CHEMICAL ENGINEERING TRANSACTIONS

VOL. 32, 2013

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

Chief Editors: Sauro Pierucci, Jiří J. Klemeš

ISBN 978-88-95608-23-5; **ISSN** 1974-9791

DOI: 10.3303/CET1332013

Applying of a Neural Network in Effluent Treatment Simulation as an Environmental Solution for Textile Industry

Jorge M. Rosa[a, b, c], Kleber R. M. Prado[a], Wonder A. L. Alves[a], Fabio H. Pereira[a], José C. C. Santana[a], Elias B. Tambourgi*[c]

[a]UNINOVE, Industrial Engineering Post-Graduation Program, Av. Francisco Matarazzo, 612, Água Branca, Zip Code: 05001-100, São Paulo, SP, Brazil
[b]Textile School of SENAI, Rua Correia de Andrade, 232, Brás, Zip Code: 03008-020, São Paulo, SP, Brazil
[c]UNICAMP, School of Chemical Engineering, Av. Albert Einstein, 500, Post Code: 6066, Zip Code: 13083 – 970, Barão Geraldo, Campinas-SP, Brazil
eliastam@feq.unicamp.br

Considerable attention has been given to issues associated with the presence of colored compounds in aqueous wastewater generated from textile industries, since water is the only efficient carrier for dyes and other compounds that are used in the dyeing and finishing processes. An average textile finishing company uses 100,000 – 150,000 liters of water per ton of textile material treated. This work aimed a simulation of the biodegradation of a dye in textile process using a perceptron multilayer neural network. A 2^{4-1} experimental design has been drawn up to study the effect of dye (0.01-0.18 g/L), glucose (0.66-2.43 %, w/v), microorganism (0.16-1.84 mL/L) concentrations and pH (5.3-8.7), on dye biodegradation index. *Pseudomonas oleovorans* was used in biodegradation of Remazol Brilliant Blue R. Experimental results used to validate the proposed numerical approach. The best conditions have found at 0.15 g/L of dye, pH 8, 1.5 mL/L of microorganism and 1 g/100 mL of glucose, while a dye biodegradation index of 96% was achieved. The perceptron multilayer neural network has been efficiently in simulation of dye biodegradation on reduced conditions of data set.

1. Introduction

The concept of innovation has been used in a wide range of contexts and theoretical development has proven extremely valuable, providing important insights into intra-market competition, strategies and regulatory policies. The industrial processes offer a fertile field for progress in the theory-building process regarding innovation, especially with the introduction of alternative clean technologies (Giraçol et al. 2011; Passarini et al. 2012).

There are over than 100,000 commercially available dyes with more than 7 x107 tons of dyestuff produced annually worldwide. Its production in Brazil reaches 26,500 ton per year (Silveira et al., 2009a; 2009.b; Ulson de Souza et al. 2007). These dyes are widely used in a number of industries, such as textiles, food, cosmetics and paper printing, with the textile industry being the largest consumer of dyes (Pandey et al. 2007). Considerable attention has been given to issues associated with the presence of colored compounds in aqueous wastewater generated from textile industries, since water is the only efficient carrier for dyes and other compounds that are used in the dyeing and finishing processes. An average textile finishing company uses 100,000 – 150,000 liters of water per ton of textile material treated (Mohajerani et al. 2011).

Environmental biotechnology is constantly expanding efforts in the biological treatment of dye-contaminated wastewater. Although numerous microorganisms are capable of decolorizing dyes, only a few are able to mineralize these compounds into CO2 and H2O (Junghanns et al. 2008). Under aerobic conditions, azo dyes are not easily metabolized by bacteria; however, under anaerobic conditions, several bacterial strains, including Pseudomonas oleovorans, can enzymatic reduce the azo bonds in the dye molecule to produce colorless by-products (Silveira et al. 2009).

