

# Rationalizing the Use of Water in Industry—Part 1: Summary of the Instruments Developed by the Clean Technology Network in the State of Bahia and Main Results Obtained

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## ABSTRACT

Based on cleaner production concepts, a method for water use minimization has been developed by the Clean Technology Network of Bahia (TECLIM) at one of the largest industrial complexes in Latin America located in the State of Bahia, Brazil. This method is concerned with an area of secondary interest to the productive sector: the use of water. Based on the best cleaner production principles (CP), nine instruments have been developed during cooperative projects with chemical, petrochemical and copper metallurgical industries. These instruments are described in Part 2 of this paper [1]. The main benefits derived from partnership schemes include: a reduction in water consumption and effluent generation; the development of a techno-operational culture to increase eco-efficiency; and the introduction of conceptual projects to ensure the continuity of the activities in the company after the projects have been completed. The specific consumption of water was reduced by 20% as a consequence of the application of this method in Company A; a specific reduction in the generation of effluents of more than 40% was observed in Company B; a 42% fall in fresh water consumption in Company C; and a 20% decrease in the cost of effluent treatment in Company D. Among the difficulties encountered were the limited time availability of the operators and engineers for the project, the lack of measurement and calibration of available flow meters and the lack of detailed technical data.

**Keywords:** Water; Effluent; Rationalization; Industry; Cleaner Production; Clean Technology Network (TECLIM)

## 1. Introduction

Industrial processes depend and impact directly on water resources. Water in industry may be required for several activities as input, to cool or heat equipment and systems, to manufacture goods, for cleaning services and/or to be incorporated in the final product [2]. Forecasts put water as a critical environmental factor for the next two decades. In the industrial sector, water restriction may result in an increase in production costs and even the loss of the license to operate. Water management and continuous reduction of water consumption associated with the development of new methodologies and tools for optimization, as well as the formation of partnership with the scientific community have all been suggested as solutions for industries to mitigate these problems [3-5].

Globally, the per capita availability of freshwater is

steadily decreasing. This trend will inevitably continue due mainly to population growth, changes in consumption patterns in emerging economies and climate change [6]. The pressure on the existing water sources and the search for new sources of supply may increase the areas under water stress and conflicts of interest among different water users.

Historically, water supply systems were developed with the aim of providing this resource in abundance and at low cost [7]. Moreover, although the commitment to make a constant improvement in the relationship between industrial activities and the environment is recognized by the awarding of environmental certificates, this is still not enough to face up to the challenge of sustainability. On a global scale, the growth of consumption suggests that there is a need to seek productive processes

with standards of eco-efficiency of a greater magnitude. Some writers use the concept of Factor 10 [8] which represents the incremental value of the eco-efficiency of the products and processes required to stabilize the growth of environmental degradation over a time-span of five decades. This points to the urgent need to make drastic improvements in the efficiency of anthropogenic activities [9].

At the same time, as several writers have pointed out [10-13], putting practices that can reduce the use of water resources into effect requires changes in behavior as well as technology. Owing to the difficulty of achieving levels of this magnitude by just relying on advances in technology, concepts of Cleaner Production (CP, or P + L) have been employed to improve the environmental performance of the industrial sector.

A recent study, carried out in Brazilian companies certified by ISO 14001, indicates that environmental management has been treated as a preventive approach, with strategies to optimize the use of natural resources such as the application of eco-efficiency principles, e.g. the 3Rs (reduce, reuse and recycle), and the environmental management area appears more prominent in the organizational structure of such companies. However, this preventive approach does not necessarily create a competitive advantage in cost, quality, and flexibility and it does not deliver what a proactive approach could disseminate [14].

In the last fifteen years, the Clean Technology Network of Bahia (TECLIM), at the Federal University of Bahia (UFBA), has investigated ways of improving the eco-efficiency of industry, public buildings and private dwellings.

As has been observed by Bravo & Kiperstok [15], Fontana *et al.* [16], Kiperstok *et al.* [9,17-19] and Oliveira-Esquerre *et al.* [20], there has been a wide range of projects carried out with companies in the region which have enabled the development of a method for use in reducing water consumption in industry in particular.

The whole of this study is based on a perspective of Pollution Prevention/P + L which has emerged from the work of various organizations and writers, UNEP/UNIDO [21-23].

Strategies are used that give priority to addressing the source of the problem and are extended to measures involving internal and external recycling.

