Increasing Business Competitiveness with Water Recycling

Water recycling represents the most important strategy to decrease water demand in the industrial sector. It also plays an important role in reducing the contamination of water bodies.

By Francisco J. Cervantes

Introduction

As the biosphere is now supporting a population of over six billion people and growing, water availability has become a major concern. From a historical perspective, the global population has tripled in the last 70 years causing water demand to increase by six-fold because of industrial development, widespread irrigation and lack of conservation. Consequently, nearly 2.2 billion people in more than 62 countries, *i.e.* one-third of the world's population, are lacking sufficient water supplies.

Even though about 70% of Earth's surface is covered by water, less than 3% of it is fresh, and most of it is in polar ice or too deep underground to be harvested. The amount of available fresh water in lakes, rivers and reservoirs is less than a quarter of 1% of the total fresh water quantity.

This scenario represents a serious limitation for industrial development in several regions of the world. Certainly, these factors indicate a strong relationship between our very limited water resources and future industrial growth since 23% of water reservoirs are designated for industrial use worldwide. The remaining water is supplied for irrigation, 69%, and for domestic purposes, 8%. The distribution of water, however, varies considerably from one region to another. In Africa, 88% of fresh water is assigned for agriculture, 7% for domestic use, and 5% for the industry; in Asia, the distribution is 86%, 8% and 6%, respectively. In contrast, European industry requires 54% of total water available, whereas 33% and 13% is currently used for agriculture and domestic purposes, respectively.

Table 1 shows the total industrial water demand and industrial water-use intensity under different circumstances. Industrial water-use intensity under a business-as-usual scenario (BAU) refers to conventional water demand. The water crisis scenario (CRI) is projecting a worsening of the current situation for water and food policy, and the sustainable water use scenario (SUS), projecting a more positive future with greater environmental water reservation. Under SUS, industrial water demand declines compared with BAU, through technical improvements in water use and recycling and increased water prices that induce reductions in demand. Under CRI, with weakened incentives and regulations and lower investment in technology, industrial water demand increases compared with BAU, as more water is needed to produce a unit of output. In 2025, total worldwide industrial water demand under CRI is projected to be 33% higher than under BAU, while it is 35% lower under SUS. Compared with BAU, global industrial water use intensity is 1.2 cubic meters per thousand U.S. dollars higher under CRI, and 1.3 cubic metres per thousand U.S. dollars lower under SUS.

Sustainable water use will play a crucial role on the development of most industrial areas worldwide. Several strategies discussed here will need to be implemented for allowing a sustainable use of water reservoirs linked to manufacturing.

Role of Cleaner Production in Industrial Water Preservation

Cleaner production, also referred to as 'waste minimisation', differs from end-of-pipe treatment in that it minimises wastes and emissions by reducing them at their sources. Cleaner production can generally be defined as the continuous application of an integrated preventive environmental strategy to production processes in order to avoid wastes and emissions at the source, to preserve energy and raw materials, to eliminate the use of toxic materials and to improve working conditions. Cleaner production contributes to optimisation of resources, therefore reflecting environmental improvement on financial and economic benefits, as well as on technological progress. Cleaner production improves management of water resources within several industries. For instance, in the case of beverages production, precise adjustment of bottle fillers or installation of a metal sheet under the fillers can minimise losses of product during the filling stage. This measure prevents generation of contaminated streams and reduces water requirements.

Correct scheduling of processes in view of equipment cleaning can also reduce waste generation and water demand. For example, preparing light paints before dark ones, or arranging fabric requiring similar dyeing and finishing process in sequential order, will make cleaning of vats unnecessary before starting a new batch.

In many industrial sectors, using the generated wastewater from bottle washing to wash the casks, or for other purposes, will also reduce water supply demand.

Changing input materials is another cleaner production strategy to reduce generation of pollutants and water requirements. For example, water-based film developing system can be replaced by dry systems in electronic components. The application of less aggressive cleaning agents and biodegradable detergents, instead of recalcitrant compounds used for vats cleaning, can also contribute to decrease the costs of wastewater treatment at several industries promoting water recycle.

A change in production procedure

plays an important role in reducing waste volume and strength, as well as water supply demand. This includes equipment modification or modification of technology in order to decrease wastes and emissions during manufacturing. Examples of this practice consist of alteration of washing/cleaning procedure such as using counter current washing, replacement of single-pass processes by closed loop processes, use of mechanical means to transport waste (*e.g.* from poultry farm) instead of using water, among others.