Please cite this article as: Rosa J.M., Prado K.R.M., Alves W.A.L., Pereira F.H., Santana J.C.C., Tambourgi E.B., 2013, Applying of a neural network in effluent treatment simulation as a environmental solution for textile industry, Chemical Engineering Transactions, 32, 73-78 DOI: 10.3303/CET1332013

Due to their toxicity and low biodegradability of azo dyes, it is suggested to take advantage of more effective treatment methods such as advanced oxidation processes (AOPs) for destruction of these compounds in wastewater (Kim et al., 2004; Mohajerani et al. 2011). Several researches on dye degradation have done, to improve the textile effluent quality (Aleboyeh et al. 2007; Guimarães et al. 2008; Gumarães and Silva 2007; Mohajerani et al. 2011; Zarei et al. 2010). However, the main cost of Fenton reaction process with H2O2 is a disadvantage. Other problem, is that the higher addition of Fe2+ resulted in a brown turbidity that causes there combination of hydroxyl radicals and Fe2+ reacts with hydroxyl radicals as a scavenger and there is a need to remove this contaminant from the effluent, which raise the cost of the process (Kim et al. 2004).
Current, the artificial neural networks (ANN) have contributed to research fields for they are applied in search of solver to complex problems. As in mechanical engineering, where a perceptron multilayer algorithms have been developed to diagnostic the failures in induction motor (Villada and Cadavid 2007) and to determining the roughness number on motor parts (Alves et al. 2011). In management, where an ANN algorithm has been developed to monitoring the light, temperature, moisture and others conditions of the working environment and its influence on the behavior of employees of a company (Henriquéz and Palma 2011). In environmental sciences, a retro propagation ANN algorithm has applied to predict the pollutant flow in saturated, homogeneous and isotropic mediums (Garcia et al. 2010), or in the prediction of azo dye decolorization by UV/H2O2 (Aleboyeh et al. 2007), or in the modeling of phenol degradation (Balan et al., 1999. In food sciences, an ANN Kohonen algorithm has used to group the wine samples from Barbados cherry (Curvelo Santana et al. 2010).
The prediction of biodegradation index of Remazol Brilliant Blue R dye (RBBR) by use Pseudomonas oleovorans yeast have been evaluated in this study. Thus a perceptron multilayer neural network has been used in order to estimate the best condition of the biodegradation of RBBR dye and contribute for sustainable development in textile industrial process. Experimental results were used to evaluate and validate the proposed numerical approach.

2. Material and Methods

2.1. Material

The microorganism was obtained of Brazilian Collection of Industrial and Environmental Microorganisms from State University of Campinas, Brazil, previously identified as *Pseudomonas oleovorans* (CMAI 703). R8001 - Remazol Brilliant Blue R (RBBR) dye (CI: 61200, EC: 219-949-9, Empirical Formula: $C_{22}H_{16}N_2Na_2O_{11}S_3$, Molecular Weight: 626.54 and Synonym: Reactive Blue) was provided by Department of Chemical Engineering from Federal University of Sergipe, Brasil. Glucose, potassium phosphate mono- and di-basic were provided by Merck (Darmstadt, Germany).

2.2. Design and experimental system

An experimental design 2^{4-1} as shown in Table 1 was drawn up to study the effect of dye (**C_{dye}**, mg/L), glucose (**$C_{glucose}$**, g/100 mL), microorganism (**C_{mo}**, mL/L) concentrations and pH (**pH**), in initial time, on dye biodegradation index (**%Bio**). Experimental planning was done of according to Barros Neto et al. (2007), Biazus et al. (2009); Coppini et al. (2011). The experimental studies were carried out in a 250 mL conical flasks containing mineral medium and inoculated with *P. oleovorans* at 180 rpm, temperature and pressure at home (27°C and 1 atm) in an orbital shaker, for seven days. After which time, samples were centrifuged and its dye biodegradation were estimated of 4 in 4 h, by a spectrophotometer at 600 nm (Silveira et al. 2009). The dichromate ion method was used to determine the COD content (Standard Method 5220 D). The iodine-metric method (Winkler method) has been used to determine the OD concentration on zero and five day times for measurement of BOD_5 content. The titrating metric method (Walkley-Black method) was used to determine the TOC content. All methods are shown in APHA (1995); Passarini et al. (2012) and Ulson de Souza et al. (2010). The codification of the variables is:

