FS-BIO-004

TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
OF TEXTILE INDUSTRY

ROTATING BIOLOGICAL CONTACTORS (BIODISCS)

SERIES: SECONDARY TREATMENTS

TITLE	**ROTATING BIOLOGICAL CONTACTORS (BIODISCS) (FS-BIO-004)**
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INDITEX

BIODISCS (FS-BIO-004)

Date	**March 2015**		
Authors	Alfredo Jácome Burgos Joaquín Suárez López Pablo Ures Rodríguez		
Revised by			
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1.- INTRODUCTION

The Rotating Biological Contactors (RBCs) or simply "biodiscs" are part of the so-called biofilm processes. In these reactors, biofilm support material consist of discs, with a certain uniform distance between each other, coupled to a rotating horizontal shaft driven by a motor. In general, the shaft is installed above water surface level. Thus, the rotary movement causes the intermittent immersion of discs into wastewater.

The overall objective of this technology is to establish biodiscs process sizing criteria sizing in order to remove organic matter from wastewater.

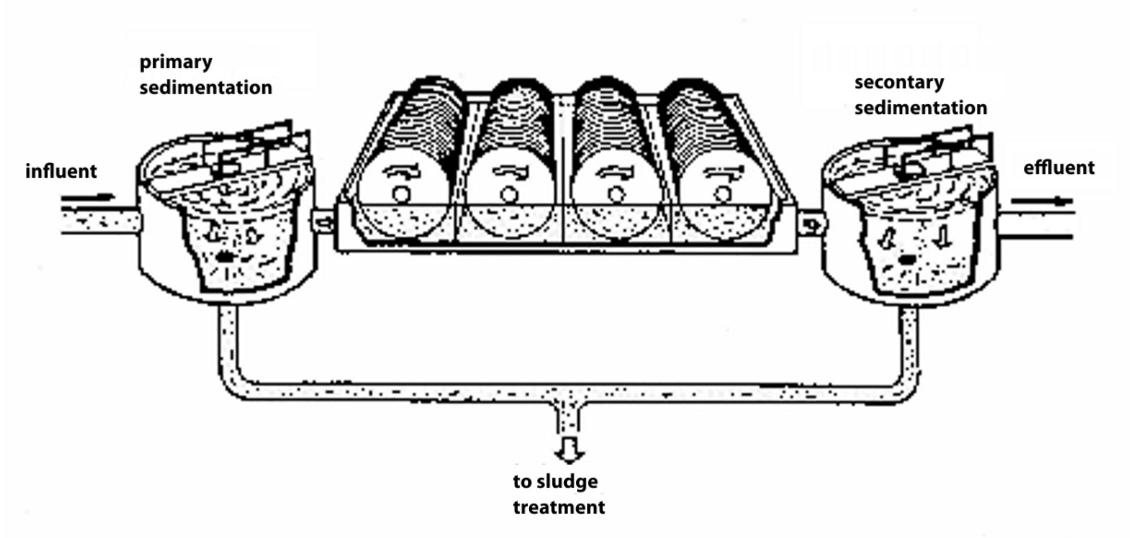

Figure 1.- Conventional biodiscs system scheme

2.- DESCRIPTION

The discs on which the biofilm is developed are coupled to one or more horizontal shafts that will be driven by variable speed motors. In general, the shaft is installed above water surface level, so that the submerged surface of the disc is typically 40% of the total disc area. Each reactor usually has several sets of discs arranged in series. In general, each set of discs represents a process stage. The reactor may be comprised of one or more stages.

The reaction vessel is commonly covered to avoid inclement weather, and to minimize or improve visual impact as possible.

The biofilm oxidizes organic matter from wastewater (BOD, COD) and/or nitrogen (joint nitrification or tertiary process) while the oxygen necessary to the metabolic activity of the microorganisms is ensured by discs rotation.

The high process kinetics is due to the high biomass concentration that can be maintained on the surface of the disc, in the order of 200 g (dry weight)/m^2, having a metabolic effect similar to that produced by a concentration of 4.000 to 6.000 mg MLSS/L in activated sludge process.

The disc configuration is specific to each manufacturer. The design of the discs always attempt to maximize the surface area, and to enhance both water mixing and aeration in the reactor. Discs are mostly manufactured of polystyrene foam, polyvinyl chloride and polyethylene.

