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Reuse of effluent from dyeing polyester fibers by thermal fixation using acid-based colors

Reutilização do efluente de tingimento de fibras poliéster por termo-fixação com uso de corantes de base ácida

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Abstract

This paper aims to enable the study of water reuse in the seat belt webbing dyeing process, achieving larger economy in water consumption since textile operations use a great amount of water. In order to reach this goal, various products were tested during the treatment of such effluents which met the following characteristics: biodegradability, greater efficiency in removing color, compliance with legislation, and low cost. Using these new products, approximately 59% of water consumption and 30% of effluent treatment were reduced on a monthly basis. Taking into account these initial results, payback is expected in approximately five months.

Key words: Biodegradability. Energy and economic efficiency. Polyester fibers dyeing. Textile effluent. Water consumption and reuse.

Resumo

Neste trabalho, objetiva-se viabilizar o reuso de água no processo de tingimento de tira utilizada para cinto de segurança, alcançando uma maior economia no consumo de água visto que as operações têxteis utilizam grandes quantidades de água. Para atingir esse objetivo de reaproveitamento, foram testados vários produtos no tratamento desses efluentes que continham as seguintes características: biodegradabilidade, maior eficiência na remoção de cor, atendimento às legislações vigentes e custo baixo. Com esses novos produtos, foram reduzidos em um mês 59% do consumo de água, e 30%, do custo com o tratamento do efluente. Com base nesses resultados iniciais, é esperado um retorno desse investimento (*payback*) em aproximadamente cinco meses.

Palavras-chave: Biodegradabilidade. Energia e eficiência econômica. Consumo e reuso de água. Efluente de indústria têxtil.

1 Introduction

Due to the creation and implementation of increasingly restrictive environmental laws and to market competitiveness, which are determinants for companies to be more competent, in an environmental and productive vision, any increase in the industrial production demand is directly linked to lower input costs and generation of pollutants (ANA, 2005; CETESB, 1976, 2009; BRASIL, 2005).

The wide variety and complexity of effluents generated in dyeing processes, in addition to legislation constraints that require even more efficient treatments, have led to the development of new technologies and products that aim at better and more appropriate treatment, always considering cost, time, and efficiency of processes in the reuse of this treated effluent.

The best use of raw materials, water, energy, reduction in generated waste, among others, provides financial gain which can be accomplished by implementing a cleaner production. This can also bring an increase of competitiveness – by reducing costs of production – improving work environment and the image of the company in society and its collaborators.

This work presents tests made with biodegradable products for the treatment of effluent from an auto parts textile industry targeting the reuse of treated water in the seat belt webbing dyeing process.

The need to reduce water-borne waste and minimize water consumption in industries, in addition to legislation such as Law 9.433 from January 9, 1997 (PNRH, 1997), establishing the charge for water abstraction and effluent discharges, have been compelling the industry to change habits and processes related to water consumption, thereby making way for the use of effluent and low quality water in their facilities. One of the earliest concepts of water reuse came from the World Health Organization (1973), where effluent reuse is defined.

Direct reuse is the planned and deliberated use of sewage treated for certain purposes such as irrigation, industrial use, aquifer recharge, and drinking water. The indirect reuse occurs when the water is used, one or more times for domestic or industrial use, is discharged into surface or ground water, and used again downstream, in diluted form. Recycling is the reuse of water inside industries, aiming at saving water and controlling pollution (WHO, 1973).

Westerhoff (1984) classifies water reuse into two major categories: potable and non-potable. Potable reuse can be direct and indirect, where the latter is subdivided into aquifer recharge and increase of superficial sources, and non-potable reuse can be subdivided into urban, agricultural, recreational, environmental and industrial reuse, aquifer recharge, and aquaculture (EPA, 2004).

In order to take advantage of reuse, it is necessary to follow criteria and guidelines that can be found in publications of governmental agencies such as *Companhia Ambiental do Estado de São Paulo* – CETESB (2009), U. S. Environment Protection Agency – EPA (2004), and World Health Organization – WHO (1973), and consulting companies such as Metcalf & Eddy (2003) and researchers as Asano (1998), Barclay and Buckley (2000), and Vandevivere, Bianchi, and Verstraete (1998).