TECLIM have developed a method for environmental optimization of industrial process focused on Cleaner Production (CP) in partnership with industries and institutions in the region. This method has arisen from a situation where industry and the university have worked together in a search to find ways to build up more sustainable processes. CP concepts were employed as a ba-

sis to help identify appropriate opportunities to define a method that includes nine main instruments:

11. The merging of academic and operational/Industrial knowledge;
12. The inclusion of CP concepts by means of continuous large-scale training;
13. Construction of reconciled aqueous stream balances considering uncertainties in measurements or estimates;
14. Compilation of a digital database of ideas that takes into account cultural, environmental and economic factors in evaluating the potential use and drawbacks of opportunities;
15. The introduction of a geographical information system (GIS) to identify the sources of water (by producers or consumers) within the context of companies and in the region;
16. Optimization of Mass Exchange Network;
17. Analysis of the region's hydro and hydro-geological characteristics;
18. Drawing up conceptual projects for reducing the use of water and generation of effluents;
19. Auditing of the sources that give rise to the effluents.

**Table 1** shows the relationship between these instruments and the CP conceptual framework, objectives and optimization strategies.

## **2. The Interaction of the Clean Technology Network (Teclim/UFBA) with a Post-Graduation Course: The University-Industry Partnership**

The Clean Technology Network (Teclim/UFBA) was first set up in 1997 with the aim of establishing and encouraging inter-institutional cooperation to undertake studies and experiments that could foster the use of the CP concept and thus help bring about sustainable development in the State of Bahia. Since it consists of various partnerships, industrial organizations, universities, foundations and development agencies, it acts under the supervision of the Clean Technology Network of the Department of Environmental Engineering at the Polytechnic College, Federal University of Bahia.

At the end of the 1990s, the so-called Sector Research Funds were consolidated with the aim of financing cooperative schemes between the universities and the productive sectors. This situation fostered the formation of new relationships between members of the academic world and personnel in industry which began to outline new means of tackling the environmental problems that were being experienced in productive processes [24,25].

With regard to this, it should be pointed out that some

**Table 1. CP conceptual framework, objectives and optimization strategies related with the developed instruments.**

Conceptual Framework	Objectives	Optimization Strategies	Developed Instruments (I)								
			1	2	3	4	5	6	7	8	9
Reduction at source	To eliminate use	Good operational practices	A	A	A	A	C	C	C	A	A
	To reduce consumption	Change in technology	B	B	B	B	C	B	B	A	B
		Changes of input <sup>a</sup>	B	C	B	B	C	B	A	A	C
Internal, external and recycling	To use without treatment	Techniques for reuse	A	B	B	A	A	A	C	A	B
	To use after treatment	Recycling techniques	A	B	B	A	C	A	C	A	C
Treatment/Discharge	To control discharge (end of pipe)	Separation of currents	B	B	C	B	A	A	B	A	A
		Final disposal	C	C	C	C	C	B	A	A	A

<sup>a</sup>The inputs and products refer to the water obtained and produced by the companies respectively. Words A, B and C represent strong, medium and low correlation with optimization strategy.

official calling for projects took place, focused on the administration of the demand for water in the CT Hidro [Water Resources Sector Fund] sphere. These lines of credit were drawn on to carry out projects on the optimization of the use of water resources and the reduction of the generation of effluents, through the lens of CP. The contributions served to finance the projects that, depending on the size of the companies involved, could reach 70% of their entire budget [19].

In 1998, the Specialization Course in Management and Environmental Technology in Industry at UFBA was set up in partnership with the Pedro Ribeiro Center for Industrial Technology, (CETIND) of SENAI (National Industrial Training Service—Bahia) [25]. With the environmental perspective of the Course, guided in the direction of CP, some research theories arose at reducing and/or eradicating the generation of residues at source. With the setting up of professional Master's degree courses in 2002, research began to be carried out in greater depth. In 2008, this Master's course was merged with the Post-Graduate Program in Industrial Engineering and further widened the scope for research and development by offering Doctorate courses.

It should be stressed that the post-graduate professional courses (whether vocational or academic) played a crucial role in forging closer links between the university and industry by supporting and carrying out innovative, environmental policies [9].

All the partnership schemes undertaken by TECLIM and the companies shared the same vision. This was to foster environmental sustainability in the company based on CP principles and in such a way that it was grounded in a culture that aspired to the concept of zero effluent.