Water Recycling in Different Business Sectors

Textile Industry

The textile industry represents an important economic sector around the world. In 2000, the European industry was composed of around 114 thousand companies (principally based in Italy, Germany, United Kingdom, France and Spain) with an average turn-over of € 198 billion a year, making it the world's leading exporter of textiles and the third largest exporter of clothing. When looking at the numbers for 2003, Asia was the largest textiles importer and exporter, and the leading exporter of clothing. The U.S.A. and Canada together are the largest clothing importers.

The increased demand for textile products over the last decades caused a proportional increase both in the water supply demand and in the production of wastewater. The demand of water supply in the textile industry varies enormously among the different processes applied. For cotton based fabrics the water demand is between 120 and 750 m^3/ton. Meanwhile, nylon and polyester textiles require 100-150 and 60-130 m^3/ton, respectively.

A huge number of chemicals that have a negative effect on the environment and public health are released through textile industry wastewaters. Chemicals such as *alkyl phenol ethoxylates* (present in detergents, wetting and levelling agents), reported to disturb the reproduction of aquatic species; along with *sequestering agents* like *EDTA* and *DTPA,* capable of forming very stable complexes with metals, thus affecting their bioavailability; and the *dyestuffs*, which are recalcitrant by design and not readily degraded by common treatment methods, are examples of hazardous compounds present in textile wastewaters. Particularly the release of colored compounds into water bodies is undesirable, not only because they reduce the transparency of water, which may drastically affect photosynthesis of aquatic plants, but also because many dyes and their degradation products are carcinogenic. Without adequate treatment, these dyes may persist in the environment for an extended period of time.

Due to the complexity of textile effluents and the recalcitrance of many of their constituents, appropriate treatment to achieve closed-loop systems within textile factories represents a challenge. Nonetheless, advanced biological treatment processes combined with distinct physical-chemical processes have emerged as alternatives to accomplish water recycle in this industrial sector. High-rate anaerobic reactors, followed by conventional aerobic treatment processes, can achieve efficient removal of COD and color from textile wastewaters. The high-rate anaerobic reactors can be supported by redox mediators, which accelerate the reduction of dyes allowing effective decolorization at short hydraulic residence times (HRT). In fact, removal of colour from textile wastewaters is the main limitation to stimulate water recycles. However, the feasibility of biological decolorization and reuse of commercial textile dyebaths has recently been demonstrated. Indeed, repetitive dyeing with the same biologically decolorized dyebath for up to five cycles using a biofilm reactor and dyebath pH adjustment during the redyeing process resulted in almost identical colour shades compared to standard made with fresh water.

For the most recalcitrant dyes, biological reactors can be combined with advanced oxidation processes, such as ozone/UV treatments, to warrant complete decolorization for close-loop water systems.

Pulp and Paper Industry

Paper production based on recycled paper has considerably increased during the last decades in order to reduce production costs and environmental impacts. The paper industry is one of the manufacturing sectors demanding large amounts of water. Several pulp and paper factories have implemented closed-loop systems, based on biological wastewater treatment processes, in order to achieve sustainable water use for paper production. The last scenario allows not only for water preservation, but also for reduced production costs.

Until 25 years ago only aerobic treatment plants were applied in the pulp and paper industry of which the activated sludge process was the most advanced and efficient. However, during the last two decades anaerobic bioreactors have become a well-established and proven technology for the treatment of pulp and paper mill effluents. Currently, over 200 anaerobic treatment plants treating pulp and paper effluents have been constructed. The implementation of anaerobic pretreatment followed by aerobic post-treatment has several advantages: (1) net production of energy in the form of biogas, (2) a significant reduction of sludge generation, (3) small footprint requirement, and (4) low emission of greenhouse gas CO_2. Furthermore, the efficiency and robustness of high-rate anaerobic bioreactors, such as UASB, EGSB and IC, combined with aerobic post-treatment, achieve the water quality required in close-loop systems.

Industriewater Eerbeek B. V. is a company that treats the wastewater generated from three different paper mills located in Eerbeek, The Netherlands. The three paper mills produce more than 350,000 tons per year of different types of paper. Jointly, the paper mills generate over 12,300 m³ per day, which are collectively treated in a treatment plant combining anaero-

Figure 1. *Cumulative water saving due to water reuse applied for irrigation of green areas in a typical hotel in Cancún (Mexico).*