Currently, available technologies to try to achieve better quality parameters for water reuse can be physical, chemical, and occasionally biological. Treatments such as activated carbon adsorption, oxidation with ozone, chlorine dioxide and hydrogen peroxide, membrane separation (microfiltration, ultrafiltration, nanofiltration, and reverse osmosis), reverse electrolysis, ion exchange, distillation and chemical precipitation are the state of the art in regard to treatment of waste-water for reuse (MANCUSO; SANTOS, 2003; METCALF & EDDY, 2003; MIERZWA, 2005).

The effect caused by the effluent is pollution and it is recognized as the process in which, somehow, the properties of air or water are changed. The simple introduction of hot or colored water in a water flow is an act of pollution.

Webbing dyeing processes generate emissions of solid, gaseous, and liquid pollutants. Emissions of liquid pollutants cause major contamination and changing of environment, and depend on the type of fibers processed and chemicals used. Other factors that determine the quantity and quality of the effluent are the operations performed and the technology involved in its manipulation. According to Sanin (1997), the textile industry is one of the largest producers of liquid effluents, and these are usually colored, even containing small amounts of colorants. A predominant feature in this type of effluent is that it is not biodegradable, which is due to the high content of colorings (10 to 15% of unfixed dyes are discharged into rivers), surfactants, and additives which are usually organic compounds of complex structures.

There are two basic types of industrial waste generated in the webbing dyeing process which flows into wastewater treatment plants:

- The concentrated one resulting from the dyeing process (waste of dye, reductive and finishing baths).
- The diluted one resulting from the four washing boxes with water and washings of tinted kitchen floor and discharges from the boiler.

These wastes are flown into separate appropriate tanks and the treatment plant operates on a batch.

2 Material and methods

2.1 Method of effluent treatment

The treatment used is chemical, which is essentially a conversion of pollutants in a solid phase, called sludge, detachable from water purified by a process of decantation and filtration. The unit is very compact and the treatment process generates little sludge.

The sequence of effluent treatment is procedural, as in the following stages:

- The sequence of effluent treatment is procedural, as in the following stages:
- Transfers of waste in the proportions of 9/1 (diluted effluent / concentrated effluent) to the treatment tank.
- Standardization of the effluent with H_2SO_4 and pH in a range of 8 to 10.
- Addition of organic polymer for coloring removal.
- Addition of aluminum polyvinyl until pH is stabilized in a range of 6 to 7.
- End with the addition of polyelectrolyte 0.20% in order to flocculate, and the agitation continues up to a precipitation of flakes.
- Suspend the agitation and allow the treated effluent to rest for a minimum of 90 minutes. After this, the supernatant water is filtered and the precipitate (sludge) is transferred to the sludge tank, being sequentially transferred to the sludge thickeners.
- With the transfer process, the flakes formed, after the addition of the polyelectrolyte, break. In the process of sludge thickening, a proportion of polyelectrolyte is added in order to increase the number of flakes. In each thickening tank, there are four numbered valves so that the filtration can be done step by step and in an approximate 90-minute decantation.
- The water, clarified with small supernatant particles, is filtered by an activated charcoal

filter, from where it will be discharged into the pluvial drainage system (river).

2.2 Chemical treatment process using biodegradable products

Due to the inefficiency of products used in the effluent treatment – taking into consideration the reuse of treated effluents which did not remove colorings (important feature for reuse in dyeing) – we searched for products with new distributors. Products which had the following characteristics: biodegradability, coloring removal efficiency, low cost, and, most important, that met National and State legislation demands, regarding effluent discharge into rivers (ANA, 2005; CETESB, 1976, 2009; BRASIL, 2005). After undertaking several bench tests (Jar-Test) with new products and carrying out analysis of these treated effluents, the new distributor was chosen.

The chemical treatment consists of the following new products: coagulant – flocculant and decolorant; decolorant; amphoteric polymer anti-odor.

2.2.1 Coagulant – flocculant and decolorant

- This product is compatible with treatment processes both physical-chemical and biological.
- It has a better performance in the pH range between 6.5 and 7.0.
- It has high yield in waters with a heavy load of contaminants – producing high-speed coagulation – less acidic than other coagulants, thus providing a considerable reduction in sludge formation.
- Great sequestering and dispersing effect, both in acidic and alkaline liquids, not generating nitrogen in effluent, so it can quickly required biochemical oxygen demand (BOD) and chemical oxygen demand (COD) required.
- It allows total reuse of water for dyeing, tanning, and stamping.

2.2.2 Decolorant

- Organic biodegradable technology formaldehyde free, used in water coloring removal of industrial effluents, particularly from industries using colorants, both natural and synthetic (textile, pulp and paper, etc.).
- The product acts destabilizing colloids in waste-waters through the formation of flocks.
- It is compatible with the treatment processes both physical-chemical and biological.
- This product has the best performance in the pH range between 6.4 and 6.7.

