

Source of effluents	Maximal frequency (time day^{-1})	Basis flow	Flow ($m^3 week)^{-1}$
Bottles Washing	-	330 $m^3 day^{-1}$	1980
Washing and rinsing of final sirup equipment	6	2.9 m^3/tank	104,4
Washing and rinsing of filling equipment	2	16/CIP	192
Washing and rinsing of syrup filtration equipment	1	32 $m^3 day^{-1}$	192
Washing of activated carbon filter	2 (back washing)	23 $m^3 day^{-1}$	276
Washing of sand filter		28 m^3/operation	28
Regeneration of softener	2 $week^{-1}$	15/regeneration	180
Regeneration of the decarbonator	-	46 m^3/regeneration	46
Washing of simple syrup equipment	1 day^{-1}	0.2 $m^3 day^{-1}$	1,2
Washing of syrup storage tank	1 $week^{-1}$	0.9m^3/operation	0,9

The bottle washer can be considered as the activities that contribute the wastewater flow increasing and pollution parameters (COD, BOD, pH, and TSS). We have observed that clean of equipment of filing and , syrup preparation and filtration and storage increase the saturation of effluent by organic matter (*Table 2*)

The effluents from the food and drink industry often have high Biochemical Oxygen Demand (BOD), thus contributing to the degeneration of local water bodies. High value of COD has been measured in contaminated process water containing oil and fats generated in CIP processes in production plant [13], particularly during pre-rinsing with hot water. The same author reported that highly contaminated pre-rinsing water has a COD of between 5000 and 10000 mgL^{-1}. It was reported that bottling plant generate wastewater that are good candidate for biological treatment [14], but fluctuates significantly in quality and quantity depending on the product mixed and production schedules.

Table 2 : *Various outlets of activities and their impact on the rejection quality (+ +: Very extremely, +: extremely, -: weakly).*

Source of effluents	Impact on the raw wastewater						
	T°C	CE	pH	COD	BOD	TSS	Flow
Bottles Washing	++	++	++	++	++	++	++
Washing and rinsing of final sirup equipment	++	++	++	++	++	+	+
Washing and rinsing of filling equipment	+	+	+	+	+	+	+
Washing and rinsing of syrup filtration equipment	-	-	-	++	++	++	+
Washing of activated carbon filter	-	-	-	-	-	-	+
Washing of sand filter	-	-	-	-	-	-	+
Regeneration of softener	-	++	-	-	-	-	+
Regeneration of the decarbonator	-	++	++	-	-	-	+
Washing of simple syrup equipment	-	-	-	++	++	+	-
Washing of syrup storage tank	-	-	-	++	++	+	-
Floors washing	-	-	-	++	++	++	++

The preparation of syrups remains the most polluting activity because it generates rejections rich in sucrose. As well as polluting flow lies between 3110 and 6000 mgL^{-1} of COD, with an average of 4500 mgL^{-1}, the major part of this pollution is in dissolved form. Indeed, the filtered COD represents approximately 60 %.

The particulate fraction is in general weak, it is represented by TSS, which fluctuates between 150 and 450 mgL^{-1} with an average value of 300 mgL^{-1} [7].

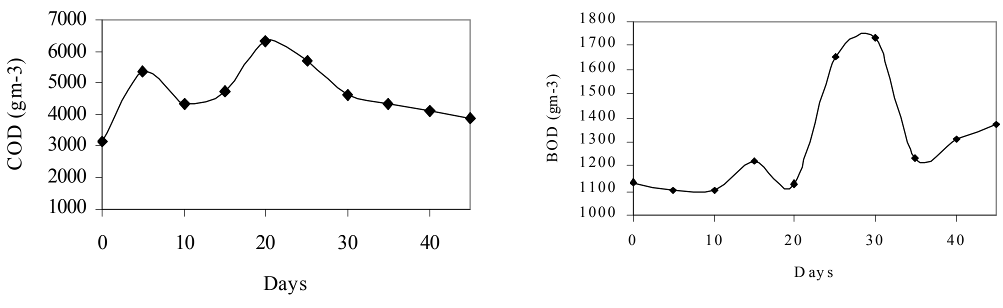

Figure 10: *Variations of total effluent quality (COD, BOD) versus days*

The values of the BOD do not change much; they oscillate around average value of 1300 mgL^{-1} *(Figure 10)*.

In function of the average characteristics, a design based on SBR technology was proposed. Its operation was simulated using process simulation software to test its robustness with respect to the large wastewater variations inherent to soft drink production. The wastewater treatment was modelled and simulated using GPS-X v4.0[16].

4. Conclusion

For the industry studied, there is no doubt that the identified water demand management and cleaner production techniques show potential for saving in water, water and effluent fees and minimisation of waste produced. This paper illustrates that the manufacturer can achieve by firstly carrying out audits to identify areas of improvement within the manufacturing process. This exercise can then be used to prioritise measures with the best returns within a certain time period, and financial regime.

In the absence of actual costs to implement the structural measures (retro fitting and maintenance) it is difficult to provide a full evaluation of the water demand management and cleaner production techniques, which are being recommended in this paper. Nonetheless, the procedure outlined here for the three industries demonstrate that Industries can do things differently in an ecologically friendly and sustainable manner. A full cost and benefit analysis would also require an indication of the actual costs of damage to the environment and the real long run marginal cost of water, which reflects the scarcity of the resource in the case of Morocco. The cost of other resource inputs e.g. energy needs to be considered.

The combination of water demand management and cleaner production concepts have resulted in both economical and ecological benefits. Processes can reduce water intake substantially and minimise resource input and the subsequent waste thereby reducing pollution of finite fresh water resources.

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