ECUVal

Deliverable 6.9: TRAINING MATERIALS

Nowadays water scarcity is a very important concern as we only have access to a small percentage of the water that constitutes the Earth. Thus, the water consumption and management is one of the greater society challenges.

In the last decades, the increase in water consumption and consequently the increase of water scarcity have led governments to create new environmental policies focused on minimising water consumption and also on recycling and reusing of water. For this reason, huge efforts are been made to improve the current wastewater treatments and specially to make them more efficient in reusing water.

ECUVal is a new proposal that aims to contribute both to improve the wastewater treatment and to enable the reuse of the treated effluent.

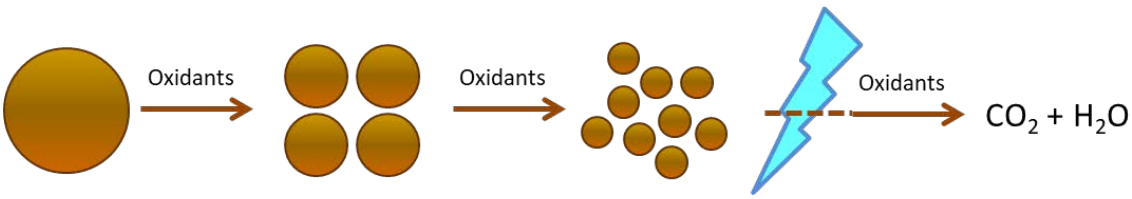
Industrial wastewater treatment

ECUVal: Water, treat to reuse

ECUVal is a green technology able to remove organic pollutants from wastewater by means of an electrochemical process combined with UV irradiation. It is especially suitable for the treatment of saline effluents containing non-biodegradable compounds.

The ECUVal system does not require the addition of chemical reagents. Unlike other techniques, ECUVal achieves the removal of pollutants only by means of electric power and no wastes are produced.

The ECUVal treatment starts with the generation of oxidant species from the salts contained in the effluents. The generated oxidants are very active and they are able to decompose the organic pollutants into soluble molecules of lower molecular weight that, depending of the amount of generated oxidants, could be subsequently fragmented. The further application of a UV light source enables to enhance the oxidation treatment and also removes the residual oxidants once the process is finished.



General objectives of **ECUVal**

- Sustainable industrial processes.
- Green technology for the treatment of salt containing wastewater.
- Recycling 70-100% water and up to 75% salt in the industrial processes.
- Economic benefits: savings in production processes, wastewater treatment cost and taxes .
- Environmental advantages: reduction of the water and salt impact, and saving in natural resources.

Applications of ECUVal …

Textile Sector

The textile dyeing and finishing industry is one of the main water consumer industries. It generates a huge volume of wastewater, generally with high colouration and salinity. Among the great range of textile dyeing processes, the dyeing of cotton with reactive dyes is one of the most common. Reactive dyes are very used due to their high fastness properties and brilliant shades. However, they have a low fixation degree. Consequently, their exhausted dyebaths are highly coloured and have high content of salts.

Dyes are large molecules with aromatic rings that provide them chemical stability and resistance to the microorganisms attack. Consequently, they cannot be removed by conventional biological treatments and the use of a specific tertiary treatment to remove colour is required. An alternative to the use of tertiary treatments is the application of the ECUVal technology to treat the coloured effluents. ECUVal enables to reuse the treated effluents.

Leather Sector

The leather industry also generates high amount of wastewater. In general, the tannery wastewater contains chloride, tannins, chromium, sulphate and organic compounds. It is also characterized by high colouration.

As in the case of textile industry, the ECUVal technology is proposed as a valuable tool to remove colour. It is especially efficient in the case of salt containing effluents. In case of low conductivity, a mixture with other saline effluents could be required. Besides the removal of wastewater colour, the reuse of the treated effluent in a new production process will provide notorious advantages.

Paper Sector

The pulp and paper industry uses large amount of resources, especially water and energy. The wastewater from paper factories is characterised by its high content of organic matter. It also contains solids in suspension, organohalogenated compounds (AOX), nitrogen and phosphorus.

The treatment of the effluents with the ECUVal system will provide a remarkable reduction of the organic matter content. This will enable the recycling of water in the process to achieve zero water discharge.

Chemical Sector

The chemical industry is of great importance in terms of its impact on the environment. The wastewaters from this industry are generally highly concentrated with organic and inorganic pollutants and can also contain toxic, mutagenic, carcinogenic and non-biodegradable compounds.

ECUVal constitutes a valuable tool to remove the organic and poorly biodegradable compounds or to degrade them into smaller molecules able to be removed in the biological plant. The reuse of the treated effluent should also be considered, depending on the type of industry.