2.2.3 Amphoteric polymer

- It is an amphoteric polymer of high molecular weight, used in the separation of liquid-solid in the funnel and flotation systems in steel mills, sugar and alcohol plants, textile industries, tannery, pulp and paper industries, mining, etc.

  It is a biodegradable product.

2.2.4 Anti-odor

- Composition of special products, with anti-odors features.
- It is characterized by its capability to prevent the formation of odors from the decomposition of organic material, usually found in biological effluent treatment, both anaerobic and aerobic.
- It eliminates odors quickly, and its lasting efficiency lasts throughout the process.

3 Results and Discussion

Two tests with different processes were carried out: a chemical treatment process using biodegradable products and analysis of the result with the change of chemicals.

The treatment of effluents with the new product has the following stages:

- Set the pH of the effluent with sulfuric acid in the pH range from 8 to 10.
- Add the coagulant – flocculant and decolorant to the pH range of 6.5 to 7.0.
- Add decolorant that performs best with a pH range of 6.4 to 6.7.
- Add the amphoteric polymer to cause the separation of liquid-solid.
- Use hydrosulfite to assist in coloring removal and, in sequence, apply the anti-odor to inhibit odor.

The stages of the waste-water treatment with the new products are shown in Figure 1.

3.1 Analysis of results with the change of chemicals

3.1.1 Cost of chemicals

The currently used chemicals were effective in the treatment of waste water in accordance to National and State laws of effluent discharge into rivers (ANA, 2005; CETESB, 1976, 2009; BRASIL, 2005), but they had never been considered the most suitable products for the purpose of reusing treated effluents in the dyeing process, and their cost was very high as well (BARCLAY; BUCKLEY, 2000).

Tables 1 to 3 show the comparison of the monthly cost of current treatment and treatment with biodegradable products, demonstrating a cost reduction of 30%.

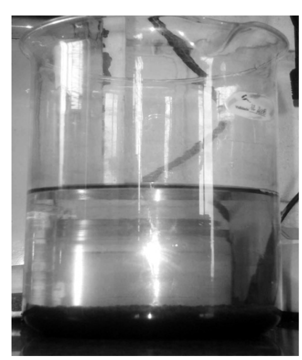
Table 1: Monthly cost of current treatment

NEW PRODUCTS (BIODEGRADABLE)	Monthly consumption (m^3)	Monthly value (US$)
Coagulant – flocculant and bleaching	5,200	3,882.40
Decolorant	600	1,647.15
Anti-odour	300	2,377.70
Amphoteric polymer	25	287.16
Sulphuric acid	8,400	5,547.90
Total	**14,525**	**13,742.31**

Stage 1

Stage 2

Stage 3



Stage 4

Figure 1: H_2SO_4 added to the effluent (stage 1); coagulant – flocculant and bleaching added to the effluent (stage 2); amphoteric polymer added to the effluent (stage 3) and sodium hydrosulfite and anti-odor added (stage 4)

Table 2: Monthly cost of treatment with biodegradable products

PRODUCTS USED IN CURRENT TREATMENT	Monthly consumption (m^3)	Monthly value (US$)
Aluminium polyvinyl	3,900	4,591.66
Organic polymer	900	2,661.96
Polyelectrolyte 0.20%	600	4,307.37
Sulphuric acid	9,600	6,340.45
Total	**15,000**	**17,901.45**

Table 3: Monthly cost comparison of current treatment and treatment with biodegradable

MONTHLY ECONOMY WITH NEW PRODUCTS	3%
ANNUAL ECONOMY WITH NEW PRODUCTS (Monthly Value)	30%

3.1.2 Water consumption

In the manufacturing plant of webbing used in safety belts, 1,229 m^3 of water is consumed on average per month (PETERS; TIMMERHAUS, 1991). With the treated effluent reuse project in dyeing processes (cleaning machinery at each change of status from black webbing to colorful webbing, preparation of reductive baths, recirculating water in the tanks for washing, preparation of polymers in WTP, and cleaning the floors in general) and with the installation of a 20 m^3 tank for treated water abstraction there will be, on average, a reduction of 59% in monthly water consumption as shown in Table 4.

3.2 Treatment process using ultrafiltration equipment

Figure 2 shows the flowchart of a typical process of ultrafiltration. All the stages are described in detail, as follows.