$$x_1 = \frac{(C_{dye} - 0.1000)}{0.0500} \quad (1), \qquad x_2 = pH - 7.000 \quad (2),$$

$$x_3 = \frac{(C_{mo} - 1.000)}{0.500} \quad (3) \quad \text{and} \quad x_4 = \frac{(C_{Glucose} - 1.0000)}{0.500} \quad (4)$$

The dye biodegradation index was given for (Rosa et al., 2009; Silveira et al. 2009a, 2009b):

$$\%Bio = \frac{(C_{dye}(initial) - C_{dye}(end))}{C_{dye}(Initial)} * 100 \quad (5)$$

The experimental results from Table 1 have been used to evaluate and validate the bootstrapped and perceptron multilayer neural network model.

2.3. Perceptron multilayer neural network configuration

The present paper used the neural network toolbox available in the Mathlab software in order to proceed with the training method. A perceptron multilayer neural network, using a backpropagation algorithm, was used due its capability of learning in this type of application. The neural architecture used for solving the biodegradation problem comprises two neuron layers. The first layer comprises 16 neurons while the second layer has 24 neurons (Aleboyeh et al., 2007; Alves et al., 2011; Curvelo Santana et al., 2010; Villada and Cadavid, 2007). The original data set, obtained from the experimental design (Table 1) was used to train the neural networks. Figure 1 shows the neural implementation for the biodegradation purpose.

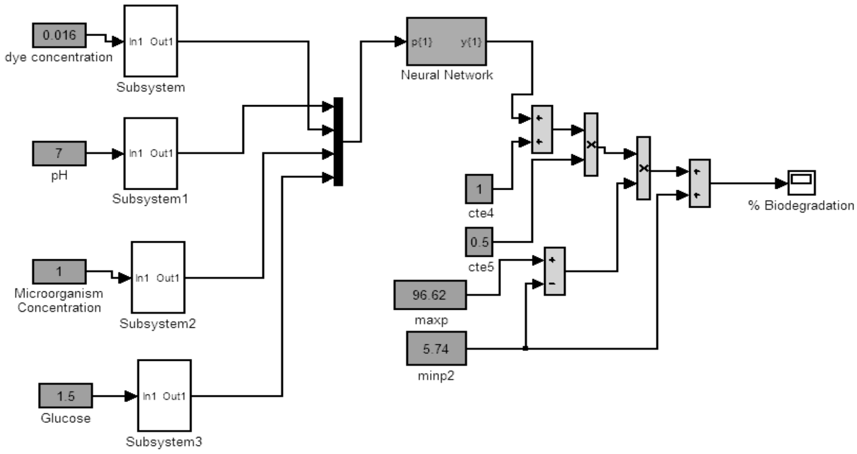

Figure 1. The neural network configuration for the perceptron multilayer neural network technique.

3. Results and Discussions

Figure 2 shows the result related to the error variation obtained during the training phase for the perceptron multilayer neural network. The performance achieved by the present training method, near $1x10^{-5}$, allows the good approximation of the output data when compared to the results expected by the conventional techniques. This demonstrate that neural network technique are good tool for simulate dye biodegradation process; as can be observed by Aleboyeh et al. (2007) and Guimarães et al. (2008) for simulation of the azo decolorization by UV/H_2O_2, by Balan et al. (1999) for simulation of the phenol degradation and by Zarei et al. (2010) in the photoelectro-fenton degradation of an azodye using supported TiO_2 nanoparticles and carbon nanotube cathode. Additionally, the results of the proposed approach were also compared with the experimental data. The performance of a linear regression between the network response and the corresponding target are presented in Figure 3. The proposed model presented remarkable coefficient of correlation between real and predicted values for the biodegradation rate, above 0.9; it is accordance Figure 3.