Pharma Sector

The pharmaceutical manufacturing industry gathers the manufacture, extraction, processing, purification and packaging of chemical and biological materials, as solids and liquids to be used as medication of humans and animals. In general, the wastewater in a pharmaceutical manufacturing industry is originated from the synthesis and formulation of the drugs. Consequently, this wastewater can contain a wide variety of compounds.

Pharmaceutical products are often not completely removed during conventional wastewater treatment processes, such as biological plants. They are frequently detected in rivers and lakes. ECUVal can be used to remove the recalcitrant compounds. The non-biodegradable effluents should be segregated and destroyed before the biological treatment.

In the pharmaceutical industry, the reuse could be limited to other purposes not directly related to the production, such as irrigation or cleaning.

Cosmetics Sector

Nowadays, personal care products have expanded importance on environment issues. Cosmetic factories generate wastewaters with very variable characteristics, thus several treatments are used. In general, it contains suspended hydrophobic materials, surfactants and high amount of organic matter.

As in the case of the pharmaceutical sector, it is advisable to treat the poorly biodegradable effluents with the ECUVal system before the conventional treatment in order to enhance the yield of the biological the plant.

ECUVal to treat coloured effluents

Many industrial sectors generate effluents with strong colouration. In general, the conventional biological treatments provide good organic matter removal, but low efficiencies in discolouration due to the resistance of dyes to microbiological attack. For this reason, currently biological treatments are combined with tertiary treatments to remove colour.

The main treatments used to remove colour are based on physico-chemical methods. These methods are efficient and achieve the separation of dyes from the effluent to produce a clearer effluent. Simultaneously, they also produce a concentrated waste that requires an additional treatment to be destroyed. Thus, the coagulation-flocculation produces sludge. In the adsorption processes, the absorbent materials (such as active carbon, silica gel or alumina) require their regeneration after several treatments. On the other hand, the use of membranes shows operational problems such as membrane fouling.

Other treatments have been proposed as an alternative to current physico-chemical methods, but they are still under research. Enzymatic decomposition still requires investigation in order to know what enzymatic process takes place. In addition, temperature and pressure have to be controlled to avoid enzymes denaturalization. Chemical oxidation methods are rather expensive and involve some operational difficulties.

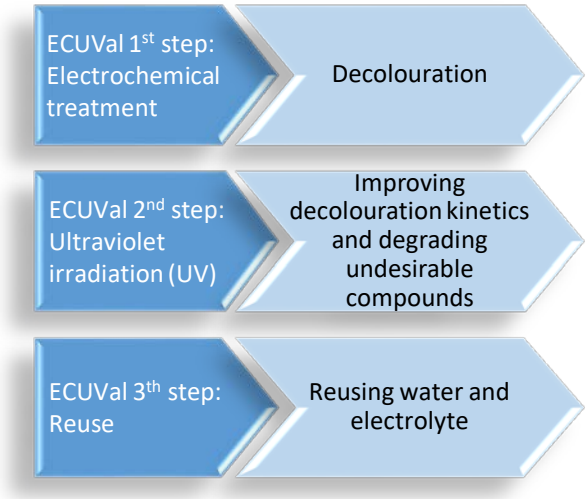
ECUVal has demonstrated its feasibility and constitutes a valuable alternative to the current physico-chemical treatments as no sludge or any other type of waste is generated. In addition, the electrochemical methods have good versatility and high-energy efficiency. They are easy for automation and safety since the treatment is carried out at smooth conditions.

Finally, the combination of electrochemical treatment with UV irradiation enhances the yield of both processes and prepares the treated effluent to be reused.

Composition and function of

ECUVal for the textile sector

The textile industry has led the way in applying the first ECUVal industrial prototype, in response to the large quantities of wastewater produced by the fabric dyeing process.



Scheme of ECUVal system for the textile sector

In general, textile wastewater contains different kind of residual dyes and chemical additives, which cannot be easily degraded. Textile effluents are also characterised by high conductivity due to the addition of salts, which are required to increase the fixation of dyes onto the fibre.

ECUVal is a new proposal combining electrochemical techniques and UV irradiation, addressed to treat exhausted dyebaths and washing effluents. It is especially efficient for the treatment of effluents with high colouration and high conductivity values, as it is the case of effluents from the reactive dyeing process.

The ECUVal treatment does not require the addition of reagents as the salts contained in the effluents act in the cells as an electrolyte. As a result, uncoloured solutions are obtained and no wastes are generated. The uncoloured effluents can be either discharged or reused after a reconstitution step. In this way, ECUVal aims to contribute both to improve the wastewater treatment and to enable the reuse of the treated effluent.

Decolouration function

ECUVal system can be applied as a complementary technique to conventional biological treatment.

The exhausted dyeing liquors and washing baths are segregated and subsequently decolourised by means of the ECUVal system. Then, the uncoloured effluents are discharged to the wastewater treatment plant in order to achieve the full elimination of the residual organic matter (mineralization).