The information and scenarios outlined below are fruit of cooperative research projects with large-sized companies located in the Camaçari Petrochemical Pole, as well

as the metropolitan district of Salvador. The rate of water consumption of these companies ranges from 100 to 4500 m<sup>3</sup>·h<sup>-1</sup>. Each project lasted from one to two years and involved 5 - 15 post-graduate researchers or scholarship students from a scientific background, including professionals with both academic and industrial experience.

The implementation and continuation of these projects enabled the development of a particular kind of method. The results obtained as a result of the first cooperative project have led to new financial investments being made as an incentive to maintaining a partnership between the university and the companies. **Table 2** shows a list of these projects.

### 3. Factors Regarding Water Management in Industry—Water Use in Industry

Water is considered the favoured medium for industrial energy management due to its relative abundance, high heat capacity, transportability and reasonably low cost [26]. In general, the quality and quantity of water used for industrial purposes depend on the industrial sector and its production. The same industry can use water in different physical, chemical or biological ways.

Water use in industry may be grouped into two main functions [2]: energy transfer and mass transfer. Energy transfer is considered the function that consumes the most water in most industries to cool or to warm flows, for example in cooling towers, heat exchangers, reactors, flash towers. This function generally accounts for most of the water consumed in industry.

On the other hand, mass transfer is used to drag materials in washing and waste disposal, it serves as a solvent in separation processes and thins compounds to facilitate chemical reactions. In addition to these uses, water is also used in industry as a raw material, for hydrostatic

**Table 2. Record of Teclim Network/UFBA projects in the area of environmental optimization. Source: www.teclim.ufba.br.**

Item	Project	Period	Financial backers	Financial Investment (\$)
1	ECO-BRASKEM 1 <sup>1</sup>	2001 to 2004	ANP, Finep, CNPq, Braskem-UNIB (ex-COPENE), CTPETRO	1 366 462.51
2	MHEN <sup>2</sup>	2002 to 2004	Fapesb, Finep, Griffin, Politeno, Monsanto	651 855.62
3	ECO-BRASKEM 2 <sup>3</sup>	2004 to 2006	ANP, Finep, CNPq, Braskem-UNIB, CTPETRO	1 958 934.89
4	ECO-BRASKEM 3	2007 to 2009	ANP, Finep, CNPq, Braskem-UNIB, CTPETRO	1 638 000.00
5	DETEN-ÁGUA	2003 to 2005	ANA, Finep, CNPq, DETEN, CTHIDRO	595 620.00
6	TRANSPETRO	2004 to 2005	Petrobras Distribuidora S/A	89 688.60
7	AGUAÍBA	2003 to 2005	ANA, Finep, CNPq, Caraiba Metais, CTHIDRO	1 181 688.68
8	ENERGIBA	2007 to 2009	Finep, CNPq, Caraiba Metais	899 204.62
9	LYONDELL-ÁGUA	2004 to 2006	Finep, CNPq, LYONDELL (atual Millenium), CTHIDRO	1 188 000.00
10	RLAM-ÁGUA	2009 to 2010	ANP, RLAM (PETROBRAS)	1 236 296.25
11	FAFEN-ÁGUA	2009 to 2010	ANP, FAFEN-BA (PETROBRAS)	1 236 296.25
12	RLAM- ÁGUA II	2011 to 2012	ANP, RLAM (PETROBRAS)	4 494 070.35
13	FAFEN-ÁGUA II	2011 to 2012	ANP, FAFEN-BA (PETROBRAS)	3 578 148.00

<sup>1</sup>Original COPENE-ÁGUA; <sup>2</sup>Mass and Heat Exchange Network; <sup>3</sup>Original BRASKEM-ÁGUA.

testing, firefighting, landscaping, sanitation, cleaning and food preparation.

One of the challenges to establish a standard of rational consumption of water is to obtain reliable values for the appropriate intake of water for an industrial activity. Information related to consumption practiced by industries found in the literature on the one hand may help in studies of water demand for the implementation of new projects, on the other hand, it might indicate a rational pattern of consumption or reduction targets set in already installed plants.

Due to the various uses of water in industry, estimates of quantities of and losses from water used should be carefully estimated [27]. The water that feeds an industry can be purchased from supply systems internally or supplied by surface or groundwater catchment (wells). This auto-supply, if not settled, ends up masking the relative water consumption of the industry in the region in which it is inserted, and could be disastrous for the regional control systems of water resources.

In fact, the operating conditions of similar industries located in different geographical regions tend to vary considerably. The uses and quantities of water required in the industry vary depending on the type of industry, the technology used, the level of control and maintenance, the weather conditions, the type and quality of raw material used, the operational culture, the cost and availability of resources in the region where the industry is installed.