As in any biofilm process, design must prevent the reactor filling clogging. So, if the system consists on a multistage treatment, discs separation may vary from one stage to another. In the early stages the discs need a bigger separation, while the intermediate and final stages are installed closer as biofilm is thinner.

At steady state, the excess biofilm is removed by continuous drag due to shear forces produced by the rotation of the discs. The excess biomass will be retained and disposed through the secondary clarifier.

For small flow rates, compact biodiscs systems, with secondary settler incorporation, can be manufactured. Design view is similar to that shown in the following figure:

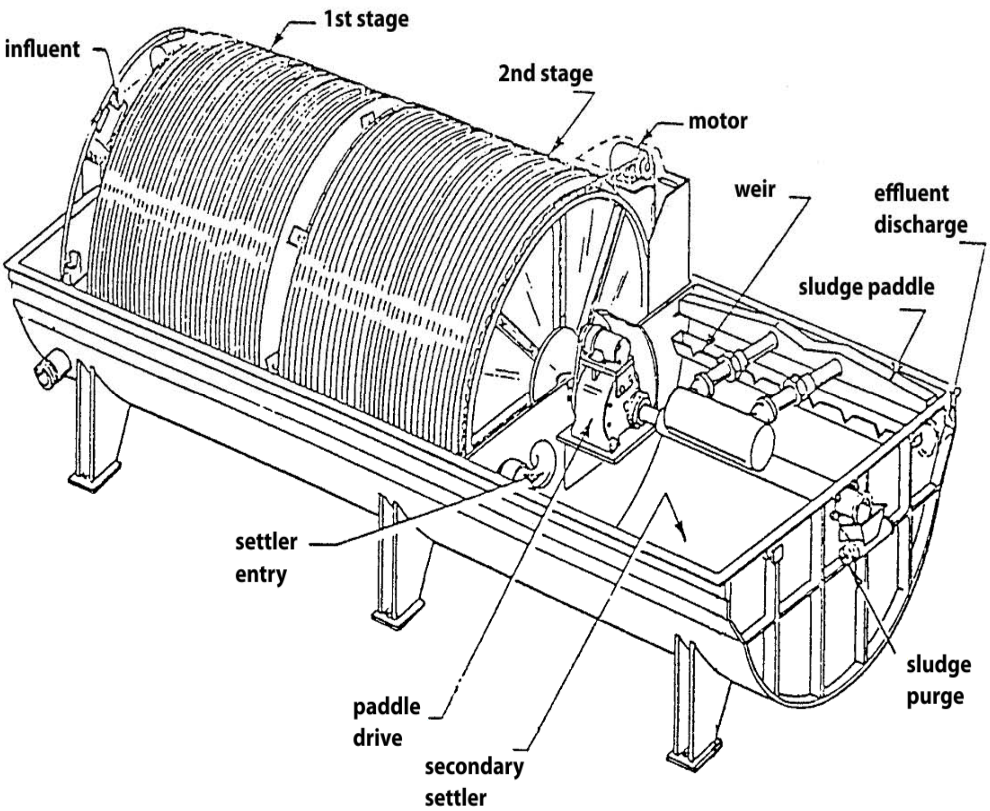

Figure 2.- Compact biodiscs system for small flows with integrated secondary clarifier

3.- DESIGN

3.1.- General criteria

Design criteria have been established for a minimum temperature of 12 ºC.

Moreover, the prevention of peak loads effects requires a design specific volume larger or equal to 5 L of tank per disc m^2. The application of this minimum criterion guarantees the necessary HRT. However, the maximum specific volume is limited to 9 L/m^2 to minimize flow dead zones in the reactor.

Standard peripheral tangential velocity is 10-20 m/min, corresponding to 3-6 rpm in discs with 1 m diameter and 1-2 rpm in discs with 3 m diameter. Taking advantage of the fact that the engine has variable speed, the rotation speed should be adjusted proportionally to the organic load of the wastewater.

3.2.- Design parameters

3.2.1.- *Surface loading, B_A*

The surface pollutant load is the key design parameter. It is expressed in grams of pollutant applied per day and square meter of biodisc.

Other design parameters are complementary hydraulic load (expressed in $m^3/d/m^2$ or simply m/d) and the hydraulic retention time, HRT.