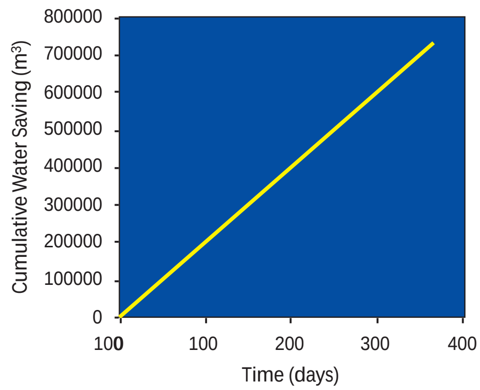

Table 1. *Total industrial water demand and industrial water use intensity under business-as-usual (BAU), water crisis (CRI), and sustainable water use (SUS) scenarios, 1995 and 2025*

Region/Country	Industrial water demand (km³)				Industrial water use intensity (m³/1,000 US$)			
	1995 Baseline estimates	2025 Projections			1995 Baseline estimates	2025 Projections		
		BAU	CRI	SUS		BAU	CRI	SUS
Asia	48.9	92.6	148.5	55.1	16.2	6.7	11.3	3.8
China	13.2	32.1	74.8	18.5	16.0	6.2	14.5	3.6
India	7.3	16	23.1	9.8	19.6	7.9	11.5	4.9
Southeast Asia	11.5	21.3	23.2	11.6	20.4	8.9	9.7	4.9
South Asia[1]	1.9	4.7	5.7	2.6	18.3	11.7	14.0	6.5
Latin America	18	30.2	36.7	16.1	10.6	5.9	7.1	3.1
SS[2]-Africa	0.9	2.5	2.3	1.3	6.3	5.8	6.2	3.0
WANA[3]	4.6	8.8	9.7	4.5	8.4	5.1	5.7	2.6
Developed countries	96.6	115.7	133.2	85.6	4.3	2.5	2.8	1.8
Developing countries	62.9	123.8	186.4	69.1	13.2	6.4	9.6	3.6
World	**159.5**	**239.5**	**319.6**	**154.6**	**5.9**	**3.6**	**4.8**	**2.3**

[1]Excluding India
[2]Sub-Saharan
[3]West Asia/North Africa

Table 2. Energy balance for anaerobic pretreatment (recycled paper mill)

	Complete Aerobic Treatment (MJ/ADT)	Combined Anaerobic-Aerobic (MJ/ADT)	Energy Savings Difference (MJ/ADT)
Energy production	0	275	275
Energy Consumption	90	20	70
Total Balance	- 90	+ 255	+ 345

bic bioreactors (UASB) and aerobic post-treatment. The total volume of water is continuously treated and recycled in a closed-loop system.

Further advantage of anaerobic treatment of paper mill effluents is the positive energy balance. Table 2 presents a typical energy balance for a European recycle mill producing corrugated case materials, with a COD release of 30 kg per air dry ton (ADT). It compares complete aerobic treatment with combined anaerobic-aerobic treatment. Thus, anaerobic pretreatment allows a positive balance of approximately 345 MJ/ADT compared to aerobic treatment alone. This quantity of energy makes up about 5% of the total energy consumption per ADT. If one considers, that there is also an up-going trend of the COD content in waste paper, the differences will be even more extreme in the future.

Tourist Facilities

Tourism represents a major economical income for emerging countries, such as Malaysia, Singapore, Brazil and Mexico. In order to guarantee sustainable water use and environmental protection, strict policies have been implemented during the last decades. Recreational facilities, such as parks, golf fields, sport centers and luxury hotels demand a large quantity of water for maintaining green areas. On the other hand, the services provided within these installations generate large volumes of diluted wastewaters coming from toilets, Jacuzzis, kitchens, laundries and washing machines. Therefore, it is reasonable to apply treated streams from these facilities to cover the large demand of water supply for green areas.

Typical hotel facilities located in Cancún (Mexico) require 400 liters of fresh water per person per day in average. For example, considering a hotel which capacity allows accommodation for 5000 tourists, the total wastewater generated would be 2000 m^3/day. Conventional treatment of these effluents in biological reactors followed by disinfection can achieve complete water reuse for different purposes, then drastically decreasing water supply demand. Figure 1 illustrates the cumulative water saving through water reuse in the hotel, which allowed a total water reuse of 730,000 m^3 per year. Most hotel facilities and recreational sites located in Cancún, Mexico are managed under these sustainable principles reducing operational costs. Thus, water treatment and recycle represent the main strategies to achieve sustainable water use in tourist installations.

Concluding Remarks

Water recycling represents the most important strategy to decrease water supply demand in several industrial sectors around the world. Water recycling through wastewater treatments linked to closed-loop systems minimise or even totally cancel industrial water discharge. Its implementation prevents contamination of water bodies by industrial effluents and drastically decreases production costs in different businesses.

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