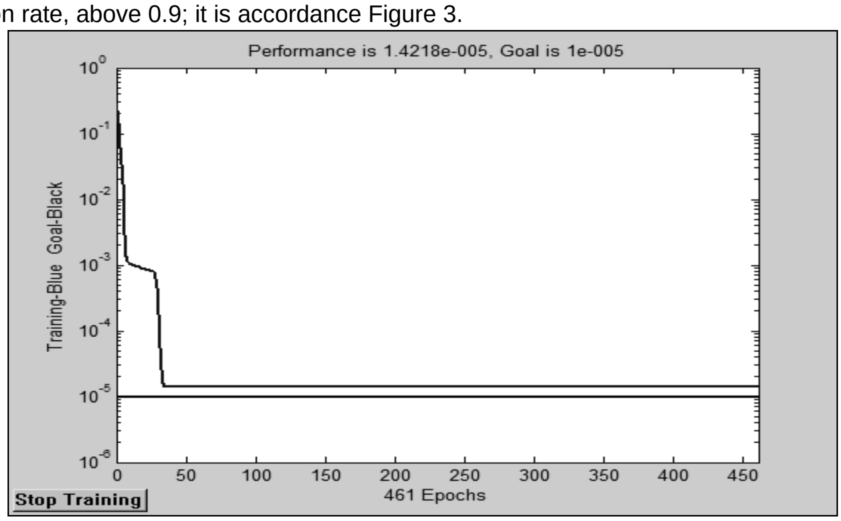

Figure 3. Error variation during the training process of the neural network

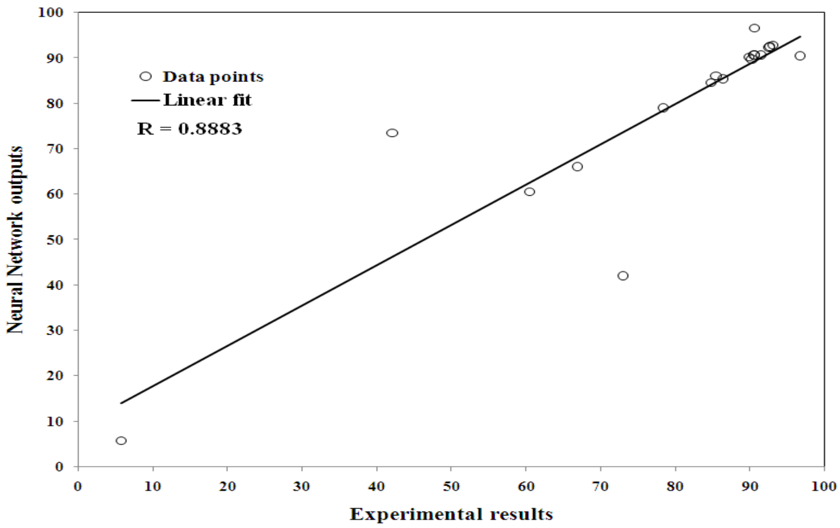

Figure 3. Linear regression results for the neural network approach

Table 1 shows a comparison of the experimental results of the dye biodegradation with the results obtained by perceptron multilayer neural network. By observing the assays 2 and 3 and 6 and 7 of the neural network, it is perceived that there was an inversion of values; it caused an incorrect prediction by reversing the values of the positions 2 to 3 and 6 to 7. Of according to Panchal et al. (2011), this error is common in simulations using back propagation neural network and it gives a false interpretation of the optimal conditions from this reaction system. This problem usually occurs in experiments with small number of assays, such as factorial designs. However, as the neural network showed a tendency is more indicated the use its optimal condition than experimental optimal condition from original data set of biodegradation index (**%Bio**). Thus, from Table 1, the best result was found at 0.15 g/L of dye concentration, 1.5 mL/L of *P. oleovorans* content and 1 g/100 mL of glucose concentration at pH 8, while a biodegradation index of 96% was achieved. This demonstrates that the *P. oleovorans* are very efficient in the dye removal and, its results are similar than photo-Fenton (Aleboyeh et al. 2007; Guimarães and Silva 2007; Kim et al. 2004; Zarei et al. 2010) and *P. pictorum* treatments (Balan et al., 1999), higher than precipitation (Kim et al., 2004), active sludge and membrane processes (Sahinkaya et al. 2008).