In this case, the ECUVal treatment constitutes an alternative to the current tertiary methods used for colour removal.

Reuse function

ECUVal is fitted with a system to treat clarified effluents for reuse. The reuse function requires the reconstitution of the treated effluent before being reused.

With this purpose, a number of sensors and measuring pumps are started up to obtain water suitable for reusing in the dyeing process.

The reconstitution is carried out in the following steps:

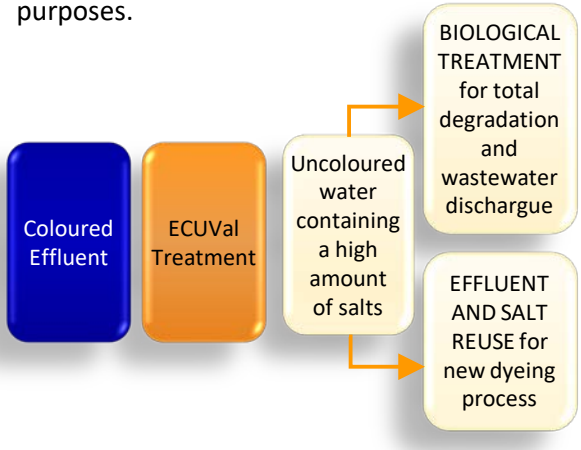
- Removal of carbonates and bicarbonates by acid addition and stripping.
- Neutralization of the effluent by alkali addition.
- Removal of residual oxidants by UV irradiation and addition of a reducing agent.

The reuse of the treated effluent is an alternative more advantageous than its discharge. This option enables to reuse 70% of the dyeing effluent and up to 75% of salts in new dyeing processes. Consequently, a reduction of effluent salinity and wastewater discharge rates is also achieved.

Applications and results of

ECUVal for the textile sector

ECUVal is a versatile proposal that can be used both for colour removal and for reuse purposes.

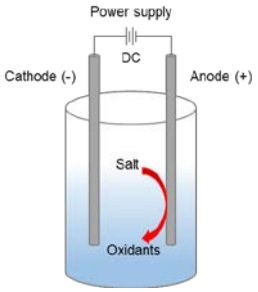


In first term, ECUVal is a solution to remove colour, based on an electro-oxidation reaction that occurs in the electrochemical cells.

Thus, this system solves the problem of effluent colouration and in addition, it enables the reuse of dyeing water and dyeing electrolyte.

The electrochemical treatment is combined with irradiation by UV rays to further reduce any residual colour and finally, to eliminate residual oxidants in order to ensure high quality dyeing results when the effluent is reused.

Scheme of an *electrochemical* cell



The main reactions that occur are the following:

Production of active chlorine:
$2Cl^- \rightarrow Cl_{2\,(aq)} + 2e^-$

Hydrolysis of chlorine:
$Cl_{2\,(aq)} + 2OH^- \rightarrow H_2O + ClO^- + Cl^-$
(active hypoclorite is produced in alkaline conditions)

Oxidation of dyes: **Dye** + ClO^-/ $Cl_{2\,(aq)} \rightarrow$
$\rightarrow$dye fragments + $Cl^- \rightarrow CO_2 + H_2O + Cl^-$
(by means of generated active chlorine, hypochlorite and oxidant radicals)

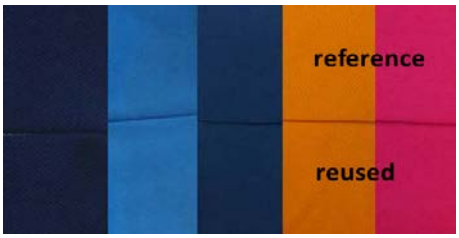
The ECUVal process starts with the segregation of wastewater from dyeing and washing dyed fabrics with certain types of colorants, such as reactive. This resulting in water contains high concentrations of salts and residual dyes.

The water passes through a series of control steps before the electrochemical process. In the cells, an electric current is applied to produce oxidants from the residual salts. The generated oxidants are used to break down the dye molecules, thus clarifying the wastewater.

The clarified effluents still contain high levels of salts and, at this point the can be sent to a conventional treatment plant or reused in a further dyeing process.

Results of colour removal using ECUVal technology

Comparison of dyeings
Reference: decalcified tap water
Reused: ECUVal treated water (70%)



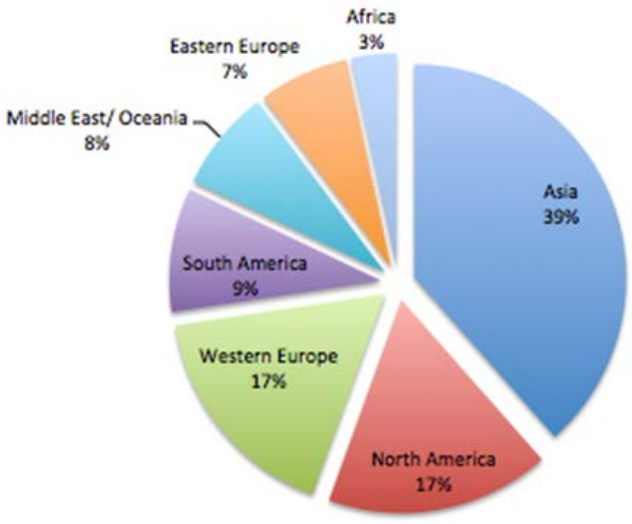
Economic sustainability

ECUVal system has clear environmental advantages that results in benefits from the economic point of view.