Figure 2:

Stage 1: the test consisted in performing a mixture 9/1 – diluted and concentrated approximately 2,500 liters. Set the pH to the range of 7 to 8 with sulfuric acid, and the mixture is sent to the ultrafiltration machine (as shown in Figure 2).

Table 4: Consumption, monthly water usage and proposal to reduce water consumption

Year base: 2008	Water consumption (m^3)	Monthly value (US$)
January	1,519	5,172.62
February	999	3,411.43
March	1,091	3,734.19
April	1,708	5,845.41
May	968	3,299.01
June	1,215	4,134.42
July	595	2,063.63
August	1,351	4,615.51
September	987	3,349.80
October	1,158	4,049.46
November	1,596	5,655.16
December	1,561	5,536.20
Annual cost	14,748	50,866.83
Monthly ratio cost	1,229	4,238.90
Proposal for monthly water consumption reduction	729	2,514.37
Proposal for annual water consumption reduction	11,148	38,768.09

After passing through the machine membranes, the water kept its coloring and lost all its solids. This water was analyzed by AMPRO Laboratories and met the standards established by current legislation, except for the coloring (the item Ammonia vanished – analysis report # 0409026 AMPRO Laboratories – maximum value allowed: 5.0 mg/L; value found: <0.001).

An amount of 2.5 m³ of water was treated, returned to the tanks, and was treated again in the physical-chemical process.

All data was recorded in a spreadsheet for controlling outflow and membrane saturation. In the beginning: 59 seconds for 1 liter; in 24 hours: 2'39" for 1 liter.

Stage 2: for coloring removal: after repeating all steps of the first stage, the colored water passes through a charcoal filter with particle size "8/25 mesh", according to indication from the sanitation company.

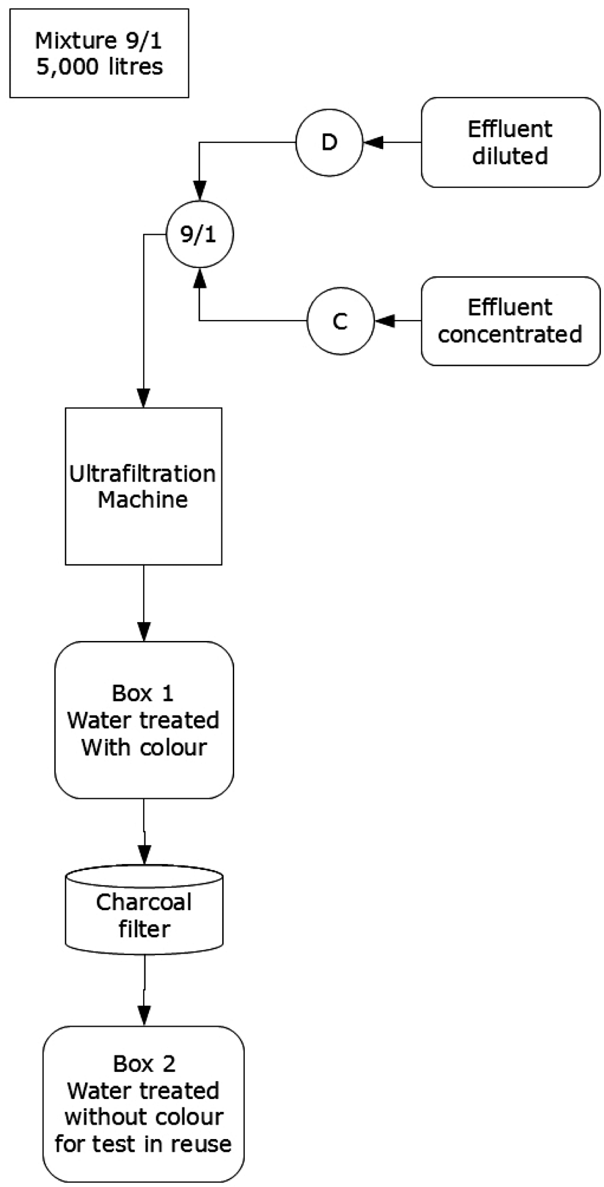


Figure 2: Schematic diagram of ultrafiltration process

The bench test with charcoal was carried out and the coloring was removed. A 1.5 m³ sample was treated and the maintenance personnel were then expected to install the water tank #2 in the containment area so that the tests with charcoal could be carried out and the water reused in production processes.