The literature about water use reduction, however, does not tell whether the new values obtained are close to

rational consumption or if there are further opportunities to be exploited. The results are usually compared with historical data of consumption per unit of product of the company itself or with its best performing industrial unit, or even with the best results reported by competitors. Such references do not help identify when the minimum is reached and how far the plant in question is from the minimal possible value.

Signs of the need to rationalize water use are shown by the increasing use of economic instruments, together with restrictions from environmental regulations [28-30]. To a greater or lesser extent, this tendency depends on the conditions that govern the water supply/demand in each region and the future prospects of this relationship.

#### 4. Developed Instruments: Importance and Difficulties

As mentioned before, the main instruments used to boost rational water use in industry will be described in detail in the second part of this paper [1]. In this first part, an attempt is made to show the importance of applying the whole method and the main difficulties related to the application of the instruments described. This division was made in order to facilitate the understanding of the goals and the paths chosen. At this point, the importance of the developed instruments and some difficulties that have arisen in employing them are highlighted:

[I1] A greater prospect of changing the paradigms was achieved by bringing academic and operational/industrial

knowledge together. This integration of the university with the shop floor of the factories engendered greater awareness about the use of water and the generation of effluents both at operation level as well as at management level. However, some companies had difficulty seeing the projects through.

[12] By incorporating the CP concepts through constant large-scale training, the possibility of introducing the concept of Clean Production became a key factor which led to the setting up of water balances and the identification of opportunities to reduce the use of water and generation of effluents. The training of personnel with the necessary skills to remain involved in the cooperative projects was also important. The main difficulty of implementing this tool lay in the scheduling of the workshops and training sessions both during and outside of working hours of the different teams.

[13] By means of the reconciled water balance, the extent that the instrument was able to characterize the water flows from the presumed flows could be determined; this included the upgrading of the system for managing the water balance of the company and the application of a method that could provide knowledge of the main aqueous streams of the system and thus enables a more rational water usage to be adopted in the process. Among the main difficulties that were encountered, the following can be highlighted: a lack of measurement, failure to calibrate already existing measuring devices; the presence of particular problems in the company such as leaks, lack of maintenance and supply lines that allow new leaks to become a constant problem; access to the technical documentation about the valves and equipment; access to the calibration records of the instruments; the existence of operational deviations and aqueous flows unknown to the operators.

[14] With regard to the bank of ideas, the relevant factors were as follows: devising an instrument to register and administer the ideas and opportunities regarding the rational use of water and reduction of effluents, the discovery of new technologies for the treatment and reuse of aqueous streams and generation of effluents, the identification of alternative sources of water (for example, underground and rainwater), the development of alternative systems to reduce the harvesting of water from external water sources and to meet production requirements, and the development of alternative systems that can lead to a reduction in water usage and the generation of effluents. The difficulties included the involvement of the technical team in the assessment of ideas and opportunities, the difficulty or impossibility of holding CP training sessions for the operators and registering new ideas, and the unreliability of the information for calculating the cost of treating the water and effluent.

[15] In the case of the geographical information system (GIS), the relevant factors were as follows: identifying opportunities for integrating water flows, carrying out consultative studies to obtain immediate replies to any kind of comparative information that might be useful in the search to find better ways of addressing the problem of the reuse/recycling of water with regard to the flows; representing the company in spatial terms by characterizing the local sites where water is consumed and effluent is generated and by displaying the information of each point in a geo-referenced database. The shortage of specific information from both water balance and hydrogeological study of the region was the main difficulty encountered.

[16] With regard to the optimization of the mass exchange networks (MEN), what stands out is the identification of a large number of opportunities for the reuse of intermediary water flows and the utilization of external flows. The difficulties include the following: working with real cases, which means multicomponent streams, and poor measuring devices together with a lack of historical data that often have not been consolidated; a lack of adequate information about the composition, flow and temperatures of the aqueous flows in the process; difficulties in attributing values to the maximum concentrations of a particular pollutant in the aqueous streams that enters each unit of the process; and last but not least, the fact that the development of methods that take into account multicomponent process streams is still in its infancy. For this reason, this instrument was never applied in the projects.

[17] The importance of an analytical tool for incorporating the company in the regional hydrological cycle is reflected in the following: outlining strategies for the improved use of water that take into account its quality and logistical factors; discovering alternative sources of supply and disposal; reduction in harvesting from the water sources that supply the population in the region and thus lead to a fair distribution of the water resources of the State of Bahia; reduction in energy consumption stemming from the harvesting of water, as well as from pumping effluents to the wastewater collection system; and consequently reduction in the costs arising from these treatment systems. At the same time, few studies have been carried out into the historic use of superficial and subterranean water and this makes it difficult to forecast future levels of demand.