Table 1. The experimental design to study of the dye biodegradation

Assay	C_{Dye} (g/L)	pH	C_{mo} (mL/L)	$C_{glucose}$ (%)	%Bio Experimental(%)	%Bio Predicted (%)
1	0.05	6	0.5	1	60.463	60.525
2	0.05	6	0.5	2	72.933	42.080
3	0.05	8	0.5	2	42.035	73.550
4	0.05	8	0.5	1	78.324	79.060
5	0.15	6	1.5	2	92.613	92.610
6	**0.15**	**6**	**1.5**	**1**	**96.621**	**90.520**
7	**0.15**	**8**	**1.5**	**1**	**90.531**	**96.620**
8	0.15	8	1.5	2	92.520	92.450
9	0.1	7	1	1.5	90.503	90.720
10	0.1	7	1	1.5	90.445	90.720
11	0.1	7	1	1.5	91.387	90.720
12	0.1841	7	1	1.5	89.799	90.280
13	0.0159	7	1	1.5	85.362	86.120
14	0.1	8.682	1	1.5	90.191	89.790
15	0.1	5.318	1	1.5	86.322	85.460
16	0.1	7	1.841	1.5	93.047	92.940
17	0.1	7	0.159	1.5	84.718	84.640
18	0.1	7	1	2.341	66.829	66.120
19	0.1	7	1	0.659	5.7394	5.740

C_{dye}, C_{mo} and $C_{glucose}$ are, respectively, the concentrations of dye, microorganism and glucose; %Bio is the biodegradation index.

According to Balan et al. (1999) and Silveira et al. (2009b), the *Pseudomonas* yeasts, when are adapted to medium, at the end of nutrients they use the dyes as a substrate to survive. This occurs because they have the ability to release several enzymes (catalases) in the reaction, able to catalyze the decomposition of the carbonic and azo links.

In the best condition, the ecological parameters were measured and it are shown in Table 2. It was observed a higher percent of removal for all parameters. Results showed into Table 2 were better than those found by Catanho et al. (2006); which studied the electrochemistry oxidation of three textile dyes (Remazol black B, Remazol Brilliant Orange 3R and Remazol Golden Yellow RNL) using electrochemical and photoelectrochemical methods. They observed that for all the dyes studied, the photoelectrochemical method was demonstrated to be more efficient than the electrochemical one. Photoelectrochemical oxidation resulted in complete decoloration after 90 min of electrolysis and total organic carbon (TOC) removal reached up to 36%. Wu et al. (2008) have shown a new technique for dye removal by ozone oxidation on presence of UV light and metals (Mn, Mg or Ti) for degradation of CI reactive red 2, obtaining good results and a reduced time to discoloration of 5 min. However, the reduction of TOC has not been effective.

This indicates a problem in methods of photochemical oxidation, the lower reduction or lack of maintenance of TOC. The study by Du et al. (2012), with metal-dye complex Acid Black 172 indicated that the biomass from *Psedomonas sp*. have gotten a higher permeability of the cell walls and denatured the intracellular proteins. The results of biosorption experiments by different cell components confirmed that intracellular proteins contributed to the increased biosorption of dyes. This favors the removal of the TOC, COD and BOD, as seen in this study. Ulso de Souza et al. (2011) have shown that by combination of oxidations and biological processes can obtain good results in reduction of COD content.

