# *The State of Art of Biotechnology in Textile Effluent Treatment*

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# Pollution

“Pollution means the introduction by man, directly or indirectly, of substances or energy into the environment resulting the deleterious effects of such nature as to endanger human health, harm living resources or interfere with amenities or other legitimate use of the environment”

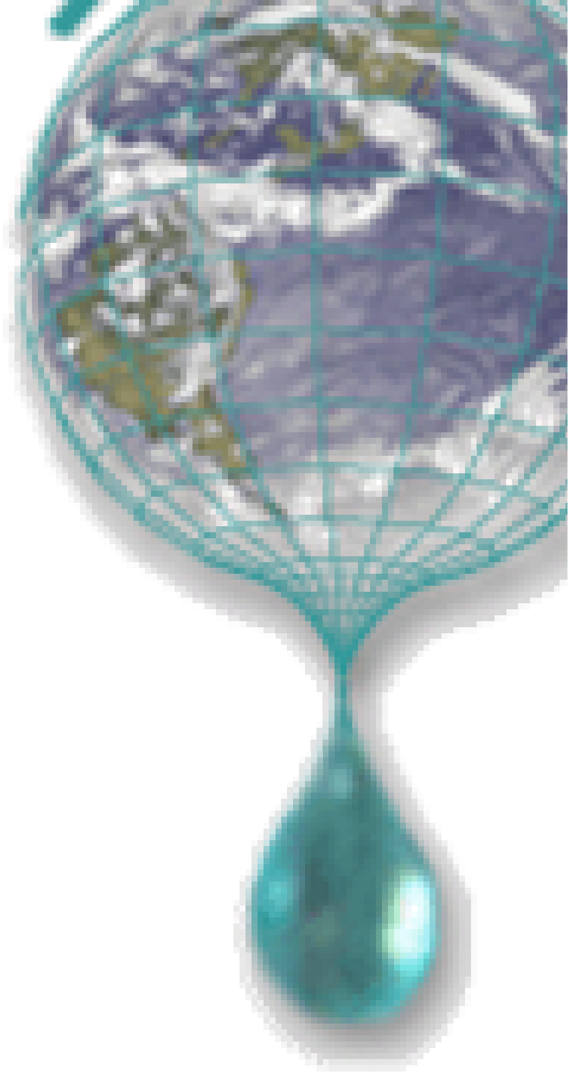
OECD

# Motto:

*“We have change so much the environment that we have now to change ourselves for living in it.”*

*Norbert Wiener*

# Is water a problem?



# Why a water concern when the planet has 71% water ?

***Problems***

- Scarcity of fresh water;
- Needs of water for life preservation;
- Needs of water in agro-industrial activities;
- Development of a consumer society;
- Cost of wastewater treatment, etc.

# *Water Sources*

## ***Water reserves Volume ($10^{12}$ L)***

| | | | |
|---|---|---|---|
| *World ocean* | 1338000 | *Lakes* fresh | 91 |
| *Ground water* | 23400 | saline | 85 |
| fresh | 10530 | *Glaciers and perm. Snow* | 24064 |
| soil moisture | 16.5 | *Swamp water* | 11.5 |
| *Ground ice* | 300 | *River flow* | 2 |
| *Biological water* | 1 | *Atmospheric water* | 1.3 |

Total water reserves 1385984 x $10^{12}$ L

Total fresh water reserves 35029 x $10^{12}$ L

(2.53%)

*Water in Crisis: A Guide to the World's Fresh Water Resources,* Ed. P.H. Gleich, Oxford Press University, Oxford, 1993

# *Water in living organisms*

- Human body 60-70% ; ~ 40 L ( 25 L inside cells and 15 L outside ).
- *Escherichia coli* 76 %

*Role of water in living organisms*:

- metabolism solvent;

- photosynthesis ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$);

- transport of substances and energy;

- temperature control, etc.

# *Water used by human activities*

(km³/year)

| Water users | 1900 | 1950 | 2000* |
|---|---|---|---|
| ***Agriculture*** | | | |
| - withdrawal | 525 | 1130 | 3250 |
| - consumption | 409 | 859 | 2500 |
| ***Industry*** | | | |
| - withdrawal | 37.2 | 178 | 1280 |
| - consumption | 3.5 | 14.5 | 117 |
| ***Municipal supply*** | | | |
| - withdrawal | 16.1 | 52 | 441 |
| - consumption | 4.0 | 14 | 64.5 |

*Water in Crisis: A Guide to the World's Fresh Water Resources,* Ed. P.H. Gleich, Oxford Press University, Oxford, 1993

# *Water consumption in textile processing*

## Cotton industry:

- 100 – 130 L/kg - continuous processes;
- 160 – 220 L/kg - batch operations.