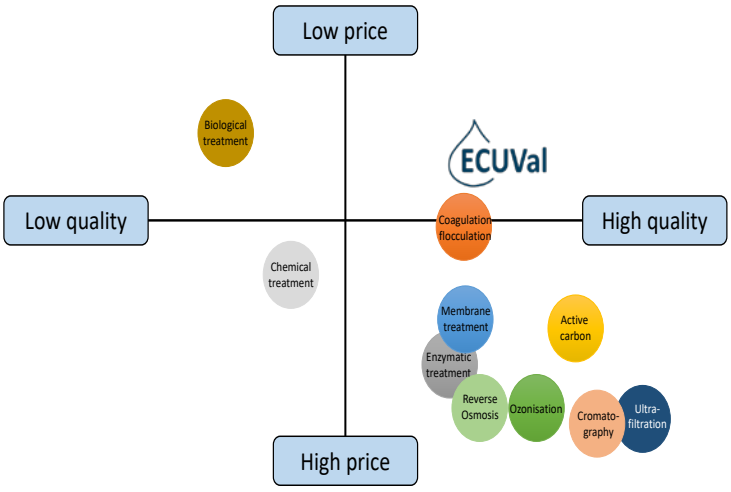
With respect to other technologies, the operational costs of ECUVal are favourable because:

- Only the more coloured and with high salt content effluents are treated.
- No chemicals are required to carry out the electrochemical process.
- The only cost of the ECUVal treatment is the electric power supply.
- No wastes are generated.
- As the high coloured effluents are segregated to the ECUVal system, the tertiary treatment for colour removal can be supressed in the wastewater treatment plant. This results in a significant reduction of reagents and sludge disposal costs.
- Discharge taxes are lowered due to the reduction of wastewater salinity.
- The system does not need maintenance. The electrodes are very stable and can be used over 5-10 years.
- Less cost in water. Savings of 70-100% dyeing water
- Less cost in salt. Savings up to 75% salt are achieved with the reuse.

On the bases of these advantages and the operating costs, the ECUVal investment will be amortized in 4-5 years.



Global textile processing industry in 2014 (Source: http://igem.org/)



Market segmentation of ECUVal with respect to other technologies

Operating costs of ECUVal treatment

INTENSITY (A)	CONSUMPTION (kWh/m³)	COST (€/m³)*
25	0.53	0.049
100	2.12	0.195
200	4.25	0.391
400	8.5	0.782
800	17	1.564

** Cost kWh = 0.092€*

Comparison between ECUVal and current treatment methods

Method	Colour removal	Rate	Cost	Other specifications
Active carbon	Very good	Low	High	Regeneration
Membranes	Good	High	High	Maintenance and cleaning
Ozonization	Good	Medium	Very high	By-products
Coagulation– flocculation	Good	Medium–High	Medium	Sludge generation
ECUVal	Good	High	Medium	Clean and recycle option

Environmental benefits and resource efficiency …

Three scenarios are considered to perform the life cycle assessment of the ECUVal technology in the textile sector:

A. CURRENT PROCESS

Currently, after the dyeing process, the effluents are generally discharged to be treated in a biological plant. As the biological treatment is not able to remove colour, a tertiary treatment is added with this purpose.

The current dyeing process and wastewater treatment, have a high impact on human toxicity, especially due to the salt and carbonate consumption in the dyeing process.

B. ECUVAL PROCESS to decolourise

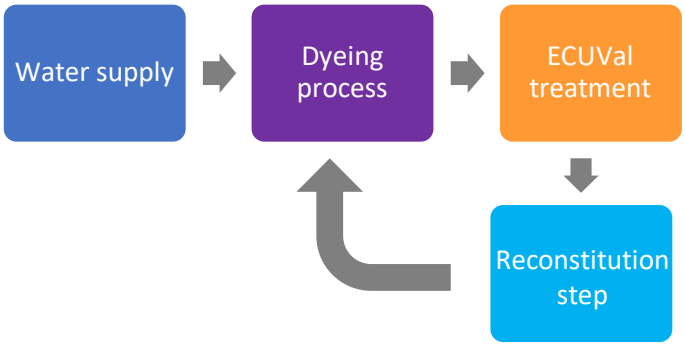
When the ECUVal treatment is applied, the dyeing effluents are previously segregated and decoloured. Subsequently, the decoloured effluents are discharged to the biological plant in order to remove the residuals organic matter. In this case, the tertiary treatment is not required. Therefore the environmental impact of the process decreases.