[18] The instrument for planning conceptual projects can enable the company to introduce new ideas regarding the rational use of water and reduction of effluents in the process, and give continuity to their activities even after the project has been completed. The difficulty of obtaining historical data and the lack of measurements are the

main obstacles that have to be overcome.

[19] In auditing the sources of the effluents, attention is drawn to auditing the activities and procedures to reduce the volume of effluents in each industrial unity, seeking to improve the quality of the effluents by keeping the loss of products to a minimum. The lack of complete documentation of the whole process, as well as the costs and logistical factors related to the chemical analyses, are some of the difficulties faced in implementing this instrument.

In general, each cooperative project was affected by the following aspects: turnover of the team of trainees; the existence of divergent technical information; difficulty in gaining access to the company due to delays in issuing ID cards; lack of any clear procedure to be followed to gain access to the company and operational areas during operational shut down; public demonstrations blocking access to businesses; bureaucracy and sluggish performance in financial management by government agencies and last but not least, the little time available for the operators and engineers to contribute to the project.

The general results obtained during cooperative projects with chemical, metallurgical and petrochemical industries are presented in the next section. The name of each industry is hidden to preserve the confidentiality of information.

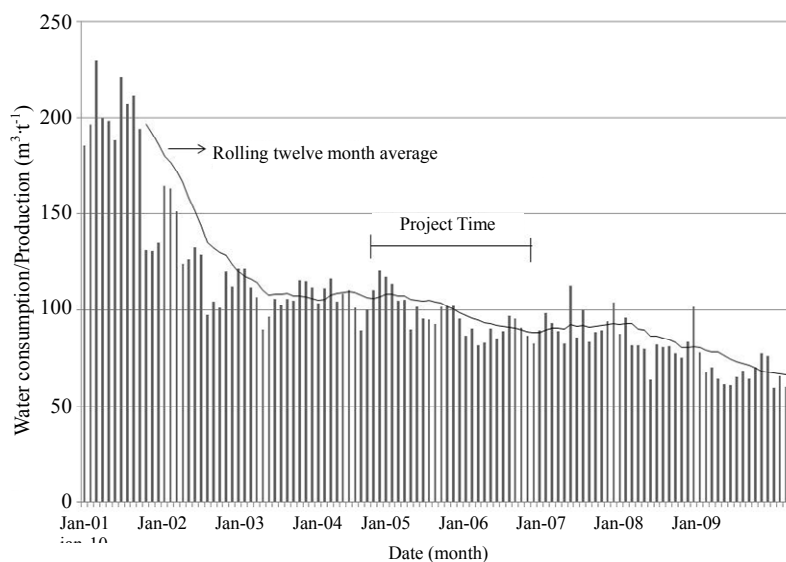
## 5. Results

The partnership between the university and the institutions has enabled a techno-operational culture to be formed that targets the environmental optimization of

industrial processes and an increase in eco-efficiency. This has resulted in significant reductions in water consumption and effluent production in all sites where the present method was applied. The constant presence of several researchers and trainees involved in projects concerning rational water use on the battery limits of the factory had a widespread beneficial effect that is imperceptible but is clearly borne out by the fact that there has been a reduction in the generation of effluent without any capital investment being required to tackle the problem.

This change remained evident even after the end of the project and continued for some time. **Figure 1** shows the pattern of water consumption in Company A.

**Figure 1** shows that the Company “A” had already taken measures to reduce water consumption before the project, leading to a significant decrease in water consumption up to 2002 when it reached a plateau then a slight decrease is observed. In 2004, the cooperative project started and lasted for two years. In the course of the project, the large-scale training sessions in CP led to a 13% reduction in water consumption, saving around 500 m<sup>3</sup>/h of freshwater, without any technological changes being put into effect [9]. After the project had been completed, the average water consumption was maintained for about two years and started to decrease again partly as a result of the implementation of studies based on the ideas bank collected during the course of the project. By the middle of 2009, the factory had managed to bring the rate of water consumption down to 42% of the level recorded in 2002. This case has been the subject of many comments in the Matrix International Corporation, in which this company is currently taking part [2].