3.2.2.- Calculating the required surface of discs

The minimum required area of bio-discs for the oxidation of organic matter is given by:

$$A_{BOD} = \frac{Q_{ave}\ L_0}{B_{A,BOD}}$$

Where:

A_{BOD} = biodiscs contact surface for organic oxidation (m^2)
$B_{A,BOD}$ = organic surface applied load (g $BOD_5/m^2/d$)
F_{ave} = average total daily flow (m^3/d)
L_0 = average influent BOD_5 concentration without recirculation (mg/L)

Moreover, the hydraulic load is calculated as:

$$HL = \frac{Q_{ave}}{A}$$

3.3.- Secondary treatment sizing criteria

The reactor can be designed from 2 to 4 biodiscs stages:

Table 1.- Criteria for biodisc systems with 2 stages

In 1st stage	Overall
$B_{A,SBOD}$ <= 12 g/(m^2·d)	$B_{A,SBOD}$ <= 4 g/(m^2·d)
$B_{A,TBOD}$ <= 24 g/(m^2·d)	$B_{A,TBOD}$ <= 8 g/(m^2·d)

Where, TBOD = total BOD_5 total; and SBOD = soluble BOD_5. In the absence of data, the SBOD/TBOD ratio in the influent of the first stage of biodiscs will be considered as 0.50.

Table 2.- Criteria for biodisc systems with 3 or 4 stages

In 1st stage	Overall
$B_{A,SBOD}$ <= 12 g/(m^2·d)	$B_{A,SBOD}$ <= 5 g/(m^2·d)
$B_{A,TBOD}$ <= 24 g/(m^2·d)	$B_{A,TBOD}$ <= 10 g/(m^2·d)

For small plants, between 10 and 200 m^3/d, due to relative peak flows and loads, it is recommended to linearly reduce the overall applied load of TBOD from 8, or 10, g/(m^2 • d) to 4 g/(m^2 • d).

In any case, it will also verify that the hydraulic load does not exceed 0.25 m/d and the HRT is not less than 0.7 hours.

3.4.- Performance

The level of performance depends on the applied organic load. In the case of urban wastewater, if global loads are within a range of 6-12 g TBOD/m^2/d, the reductions achieved range from 80 to 90% in BOD_5.

The expected effluent quality will be:

- As secondary treatment: 15-30 mg/L BOD_5

In order to predict the BOD_5 removal efficiency, a second-order model proposed by Brenner - Opatken (US EPA 1985) can be used:

$$S_n = \frac{1 + \sqrt{1 + 4kt\left(S_{n-1}\right)}}{2kt}$$

Where:

S_n = soluble BOD_5 concentration in stage n (mg/L)
k = kinetic coefficient second order (L/mg/h)
t = HRT in stage n (h)
S_{n-1} = soluble BOD_5 influent concentration to stage n (mg/L)

The kinetic constant, k, has a value of 0.083 L/mg/h obtained from field record of nine multistage RBC's at industrial scale.

The model is based on soluble BOD, which is not affected by primary sedimentation. However, not all suspended BOD is removed in a primary clarifier, and thus may be retained by the biofilm and hydrolyzed. Thus, the influent soluble BOD would be increased by a hydrolysis factor, which has been considered in the experimental constant value.

3.5.- *Sludge production*

The specific production of sludge will not be less than 0.75 kg SS/kg BOD_5 for sizing purposes.

4.- SECONDARY CLARIFICATION

In the clarification process, static clarifiers, which may be rectangular or circular, are used. SS concentration at the outlet of the reactor does not usually exceed 150 mg/L, where the sedimentation theory of flocculent particles remains applicable. This factor is a differentiator element regarding the biomass in suspension process.

4.1.- *Design variables*

- **Hydraulic loading rate**: it is based on the real flow rate through the unit, that is, the discharge flow through the outflow weir.

$$HLR = \frac{F}{A}$$

Where:
HLR = Hydraulic loading rate (m/h)
F = outflow (m^3/h)
A = horizontal clarification surface (m^2)

- **Hydraulic retention time**

$$HRT = \frac{V}{F} = \frac{A\,h}{F}$$

Where:
HRT = hydraulic retention time (hours)
h = depth under weir (m)
V = net clarification volume (m^3)
F = F_{max} (m^3/h)

- **Hydraulic load over weir**: it corresponds to the effluent flow per linear meter of outflow weir.