C. ECUVAL PROCESS to reuse

After the ECUVal treatment, the decoloured effluents are able to be reused in new dyeings (instead of being discharged in the biological plant). In this case, a reconstitution step is necessary before the reuse.

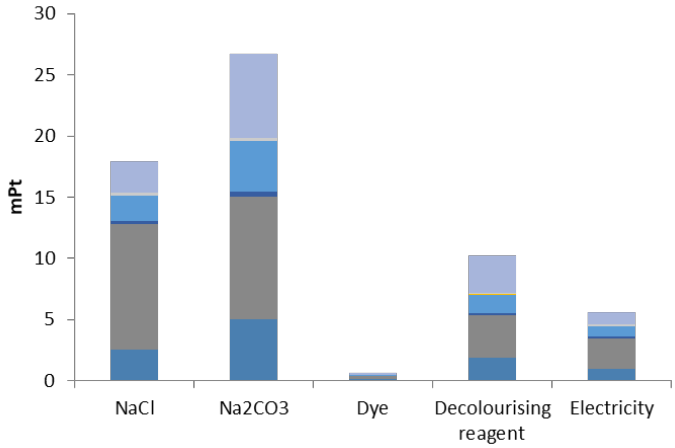
ECUVal does not generate wastes, which is an important environmental advantage respect to the current colour removal methods. Also, up to 75% of salt is recovered and recycled in a new dyeing process. Thus, the reuse of salt is another important advantage of ECUVal since the current methods employed to remove salts from effluents (mainly reverse osmosis membranes) are expensive and also show operational difficulties.

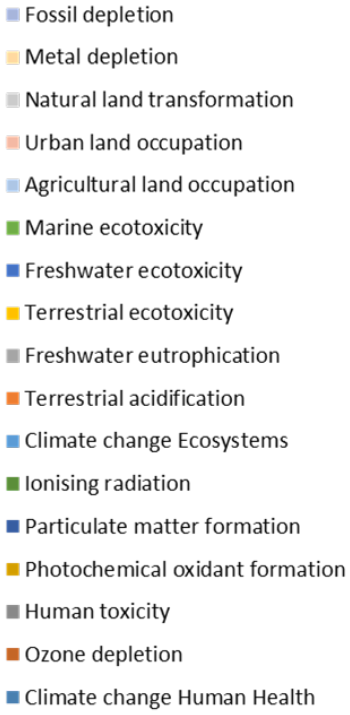
In addition, the ECUVal system enables to recycle the total exhausted dyeing baths, which reduces up to 70% water consumption due to the cyclic process.



… impact of the different scenarios

A. CURRENT PROCESS





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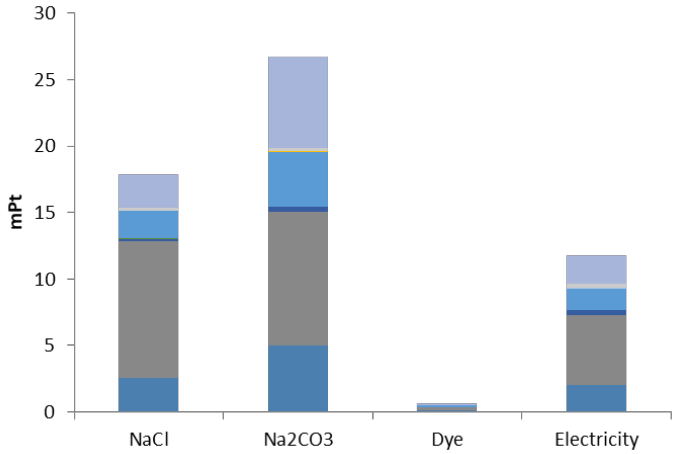
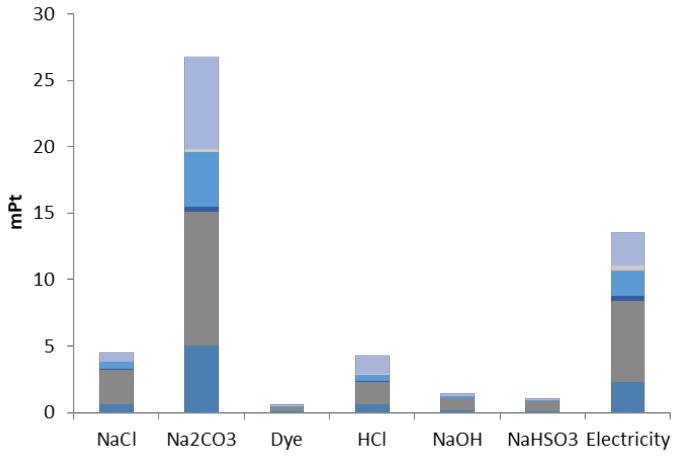
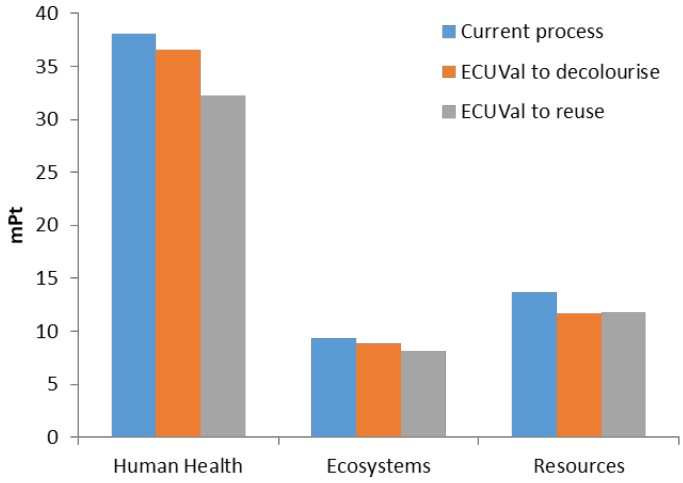