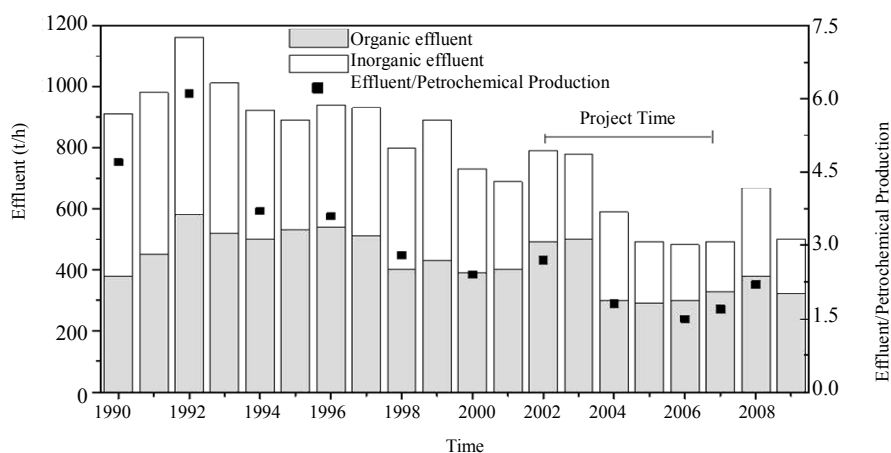


**Figure 1. Pattern of water consumption with particular regard to Company A (m<sup>3</sup> per ton of product). Source: adapted from Kiperstok, *et al.* [2].**

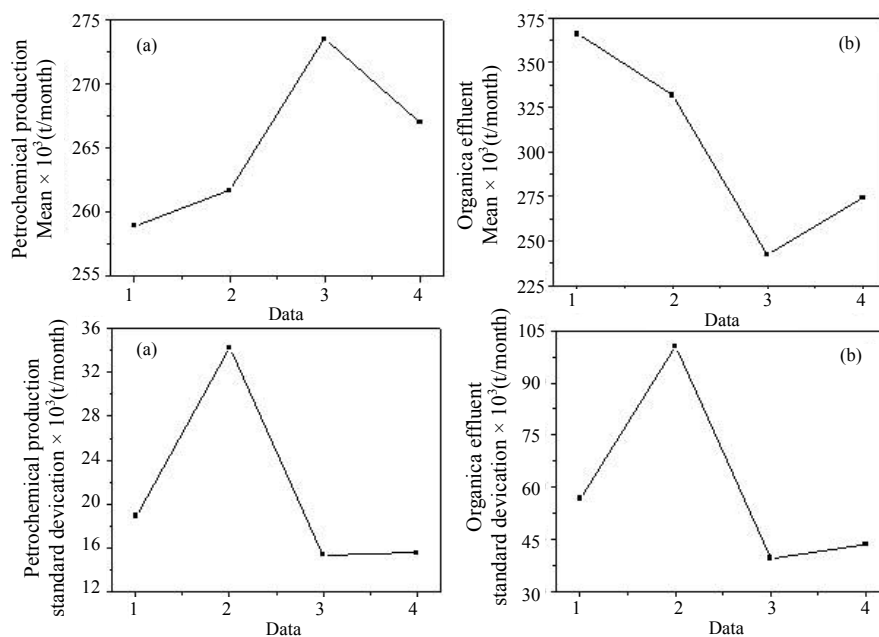
According to Kiperstok *et al.* [19], since the project in Company “B” was implanted, the company has experienced a continuous reduction in the generation of effluents (**Figure 2**). **Figure 2** shows that when the project researchers first went to the installations both inorganic and organic effluent generation had already fallen; moreover, the dispersion of the data was reduced [9]. The reduction in the generation of effluents since the beginning of the project was about 250 m<sup>3</sup>/h, and this corresponds to more than 40% of its historical value. This reduction was achieved in less than 2 years, that is, the period of the project [20]. As the ideas and conceptual projects for water consumption reduction had not been implemented or put into effect during this period of time,

this outcome was attributed to the fact that the operation staff had started to pay careful attention to water use [9,19].

After the end of this project in 2007, there was a rise in wastewater generation due to the occurrence of continuous industrial maintenance in the plant. Time series plots (**Figure 3(a)**) show a clear inverse relationship between the plant production stability and the organic effluent flow rate. The cause-effect relationship was confirmed by comparing the biannual mean ( $\bar{X}$ ) and standard deviation ( $S$ ) for both measurements (**Figure 3(b)**). The higher the standard deviation of the process output, the lower its stability. The effluent value grows as the  $S$  value goes up as seen in the lower graphs in **Figure 3**.