$$OW = \frac{F}{Lw}$$

Where:
OW = overflow on weir (m^3/h/m)
L_w = weir length (m)
F= maximum flow (m^3/h)

4.2.- *Summary of design values*

Table 5. Design values for secondary settling of biodiscs

Parameter	Value
Hydraulic loading rate (m/h)	< 0.6 (F_{ave}) < 1.5 (F_{max})
Hydraulic load over weir (m^3/h/m	< 10 (F_{max})
Hydraulic retention time (h)	> 1 (F_{max})
Sludge concentration (%)	≤ 1
Minimum water depth under weir (m)	≥ 3.0

Clarifiers with truncated cone shape, also called vertical flow clarifiers. For technical and constructive reasons, the diameter will not be greater than 5 m.

The slope of the conical wall area responds to an angle greater than or equal to 60 ° (see figure below).

For these vertical flow clarifiers, the effective horizontal surface is set at the midpoint of the height between the unit water entry (that is, out of the central baffle) and the elevation of the free water level (see figure below).

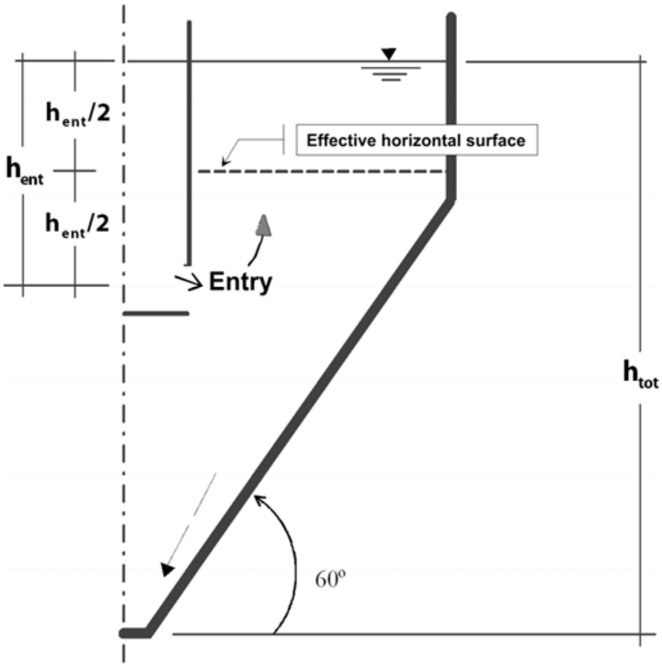

Figure 3.- Scheme of a vertical flow secondary clarifier

5.- TECHNICAL CONDITIONS

Compact systems can be used in the case of very small population systems (up to 20 m^3/d), as long as they comply with the before established sizing criteria.

All biodiscs systems require previous wastewater treatments. It is always recommended that the minimum treatment shall be the primary treatment (eg, primary settling unit). For instance, a rigorous pretreatment based on coarse screening (20 mm), sieving unit (pore size 6 mm) and degritter-degreasing unit, can be enough with wastewater flow rates up to 100 m^3/d.

The disc surface may be smooth or corrugated. The thickness depends on the disc manufacture material, being in the range from 2 to 25 mm (typically <10mm).

At any stage, above organic total BOD_5 loads of 20 g/m^2/d, the spacing between discs must be at least 20 mm. If the organic load is less than 20 g total BOD_5/m^2/d, the minimum recommended spacing is 15 mm.

An adequate separation distance between the edge of the discs and the walls of the tank is 10% of the disc diameter.

Regarding the secondary clarifier design, the following shall apply:

- The decanted water collection weir; shall be of stainless steel 304L, attached to profiles assembled with the same materials.
- In any case, the secondary clarifier must have a baffle in order to avoid floatable materials discharge.
- Withdrawn foams and floating materials will never be returned to the plant head or to the pumping well.
- All bushings and stretches that will be effectively embedded in slabs or foundations are 304L stainless steel.
- The structural design shall consider the clarifier emptying.

- From the secondary clarifier treated water is transferred by gravity to the final discharge, which will have a manhole to cancel foam production, and a non-return valve so as to prevent any backflow.