C. ECUVAL PROCESS to reuse





Comparison of impact of the three scenarios

From an environmental point of view, the application of the ECUVal system is highly recommended since the impact of the process decreases up to 15% with respect to the current option.

Basic installation

Control module

- System control by colour touch screen
- Graphical interface that shows the process status and actuators
- Possibility to program different levels of colour removal

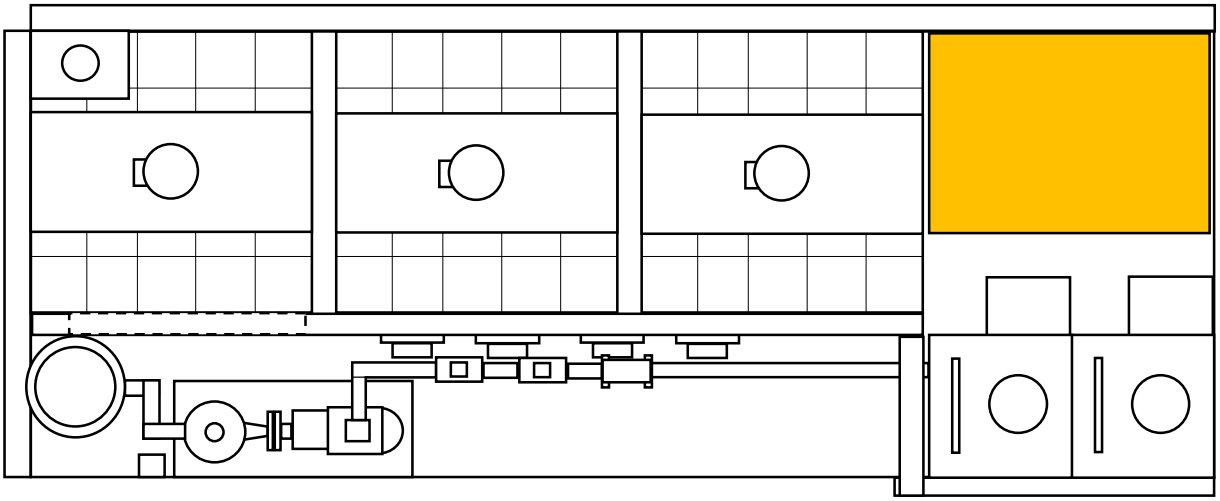
Decolouration module

- System equipped with sensor to ensure the correct operation
- Colour sensor to control the degree of decolourization
- Treatment of dyeing wastewater with conductivity >20 mS/cm
- Treatment capacity 4m^3/h
- No chemicals are added
- No residues are generated
- No need for maintenance the first 5 years
- Cleaning of the electrodes automated by reversal polarity and controlled by the voltage measurement