Table 2. Measured parameter to the best experimental conditions of RBBR biodegradation

Parameter	Initial	End	% Removal
TOC (mg/L)	4047	2.055	99.95
COD (mg/L)	10150	28.22	99.72
BOD (mg/L)	6394	5.089	99.92

4. Conclusions

According to multilayer perceptron neural network the best condition to biodegradation the Remazol Biliant Blue R was found at 0.15 g/L of dye, pH 8, 1.5 mL/L of microorganism and 1 g/100 mL of glucose, while a biodegradation index of 96% have been achieved.

The proposed approach could be useful for problems in which the initial collected data set is very small, the magnitude of variable effects is ambiguous and the data gathering costs are high. Efficient methods to estimate a full biodegradation of textile industrial process may be useful to contribute for the sustainable development of the textile companies.

Acknowledgement

Authors would like to thank Nove de Julho University for the financial supports.

References

Aleboyeh A, Kasiri MB, Olya ME, 2007. Aleboyeh H. Prediction of azo dye decolorization by UV/H_2O_2 using artificial neural networks. Dyes Pigm. 77: 288-294.

Alves ML, Ferreira BB, Leta BFR., 2011. Evaluación de parámetros de rugosidad usando análisis de imágenes de diferentes microscopios ópticos y electrónicos. Inf. Tecnol. 22(4): 129-146.

Anbia, M.; Salehi, S., 2012. Removal of acid dyes from aqueous media by adsorption onto amino-functionalized nanoporous silica SBA-3. Dyes Pigm. 94: 1-9.

APHA (American Public Health Association), 1995. Standard methods for the examination of water and wastewater. Washington: American Public Health Association.

Balan, SM, Annadurai G, Sheeja RY, Srinivasamoorthy VR, Murugesan T., 1999. Modeling of phenol degradation system using artificial neural networks. Bioproc Eng. 21: 129-134.

Barros Neto B, Scarminio IS, Bruns RE., 2007. How to experiments: research and development in industry, third ed. Campinas, SP, Brazil: EDUNICAMP.

Biazus JPM, Souza RR, Márquez JE, Franco TT, Santana JCC, Tambourgi EB., 2009. Production and characterization of amylases from *Zea mays* malt. Braz Arch Biol Technol. 52(5): 991-1000.