## Wool industry:

- 100 – 300 L/kg

L. Kramer, *L'industrie Textile*, **1995**, *1266*, 44-47

# *Water consumption in textile processing*

| Processing Subcategory | Value (L/kg) Minimum | Median | Maximum |
|---|---|---|---|
| Wool | 110.9 | 284.4 | 658 |
| Woven | 5 | 113.6 | 507.9 |
| Knit | 20 | 83.4 | 377 |
| Carpet | 8.34 | 46.7 | 162.6 |
| Stock/Yarn | 3.34 | 100 | 558 |
| Non-woven | 2.5 | 40 | 82.6 |
| Felted fabric | 33.4 | 212.7 | 932.4 |

B. Smith, **1986**, *Identification and reduction of pollution sources in textile wet processing.* North Carolina Dept. of Natural Resources and Community Development, Pollution prevention Pays Program, Raleigh, N.C.

# *The water cost*

The water price include the fresh water cost as well as the cost of wastewater treatment due to pollution.

**Water cost for cotton**

-18-28 FF/$m^3$ in Germany;

- 4-9 FF/$m^3$ in England;

- 2-5 FF/$m^3$ in France, Italy and Spain

While the cost for the treatment of the wastewater from wool industry is 100 FF/$m^3$

L. Kramer, *L'industrie Textile*, **1995**, *1266*, 44-47

# *The consumption and water cost*

## Data from UK finishers

| Effluent flow | Source | Cost |
| --- | --- | --- |
| 175 $m^3$/day | River and moors | £353/year |
| 15 $m^3$/day | Town water | £0.592/$m^3$ |
| 130-160 $m^3$/week | Town water | £0.55/$m^3$ |

C. Diaper, V.M. Correia, S.J. Judd, *JSDC*, **1996**, *112*, 272-281

# *Water pollution*

The degradation of water quality by introduction of chemical, physical or biological parameters

***Water pollutants**:*

- waste from: industrial effluents, domestic and agricultural sewage, radioactive discharge, etc.;
- oil spillages;
- acid precipitation;
- suspended solids

# *Basic Parameters in Wastewater Characterization*

- ***Source information*: waste constituent, discharge rate, batch discharges, frequency.**
- ***Physical properties*: temperature, particulates, color, odor, foamability, etc.**
- ***Chemical composition*: COD, TOC, toxic compounds, heavy metals, specific ions, pH, etc.**
- ***Biological factors*: BOD, toxicity ($LC_{50}$, TU) for plants, bacteria, fish, animals.**

# *Pollution in textile wastewaters*

## Chemical pollution:

- inorganic compounds (acids, alkalis, salts, redox agents, etc.);
- complexing agents (polyphosphates, EDTA);
- metallic ions: Cr (III), Cr (VI);
- surfactants;
- carriers;
- pesticides;
- resins;
- oils and greases, etc.

# *Pollution in textile wastewaters*

Physical pollution:

- color;
- suspended solids;
- temperature.

# Textile wastewaters characteristics

- Different content, due to the variety of materials and operations;
- Discontinuous effluent content due to the modification of the production in connection with market demands;
- Presence of toxic compounds such as: metals, surfactants, chlorinated organics, pesticides, toxic anions, etc.

# *Typical sources of Metals in Effluent*

| Metal | Source |
|---|---|
| Cadmium | Impurity in salt |
| Chrome | Dyes |
| Cobalt | Dyes |
| Copper | Dyes, fiber |
| Mercury | Dyes, chemical impurity |
| Nickel | Dyes |
| Tin | Finishing chemicals |
| Titan | Fibers |

S. Wagner, *Improvement in products and processing to diminish environmental impact*, COTTECH Conference, 11-12. Nov **1993**, Raleigh, N.C.