6.- SPECIFICATIONS FOR THE TREATMENT OF WASTEWATER OF TEXTILE INDUSTRY

In the textile industry a number of studies at laboratory and pilot scale are available, in order to assess the effectiveness of the biodiscs process COD and color removal. It is noteworthy; that in many cases mixed biofilms composed by bacteria and fungi are used, the latter especially for color reduction. The following paragraphs provide a chronological overview of collected applications for biodiscs in the textile sector. Also, in a sub-section experiences are collected with waste water from other industrial sectors.

Axelsson et al. (2006) performed the experimental application of technology biodiscs for bleaching textile wastewater contaminated basically by 2 colorants or dyes in particular: red reagent 2 and reactive blue 4. With a **HRT of 3 days**, they observed a 96% reduction on the molecular absorbance of light at 538 nm when the concentration of each dye in the water problem was 50 and 100 mg/L. With a dye concentration of 200 mg/L, a reduction in light absorbance at 538 nm (red-sensitive reagent 2) was 81%. Reduction values corresponding to 595 nm (blue-sensitive reagent 4) were 94 and 80%, respectively. The biodiscs were cultured with fungus *Bjerkandera sp*. Strain BOL 13.

Pakshirajan et al. (2009) used a biodiscs process to remove the dye "turquoise 86" of a textile wastewater. With a **HRT of 2 days** achieved a 92% reduction of the molecular absorbance of light at 540 nm.

Goyal et al. (2010) evaluated a pilot-scale treatability of wastewater from a cotton textile industry with a 4 stage biodiscs process. The aim was to remove color and COD. Employing a **HRT of 12 hours**, the maximum reduction achieved percentages were 90±5% and 95±3% in color and COD respectively. They also noted that the first two stages were responsible for 75±5% of the total reduction of color and COD. Finally, the biocenosis, especially in the 2nd and 3rd stage, consisted of a consortium of bacteria and fungi.

Sima et al. (2012) conducted a pilot study for textile wastewater decoloring using a biodiscs process cultivated with fungus *Irpex lacteus*. The target of the study was to remove the reactive dye remazol brilliant blue R (RBBR). With a **HRT of 8 hours**, the 95% of the absorbance at 592 nm produced by RBBR dye color is reduced.

Karthikeyan et al. (2014) presented results at laboratory scale suggesting that it is possible to effectively treat textile wastewater using a process incorporating biodiscs cultivated with *P. chrysosporium* fungus. The disc material was polyurethane foam. This process removed **55% of color**, and **63% and 48% of phenol and COD**, respectively.

6.1. – Applications in other industry sectors

Guimaraes et al. (2005) used a biodisc process for sugar industry wastewater decoloring. The biodiscs were seeded with fungus *Phanerochaete chrysosporium*. At a **HRT of 3 days**, the reduction (in percent) observed for color, COD and phenol were 55, 63 and 48%, respectively.

7.- PARAMETERS AND CONTROL STRATEGIES

7.1.- Aeration control

A particularly important parameter to be controlled in biological reactors is the dissolved oxygen (DO) concentration. In the case of biodiscs, DO control is crucial in the first stage of the process because it is facing the most part of the organic load. In order to perform this control, a DO probe is used. A DO range between 3 and 4 ppm is acceptable for an efficient oxidation of organic matter. In larger plants, the aeration system is usually automatic. Automated DO control can allow the regulation of the rotation speed of the discs, permitting energy savings.

7.2.- Settling and sludge purge control

In the case of more than one clarification line, it shall be ensured that the biological reactors outflow is equally shared among all secondary clarifiers.

Furthermore, operators should prevent secondary sludge to remain for a long time in the clarifier. This requires controlling sludge drain pumping frequencies. In general, program will be set to one purge period per hour.

A treatment facility, even when properly operated, produces a certain amount of detached biofilm and/or low density flocs that will float in the clarifier water surface. A peripheral baffle will prevent floating materials from leaving with the treated water outflow.

7.3.- Daily maintenance in the reactor and in the clarifier

The tasks to be controlled and performed are:

- Observe the appearance of water in reactors and settlers.
- Adequate maintenance and lubrication of the aeration unit.
- Brushing the outflow weirs of settled water.
- Removal of fats and other floating materials such as plastic or rubber pieces.

8.- OPERATING PROBLEMS

The main problem of operating a biodiscs process is related to the DO deficiency that may especially occur in the first treatment stage. The first stage receives most part of the organic load, and possibly ammonium load, being therefore exposed to a lack of aeration trouble. However, if the design is conservative, ie, if the load applied to the first stage is limited, this problem would not occur.