The water was filtered in a charcoal filter which resulted in the coloration shown in Figure 3.

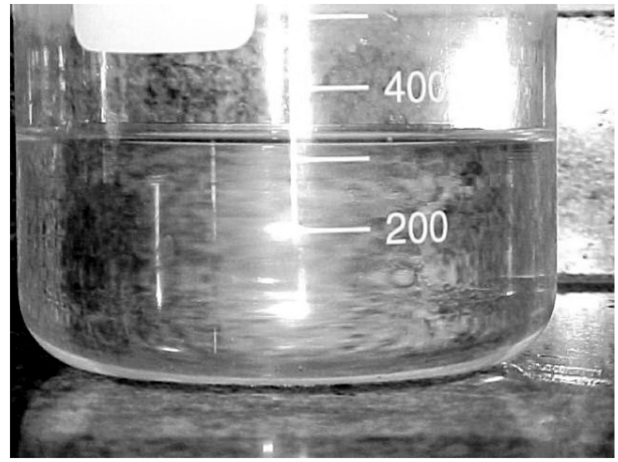


Figure 3: Water after completion of stage 2

This water was stored in cylinders and reused in washing boxes in the dyeing processes.

This test was approved, according to the quality report presented by the responsible laboratory.

Based on these two tests, analysis of the results of the ultrafiltration system can be performed.

3.2.1 Analysis of results of the ultrafiltration system

The ultrafiltration system showed efficiency in the results of treated water, but the cost of its implementation would require a drastic change in the existing layout. Due to this factor, it should be re-analyzed when the need of adaption in the new plant occurs.

By using biodegradable chemicals, the water can be reused in the seat belt webbing dyeing processes and the preparation of polymer in the WTP, thus considerably reducing water consumption. The use of these products in effluent treatments was efficient and there was no problem in implementing this product in the process. There was no change in the process flowchart – as can be seen in Figure 4 – only more products were added from the new treatment.

Table 5 shows results obtained with some specific tests and visual inspection of these samples.