# General characteristics of textile wastewaters

**pH:** 4-12 (4.5 knitted wool, 11 cotton);

**COD:** 250 – 150 mg/L;

**BOD:** 80 -500 mg/L;

**COD/BOD:** 3-5;

**Color:** 500 -2000 Pt-Co units;

**Suspended matter:** 30 -400 mg/L , sometimes 1000 mg/L for cotton;

**Cr (VI):** 1-4 mg/L

**Sulphide:** 0-50 mg/L

E. Puscas, M.D. Stanescu, M. Fogorasi, V. Dalea, *Dezvoltarea durabila prin protectia mediului si biotehnologii textile*, Ed. UAV, **2003**, p. 179.

# *Textile wastewaters treatments*

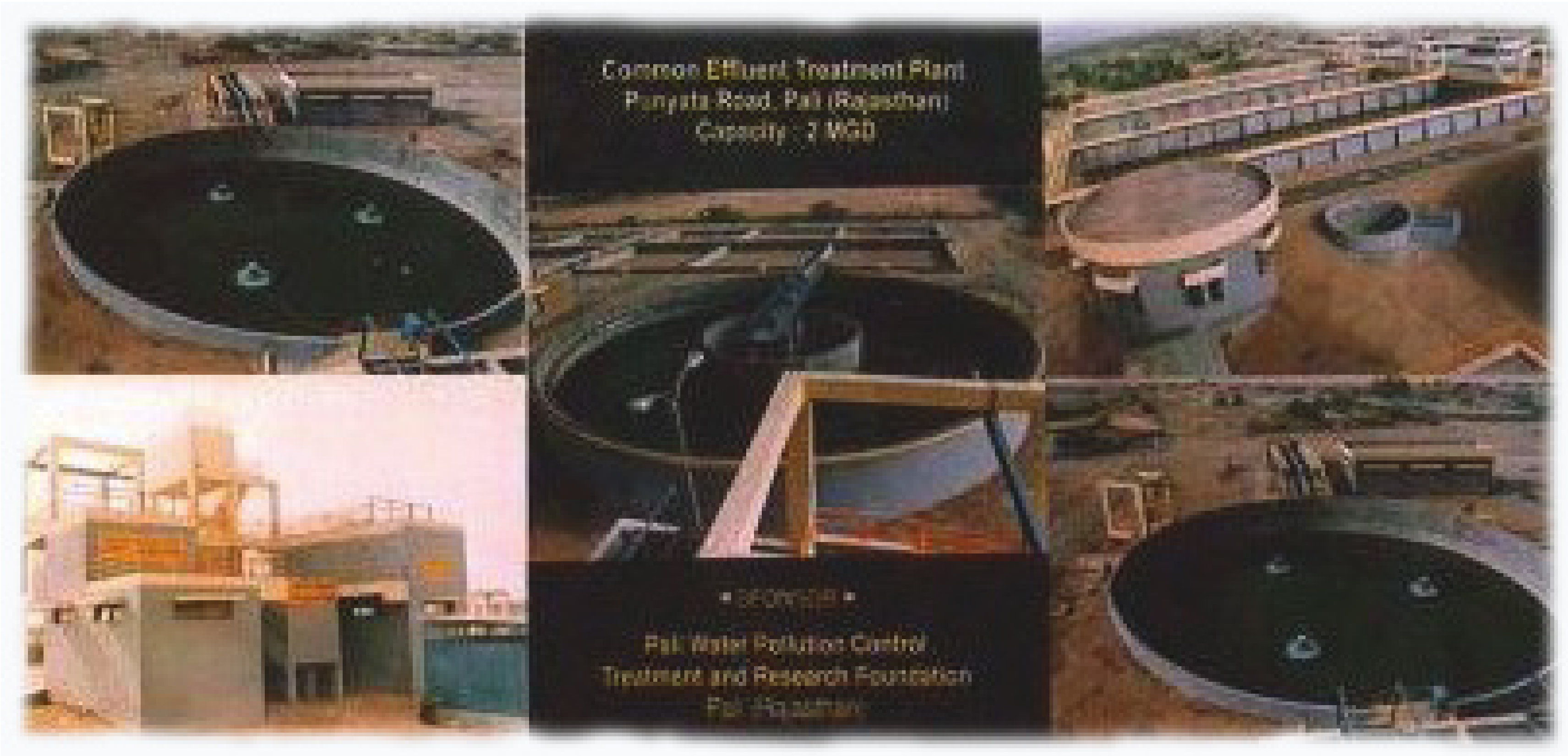
The state of art for textile effluent decontamination involves a centralized treatment plant for both either end of pipe textile effluents alone or mixed textile and domestic wastewater.