**Figure 2.** Historical data of wastewater generation in petrochemical industry B. Source: adapted from [2].



**Figure 3.** Control charts ( $\bar{X}$ -bar,  $S$ ) of the (a) petrochemical production (t/month) and (b) organic effluents (m<sup>3</sup>/h).

This strong correlation between the production of effluents and operational plant stability shown in **Figure 3** demonstrates that the maintenance of stable operation conditions is an important factor affecting water consumption in the process industry.

In the case of the cooperative project with Company C (**Figure 4**), downward trends in both water consumption and effluent production were observed. The project took place between June 2003 and August 2004 (see arrows indicating). The curve representing the consumption of clarified water, referenced on the left axis of the graph, indicates a 17% reduction in just one year. The specific production of effluent fell 43% during the project, and the total water consumption of Company C fell by 42%. Again, this result was obtained without any technological changes but with a more careful use of water in each process unity. The 42% reduction in the specific consumption of drinkable water suggests changes in the way water is used by each operator as there was no significant increase in the number of staff during the monitored period.

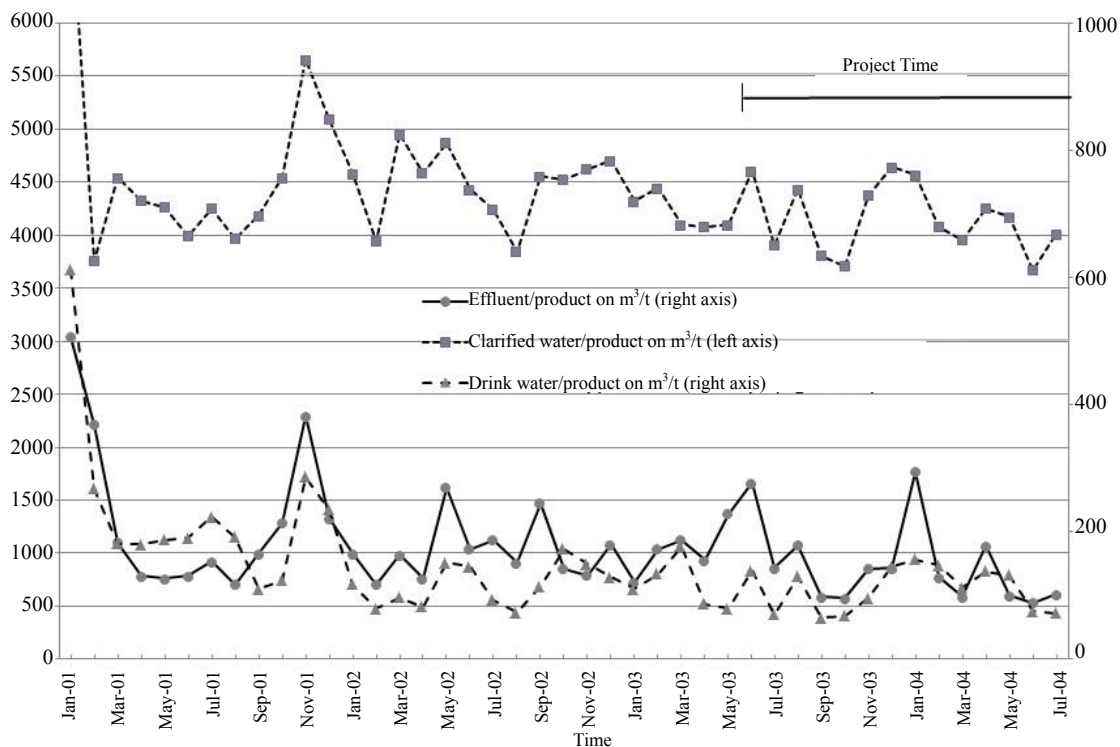
During the cooperative project with Company “D”, the reduction in water consumption was compromised because of the high content of organic compounds in the effluent. The focus on water reduction and reuse would have further increased the concentration of organic compounds in the effluent, which frequently exceed the limits stipulated by the environmental agencies. There-

fore, the focus of the project was changed to reducing pollution at source. The opportunities identified in the project and discussed with the company were implemented and contributed to a reduction of more than 20% in the cost of treatment during the project period (see **Figure 5**), corresponding to a yearly decreasing of about US \$650,000 in effluent treatment costs.