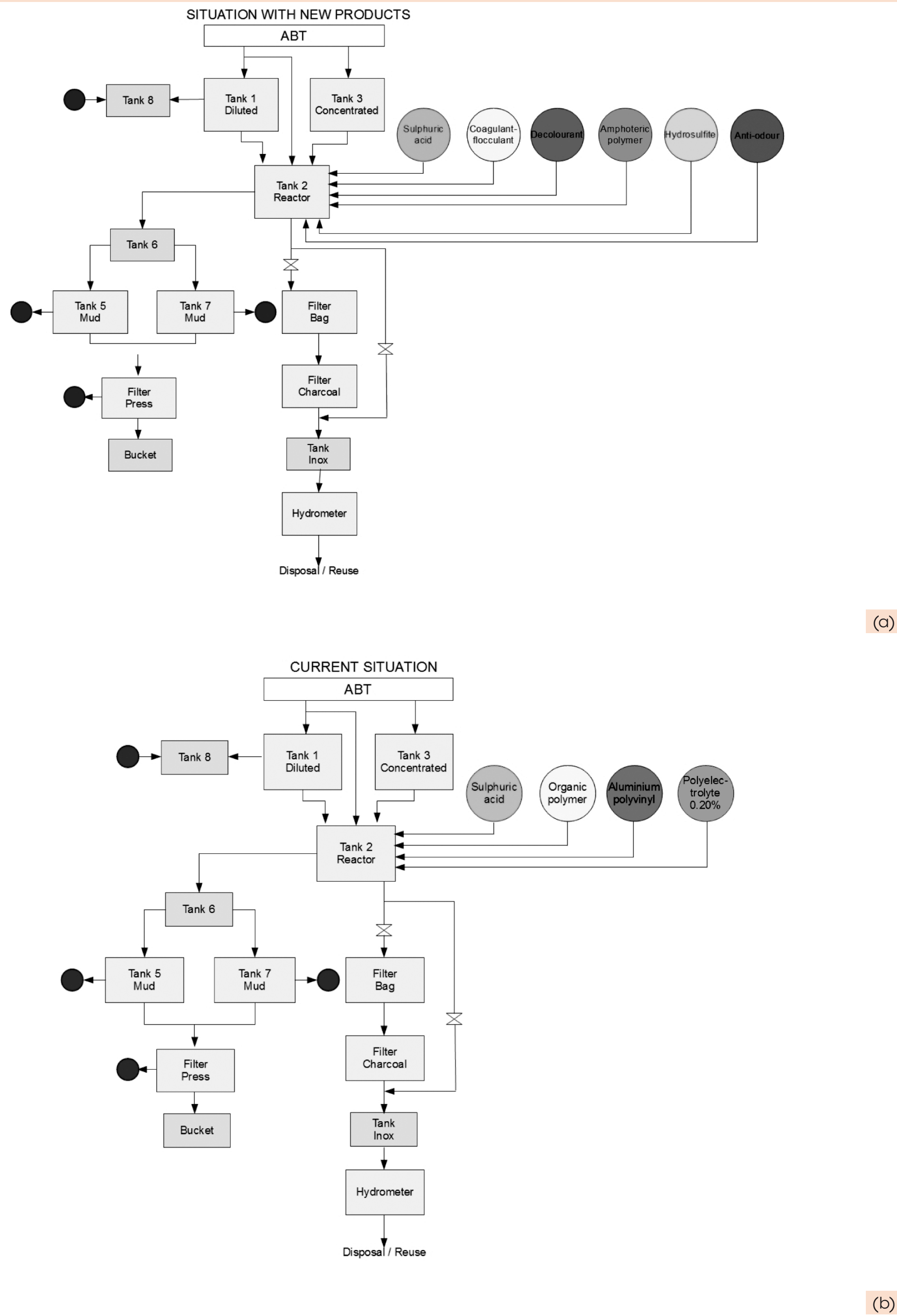
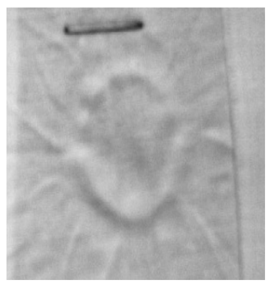
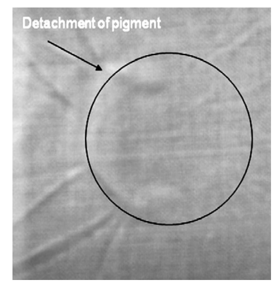
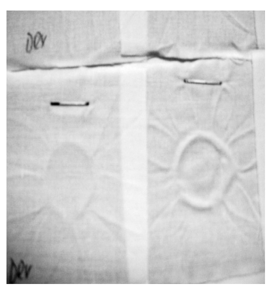
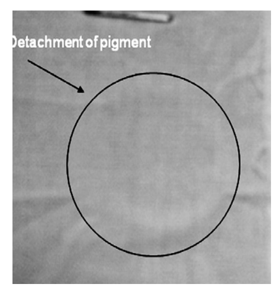
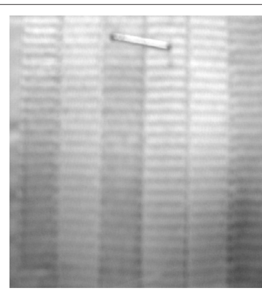
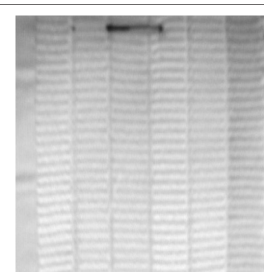
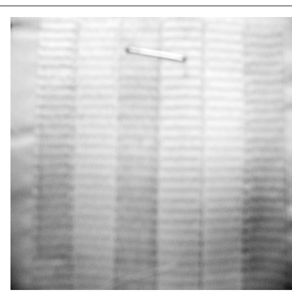


Figure 4: Comparison between the flowchart of current treatment process (A) and the flowchart of the proposed treatment process with new products (B)

Table 5: Comparison of 10 samples in 5 different tests

Test	Biodegradable chemicals used in samples	Current chemicals used in samples
Perspiration with permeable filter	 Result: OK	 Result: NOK
Crockmeter with ethanol in the final product	 Result: OK	 Result: NOK
Crockmeter with permeable filter	 Result: OK	 Result: NOK
Crockmeter with permeable filter in product 4011	 Result: OK	 Result: NOK
Crockmeter with permeable filter in product 7050	 Result: OK	 Result: NOK

4 Conclusion

Based on the results obtained in the technical and economic analysis, conclusions are that, in order to implement the new technologies or products used in effluent treatments, aiming at a better use of natural resources, and also its minimization, it will be necessary to considerably reduce water consumption and therefore its cost. In this new proposal, about 59% of the cost of water and 30% of the cost for effluent treatments were reduced on a monthly basis. Payback is expected with this investment within five months.

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