More than 80 % of textile finishers from UK discharged their effluent to sewers, paying the local water industry (C. Moran, M.E. Hall, R. Howell, *JSDC,* ***1997***, *113*, 272-274)

All textile factory from Romania discharge their effluent to sewers sometimes after a pretreatment

Pollutants to be removed: COD, BOD, nitrogen, heavy metals, dyestuffs, pesticides.

# *Wastewater treatment plants*



# *Textile wastewaters treatments*

Generally the treatment consists in:

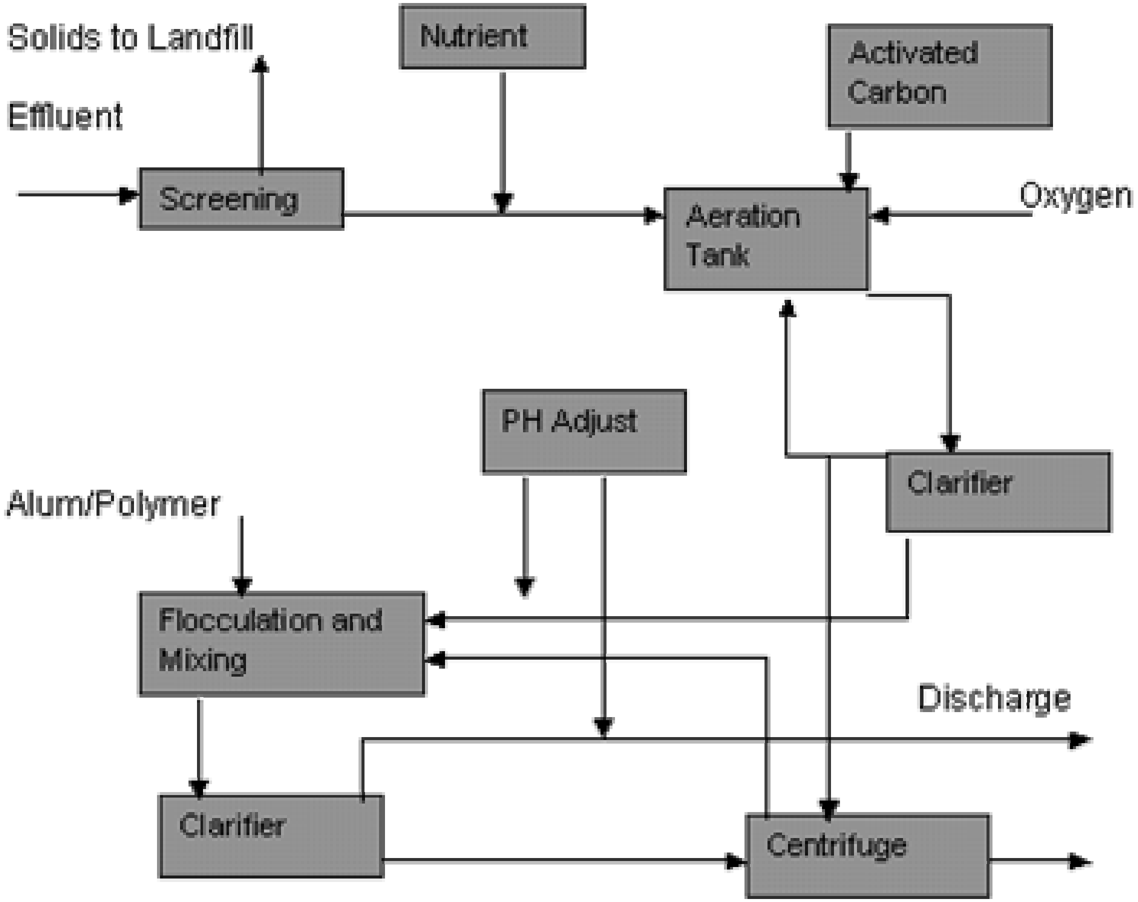
- physicochemical treatments (screening, filtration, equalization, aeration, coagulation, flotation, neutralization, oxidation, etc.);
- biological treatments [aerobic (activated sludge, bio-filters), anaerobic, plant absorption, etc.]
- physicochemical post-treatments (sorption processes, membrane filtration, oxidation, etc)

# *Textile wastewaters treatments by biological methods*

“Mainly by empirical means a variety of biological treatment systems have been developed, ranging from septic tanks and sewage farms to gravel beds, percolating filters and activated sludge process coupled with anaerobic digestion. The primary aim of all these systems or bioreactors is to alleviate health hazards and reduce the amount of organic compounds, producing a final effluent that can be discharged into natural environment without any adverse effects”

J.E. Smith, *Biotechnology*, 2nd edition, Chapman and Hall, New York, 1988, p. 113.