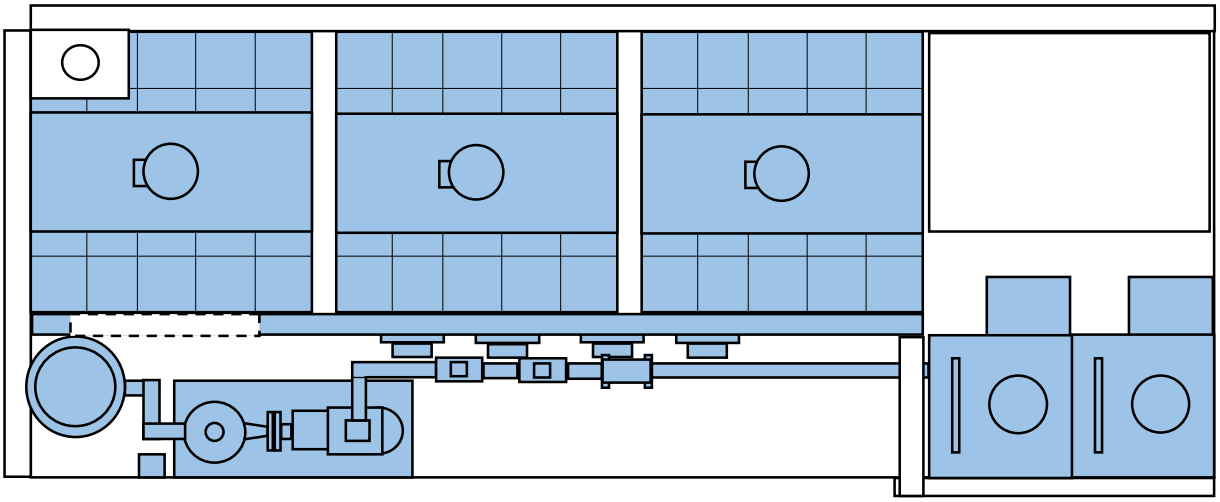
Reuse module

- Effluent reconstitution completely automated
- Consumption of auxiliary reagents for the reconstitution step:
  - 25L/m^3 acid
  - 0.5L/m^3 alkali
  - 0.08L/m^3 reducing agent