Catanho M, Malpass GRP, Motheo AJ., 2006. Avaliação dos tratamentos eletroquímico e fotoeletroquímico na degradação de corantes têxteis, Quim Nova. 29: 983-989.
Coppini N L, Santana JCC, Baptista EA, da Rosa DB, Alcantara A., 2011. Experimental Design Applied to the Machining of Windows Cage Ball Joints Homokinetic SAE 8620 Steel with CBN Tool. Adv Mater Res. 223: 573-578.
Curvelo Santana JC, Dias CG, Souza RR, Tambourgi EB., 2010. Applying of neural network on the wine sensorial analysis from Barbados cherry. J Food Process Eng. 33: 365-378.
Du L-N, Wang B, Li G, Wang S, Crowley DE, Zhao Y-H., 2012. Biosorption of the metal-complex dye Acid Black 172 by live and heat-treated biomass of *Pseudomonas sp.* strain DY1: Kinetics and sorption mechanisms. J Hazard Mater. 205-206: 47-54.
Garcia I, Rodriguez JG, Lopez F, Tenorio YM., 2010. Transporte de contaminantes en aguas subterráneas mediante redes neuronales artificiales. Inf. Tecnol. 21(5): 79-86.
Giracol J, Passarini KC, da Silva Filho SC, Calarge FA, Tambourgi EB, Curvelo Santana JC., 2011. Reduction in ecological cost through biofuel production from cooking oils: an ecological solution for the city of Campinas, Brazil. J Clean Prod. 19(12): 1324-1329.
Golob V, Vinder A, Simonic M., 2005. Efficiency of the coagulation/flocculation method for the treatment of dye bath effluents. Dyes Pigm. 67: 93-97.
Guimarães OLC, Silva MB., 2007. Hybrid neural model for decoloration by UV/H_2O_2 involving process variables and structural parameters characteristics to azodyes. Chem Eng Process. 2007; 46: 45–51.
Guimarães OLC, Villela-Filho DN, Siqueira AF, Izário Filho HJ, Silva MB., 2008. Optimization of the AZO dyes decoloration process through neural networks: Determination of the H_2O_2 addition critical point. Chem Eng J. 141: 35–41.
Haykin S., 1999. Neural networks: A Comprehensive Foundation. New York, USA: Prentice Hall.
Henríquez MR, Palma PA., 2011. Control automático de condiciones ambientales en domótica usando redes neuronales artificiales. Inf. Tecnol. 22(3): 125-139.
Junghanns C, Krauss G, Schlosser D., 2008. Potential of aquatic fungi derived from diverse freshwater environments to decolourise synthetic azo and anthraquinone dyes. Bioresource Technol. 99: 1225-1235.
Kim T-H, Park C, Yang J, Kim S., 2004. Comparison of disperse and reactive dye removals by chemical coagulation and Fenton oxidation. J Hazard Mater. 112: 95–103.
Panchal G, Ganatra A, Shah P, Panchal D., 2011. Determination of over-learning and over-fitting problem in back propagation neural network, Int J Soft Comput. 2: 40-51.
Pandey A, Singh P, Iyengar L., 2007. Bacterial decolorization and degradation of azo dyes, Int Biodeter Biodeg. 59: 73-84.
Passarini KC, Gamarra FMC, Vanalle RM, Santana JCC., 2012. Reutilización de las Aguas Residuales en la Irrigación de Plantas y en la Recuperación de los Suelos. Inf Tecnol. 23(1): 57-64.
Rosa JM, Baptista EA, Santana JCC., 2009. Estudo da influência do pH na degradação fotoquímica de grupos antraquinônicos em corantes reativos do tipo vinilsulfônico (VS), Química Têxtil. 96: 26-32.
Sahinkaya E, Uza N, Yetis U, Dilek FB., 2008. Biological treatment and nanofiltration of denim textile wastewater for reuse. J Hazar Mater. 153: 1142–1148.
Silveira E, Marques PP, Silva SS, Lima-Filho JL, Porto ALF, Tambourgi EB., 2009. Selection of *Pseudomonas* for industrial textile dyes decolourization. Int Biodeter Biodegr. 63: 230-235.
Souza MCP, Lenzi GG, Colpini LMS, Jorge LMM, Santos OAA., 2011. Photocatalytic discoloration of reactive blue 5G dye in the presence of mixed oxides and with the addition of iron and silver. Braz J Chem Eng. 28(3): 393 – 402.
Ulson de Souza SMAG, Forgiarini E, Ulson de Souza AA., 2007. Toxicity of textile dyes and their degradation by the enzyme horseradish peroxidase (HRP). J Hazard Mater. 147: 1073-1078.
Ulson de Souza SMAG, Karin KAS, Ulson de Souza AA., 2010. Removal of COD and color from hydrolyzed textile azo dye by combined ozonation and biological treatment. J Hazard Mater. 179: 35-42.
Villada, F.; Cadavid, D. R., 2007. Diagnostico de fallas en motores de inducción mediante la aplicación de redes neuronales artificiales. Inf Tecnol. 18(2): 105-112.
Wu C-H, Kuo C.-Y, Chang C.-L., 2008. Decolozation of C.I. Reactive Red 2 by catalytic ozonation process. J Hazard Mater. 153: 1052-1058.
Zarei M, Khataee RA., 2010. Ordikhani-Seyedlar, R.; Fathinia, M. Photoelectro-Fenton combined with photocatalytic process for degradation of an azodye using supported TiO_2 nanoparticles and carbon nanotube cathode: Neural network modeling. Electrochim Acta. 55: 7259–7265.