# Activated Sludge Process

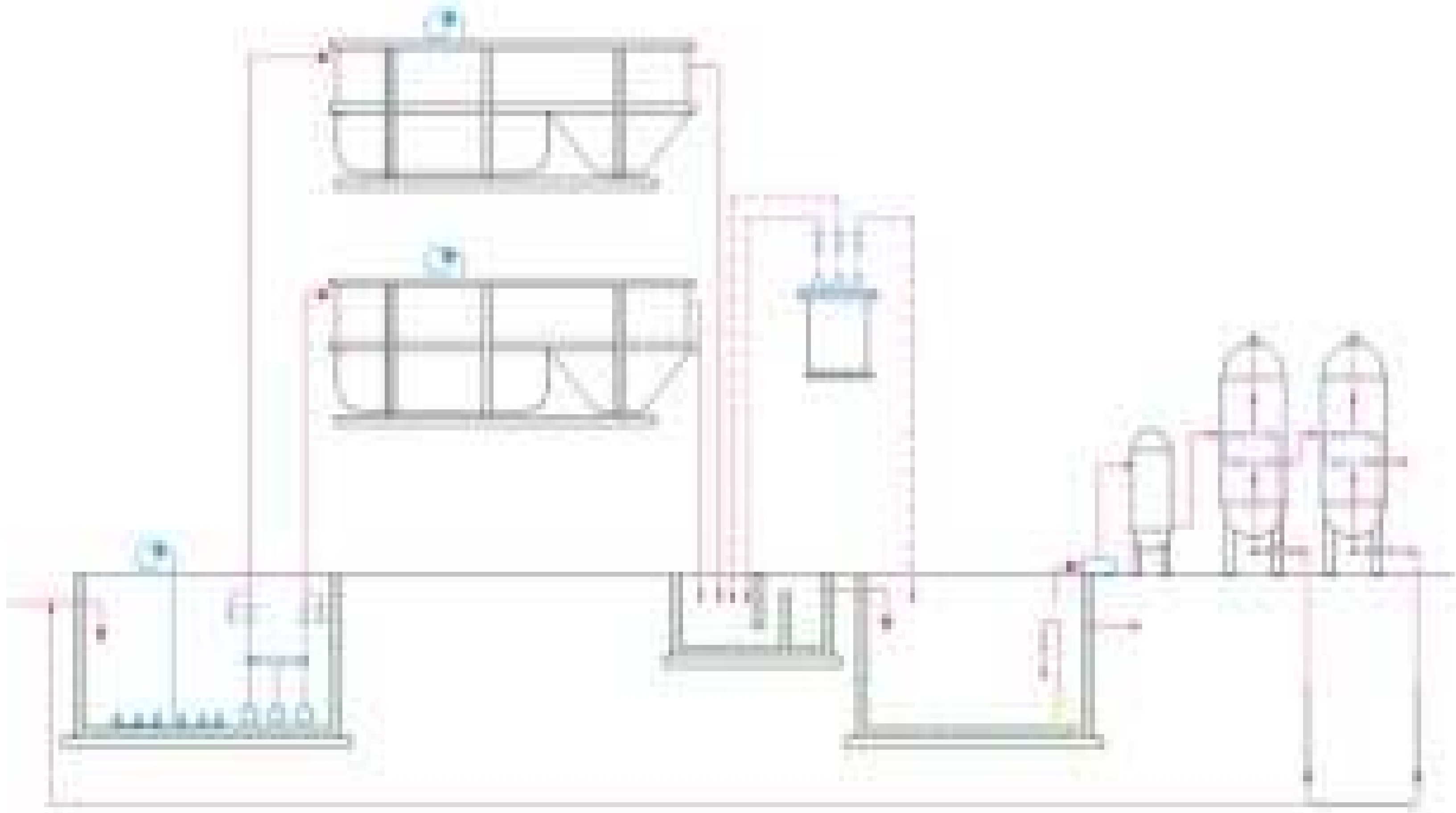


# Biological Plant: active sludge treatment, nitrification & denitrification

# *Wastewater purification mechanism by activated sludge*

| Equalizing tank → | Activated sludge → | Settling tank |
|---|---|---|
| (equalization, pH adjustment) | (aeration) | (separation) |
| *Organic Substances* | *Microbes* | *Sludge* |
| | *(anabolism, catabolism)* | *H2O, CO2, residual o.s*. |

- In general about 90-95 % of the BOD load is removed;
- The supernatant is discharged as treated water;
- The activated sludge is re-circulated.