The peak in 2009 corresponds to a general maintenance shutdown of the plant. The best downward trend is identified from March to July 2010. This corresponds exactly to a monitoring period based on an opportunity. In April 2010, the UFBA team finished monitoring activities of this opportunity. After this period, without monitoring, there was an increasing of the effluent discharge. This demonstrates the importance of a close monitoring of the effluent load.

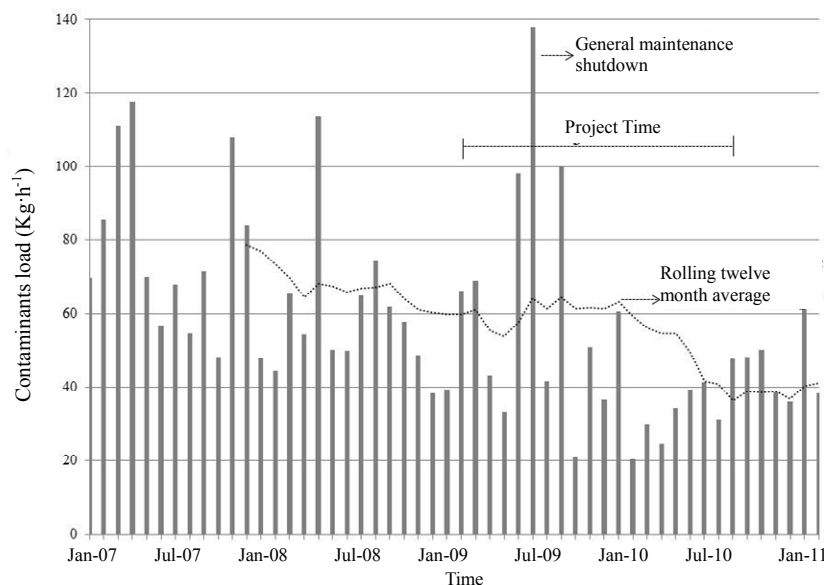
## 6. Conclusions

Water stress highlights the urgent need to promote changes in the productive sectors with respect to the rational use of water through the adoption of mechanisms to promote Cleaner Production (CP) and improve water management by companies. Priority should be given to the reduction at source instead of using the so-called “end of pipe” model in the search for higher levels of eco-efficiency.



**Figure 4.** Evolution of water consumption and effluent production in Company C. Source: adapted from Kiperstok *et al.* [2].





**Figure 5. Evolution of the cost of organic wastewater treatment in Company D. Source: Report of Project (not published).**

As exemplified by the results from Companies A, B, C and D, cooperative projects enable the development of a culture focused on technical and operational environmental optimization of industrial processes and increased eco-efficiency. The specific consumption of water was reduced by 20% as a consequence of the application of this method in Company A; a specific reduction in the generation of effluents of more than 40% was observed in Company B; a 42% fall in fresh water consumption in Company C; and a 20% decrease in the cost of effluent treatment in Company D. These relevant reductions in water consumption, waste production and the cost of effluent treatment have been obtained without major investment or technological changes.

The TECLIM method applied in these cases has helped to demonstrate that there is a need for measurement devices for water and effluent streams and a need to develop a reconciled water balance. These all require maintenance and calibration. The more precise information that they provide can improve the quality of knowledge about water flows inside the industrial plant and help identify new opportunities for more rational use of water.

The strong correlation between the production of effluents and operational plant stability observed in some cases demonstrates that this is an important factor affecting water consumption in process industries.

Water rationalization efforts should be directed to within production processes. A better understanding of the relationships that influence the consumption of natural resources and their management is required. The ini-

tiations or a structural process have considered the awareness of the staff to implement actions in the short or medium term. These initiatives have been motivated by the analysis of ideas presented by them and discussed with the entire project team. The simultaneous application of the instruments cited in the text lead to a permanent instigation of cultural changes in the modus operandi and modus of thinking in industry lasting after the end of projects.

The motivation of the operators and engineers who took part helped the progress of the projects, which is an important point in the method. Motivated employees promote demand for the project from the bottom up in the hierarchical structure. This awareness arises from a praxis that can be revolutionary and lasting and it was observed in all the teams involved in the projects that have been carried out, both from the university itself and in the teams from the companies taking part.

The significant reduction in water consumption and/or in the generation of effluents has brought environmental and economic benefits and led to a culture of Clean Production in the industrial environment. The results obtained have resulted in new partnerships being formed every year and awoken an interest in this research area. Apart from giving rise to new projects every year, the concepts devised and the method used have enabled progress to be made in the reuse of domestic and urban water and other lines of research in the TECLIM network.

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