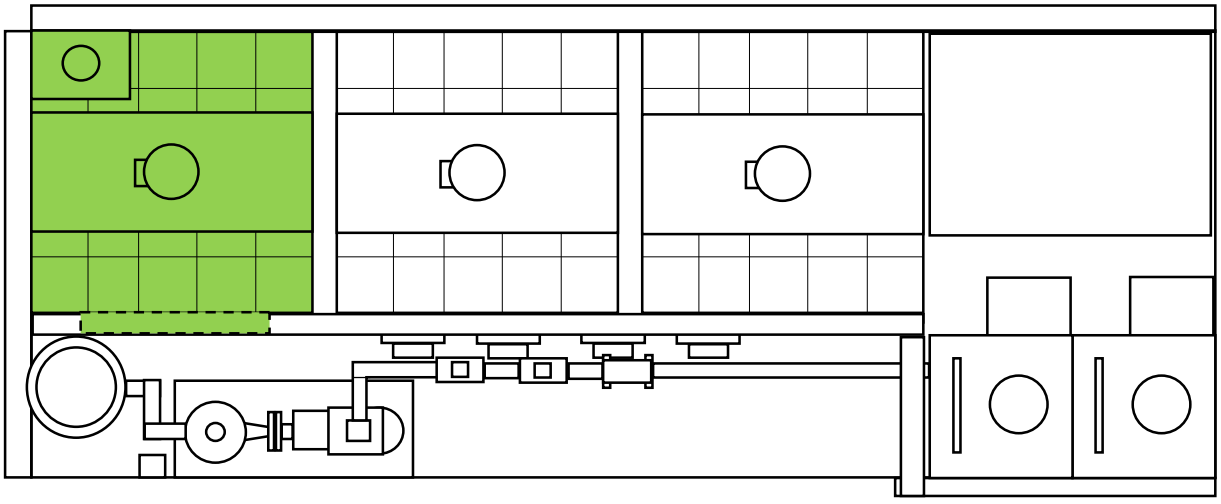
Control module



Decolouration module



Reuse module



Advertisement ad feedback

Mounting characteristics

Max. electric consumption: 52 kW

Network voltage: 3-phase 400 v

Frequency of the network: 50 HZ

Compressed air: 6 bar

Extracción:: min 240 m^3/hour or machine installed in a well ventilated area

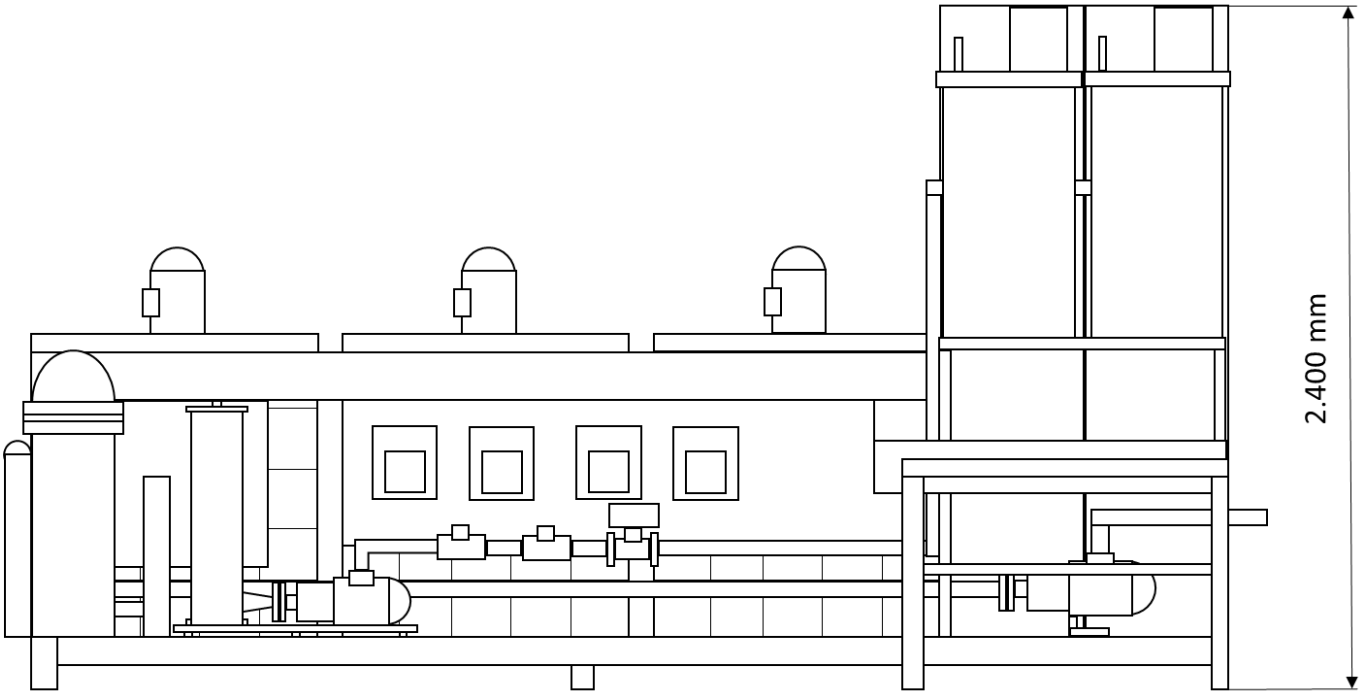
Weight and space required for installation

Weight:

Empty: 1500 kg

Full: 4500 kg

Space: approx. 7000 mm x 4200 mm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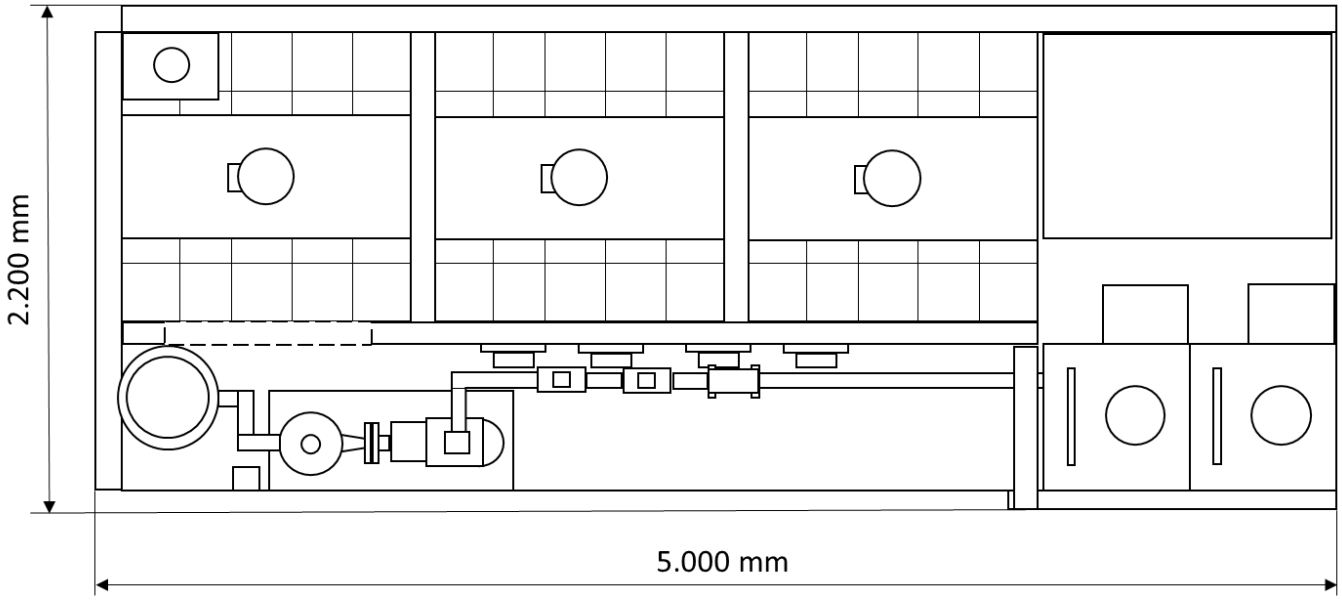
2.200 mm
5.000 mm

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EASME
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