*Example of a BIOCLAR application: a modular plant for large communities with seasonal fluctuations and recovery system.*

# *Bioclar Process*

The wastewater treatment consists in:

- Aeration in contact with recycled activated sludge;
- Oxygenation;
- Sedimentation.

Characteristics:

- High concentration of sludge;
- Re-aeration of sludge in the second step.

Performance:

- Removal of more than 94% BOD, COD.

# Problems and Solutions

**Necessity to remove nutrient (N, P).**

***Nutrient excess in the effluent – algal bloom and deaeration of the water course (eutrophication).***

## Removal of N:

***Nitrification:***

- two stage activated sludge process: carbonaceous removal, nitrogen removal;

- single stage trickling filters for a low BOD (20 mg/L)

# Problems and Solutions

***Denitrification:***

- anaerobic reduction

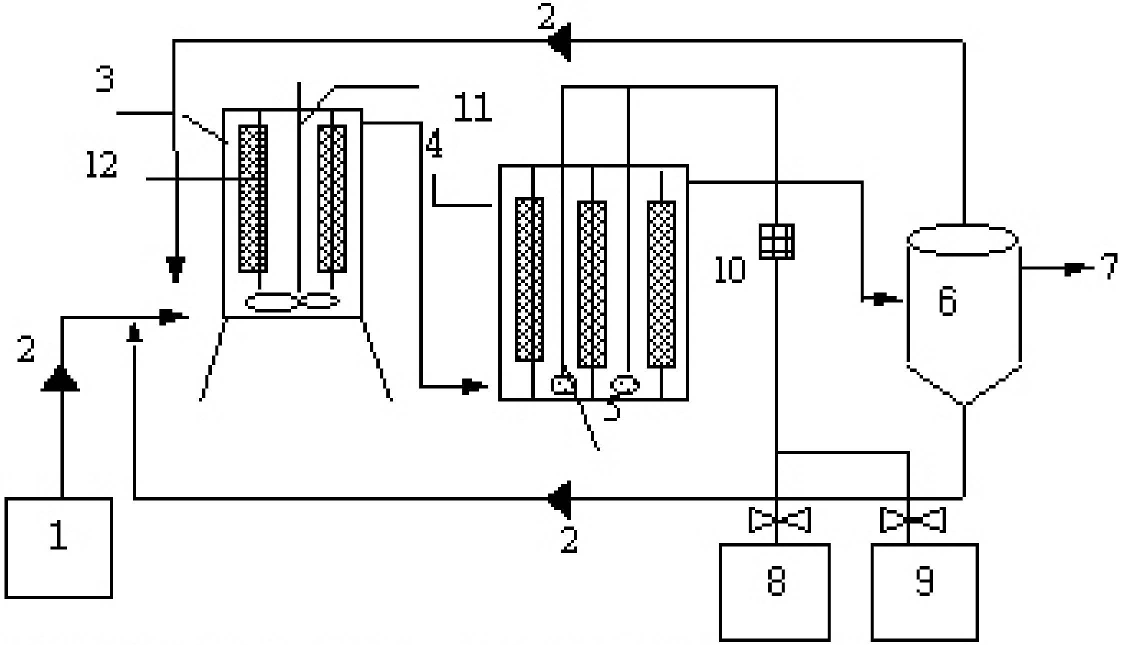
**Removal of P:**

Phosphorous is a limiting bio-element ($10^{-3}$mg/L required before algal growth will occur)

- aeration help phosphor removal

Combination of aerobic and anaerobic procedures helps nutrients removal.