In any case, the process design must consider certain operation flexibilities in order to improve the operation and maintenance. It is noteworthy (WEF-ASCE, 1992; WEF, 2000):

- Possible additional aeration motor drive systems to cope with higher organic loads from one stage.
- Means to remove excess biofilm growth such as chemical additives, wash water or air (drag), control of the rotational speed, changing the speed of rotation, alternation of the feed.
- Variable speed in 1st and 2nd stage.
- Multiple treatment lines.
- Portable baffles between all stages.
- Control tributary to each unit or line flow.
- Controllable distribution systems, such as staggered power flows.
- Control and measurement of airflow to each axis in pneumatic drive systems and improve aeration.
- Secondary effluent recirculation.
- DO meter equipment in early stages.
- Accessibility axes, middle support and other mechanical equipment needing inspection, maintenance and periodic replacement or possible elimination.
- System emptied from the reactor (required).
- Load cells for weighing each axle assembly (required).
- When RBCs are installed in buildings: ventilation (besides oxygen requirements of RBC), humidity control, heating and measures to remove and replace axles and carrier medium.

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ANNEX 1
SURFACE REQUIREMENT ESTIMATION

1.- BIOLOGICAL REACTOR REQUIRED SURFACE

Table demand over biodisc biological reactor surfaces for different sizes of textile industrial facilities are expressed in terms of the average treatment flow. An homogenization tank for flows and concentrations are considered to be prior to the reactors.

The main work hypothesis is that the minimum HRT for the treatment of textile wastewater should be 8 hours. The other criteria (dimensions of axles, specific volume, etc.) are detailed below.

a.- Design criteria	Reference	Adopted
HRT (hours)	8 - 48	8
Specific volume (L/m^2)	4 - 9	4
Axis length (m)	<7.2	7.2
Discs diameter (m)	<3.6	3.6
Discs surface discs per axis (m^2)	9200 - 9400	9300

b.- Preliminary calculations	
Width by stage (m)	8.00
Stage length (m)	4.00

Table 1.- Land area required for the biodiscs process according to the inflow

Inflow (m^3/d)	Area (m^2)	Nº lines	Nº axis/line	Volume (m^3)
400	128	1	4	133.33
800	256	2	4	266.67
2000	576	6	3	666.67

2.- AREA REQUIRED FOR SECONDARY CLARIFICATION

To estimate the necessary decanting area the following design criteria are applied:

Hydraulic load (HL) at average flow = 0.6 m/h
Minimum water height = 3.00 m

The results are presented in the following table:

Table 2. Area requirement for secondary clarification as a function of the treatment flow

Inflow	Area
(m^3/d)	(m^2)
400	28
800	56
2000	139

Finally, the minimum area required for the "secondary treatment" is obtained by addition of the reactor's surface and the secondary clarifier area. The results are presented in the following table:

Table 3. Total area requirement for secondary treatment (reactor + clarifier)

Inflow	Total area
(m^3/d)	(m^2)
400	156
800	312
2000	715

ANNEX 2
GRAPHIC DESCRIPTION OF PROCESS UNITS

Figure 1
Types of polyethylene discs 1 cm thick, hollow or gutters that are filled with water. When the disk emerges, water comes out of the gutters and air enters.

Figure 2
3-stage biodiscs for a 150 m^3/d flow (A Baña – A Coruña). Includes coarse screening, degritter and rotary sieving pre-treatments. There are discs with 3 m in diameter, made of high density polyethylene.

Figure 3
Two biofilm feature. Left: First disc the 1st stage of a lightly loaded system (influent BOD = 120 mg/L, grab sample). Right: Last disc at the end of a 2nd stage overloaded system (1st stage influent BOD = 230 mg/L; clarified effluent BOD=80 mg/L; samples). Both systems have a wastewater pretreatment based on sieving and grit removal.

Figure 4
Biodiscs system for a 100 m^3/d flow. The system incorporates secondary sedimentation, UV disinfection and it is provided with an outer cover.

Figure 5
Biodiscs system with integrated cover. It shows no odor problems or noise, so it can be installed very close to populated areas and/or housing.

Figure 6
Transport compact units for flow rate: 45 m^3/d.

Figure 7
Transport in the case of larger units for major flows.

Figure 8
Industrial plant with wastewater treatment by biodiscs