# Biofilm Process




1, Influent basin, 2, Peristaltic pump, 3, Anoxic reactor, 4, Aerobic reactor,
5, Air and pure oxygen diffuser, 6, Settling basin, 7, Effluent, 8, Air compressor,
9, PSA (Pure Oxygen Generator), 10, Gas flow meter, 11, Mixer,
12, Fibrous carrier (Filamentous substratum)

**Schematic diagram of the A/O experimental process combined with pure oxygen and submerged biofilms**

# *A/O Pure Oxygen Submerged Biofilm Process*

The wastewater treatment consists in:

- anaerobic removal of nitrogen;
- aerobic removal of organic waste;
- sedimentation.

Characteristics:

- low reactor space requirements;
- high biomass;
- high efficiency;
- reduced sludge production

# Problems

The presence of toxic and non biodegradable residues like:

– Metals;
– Pesticides;
– Toxic ions;
– Dyes;
– Organic chlorides, etc.

The reduction of toxicity of textile effluent following aerobic digestion appears negligible.

C. Moran, M.E. Hall, R. Howell, *JSDC*, **1997**, *113*, 272-274.

# Problems and Solutions

## Control of contaminants in wastewaters

Necessity to apply appropriate methods of analysis evidencing traces of low biodegradable or environmental hazardous compounds, such as:

- Spectrophotometric methods (UV-Vis, NMR, AAS, ICP-OES, ICP-MS, etc.);
- Electrochemical or Optical Biosensors;
- Chromatographic methods (GC, HPLC, TLC)

# Problems and Solutions

## Metals

- The presence of Cr, Cu, Ni, Zn < 10 mg/L decrease the activity of the sludge with 6%.
- The metals can be eliminated by:
  – Sorption on solid materials (charcoal, molecular sieves, clay, etc.);

  M. Stefan, D.S. Stefan, L. Bobirca, Proceedings RICCE 13, Bucharest, **2003**,vol 1,pp.152-157

  – Functional metal-binding proteins as ligands;

  T. Ansuki, D. Sano, T. Omura, *Water Sci.Technol.,* **2003**, *47*, 109-115.

  - Membrane technology;

  G. Ciardelli, L. Corsi, M. Marcucci, *Resources, Conservation and Recycling*, **2001**, *31*, 189-197.

# Problems and Solutions

- Bio-sorption using anaerobic sludge (extra-cell polymers);

  A.Jalal, C. Mulligan, Proceedings 18$^{th}$ Eastern Canadian Symposium, Quebec, 2002, p.17**.** G. Guibaud, A. Bouju, N. Tixier, M.Baudu, ibid, p.56.

- Reduction of Cr (VI) using an immobilized bacteria;

  P. Pattanapipipaisal, N.L. Brown, L.E. Macaski, *Biotechnology Letters*, **2001**, *23*, 61-65.

# *Problems and Solutions*

## Pesticides

- Problems in connection with organochlorides (DDT, Aldrin, Endrin, etc).
- The pesticides may be eliminated by:
  - Oxidation using UV and $O_3$;

    D.W. Major, J. Fitchko, *Hazardous Waste Treatment On-Site and In Situ*, Butterworth-Heinemann Ltd, Oxford, 1992.
  - Fungus digesting DDT and PCBs;

    P. Lenox and &, *Biotechnology for NZ Engineers*, **2003.**
  - Biodegradation and Bioremediation;etc

    M.D. Faber, *Enzyme Microb. Technol.*, **1979**, *1*, 226-232; *Pesticides Remediation in Soil and Water,* Ed. P.K. Kearney, T. Roberts, J. Wiley&Sons, Chichester, 1998.

# *Problems and Solutions*

Dyes

- The color removal is still a major problem concerning textile effluents.
- The removal of color may be done by:
  - Catalytic ($TiO_2$) photo-degradation (reactive dyes);

    C. Lizama, M.C. Yeber, J. Feer, H.D. Mansilla, *Water Sci.Technol.*, **2001**, *44*, 197-203.
  - Catalytic (CuO) oxidation (reactive dyes);

  A. Bertea, R. Butnaru, L. Dobrescu,Proceedings RICCE 13, Bucharest, 2003, vol1, pp. 96-101
  - Adsorption on activated carbon (cationic, mordant and acid dyes)

    O.Marmagne, C. Coste, *American Dyestuff Reporte, **1996,***

# *Problems and Solutions*

– Cationic polymers (disperse dyes);

A. Jemaitaitis, R.J. Zemaitaitiene, E. Zliobaite, H. Thomas, H. Hocker, *Melliand Textilberichte*, **1994**, *4*, 312-315.

– Special microorganism or enzymes:

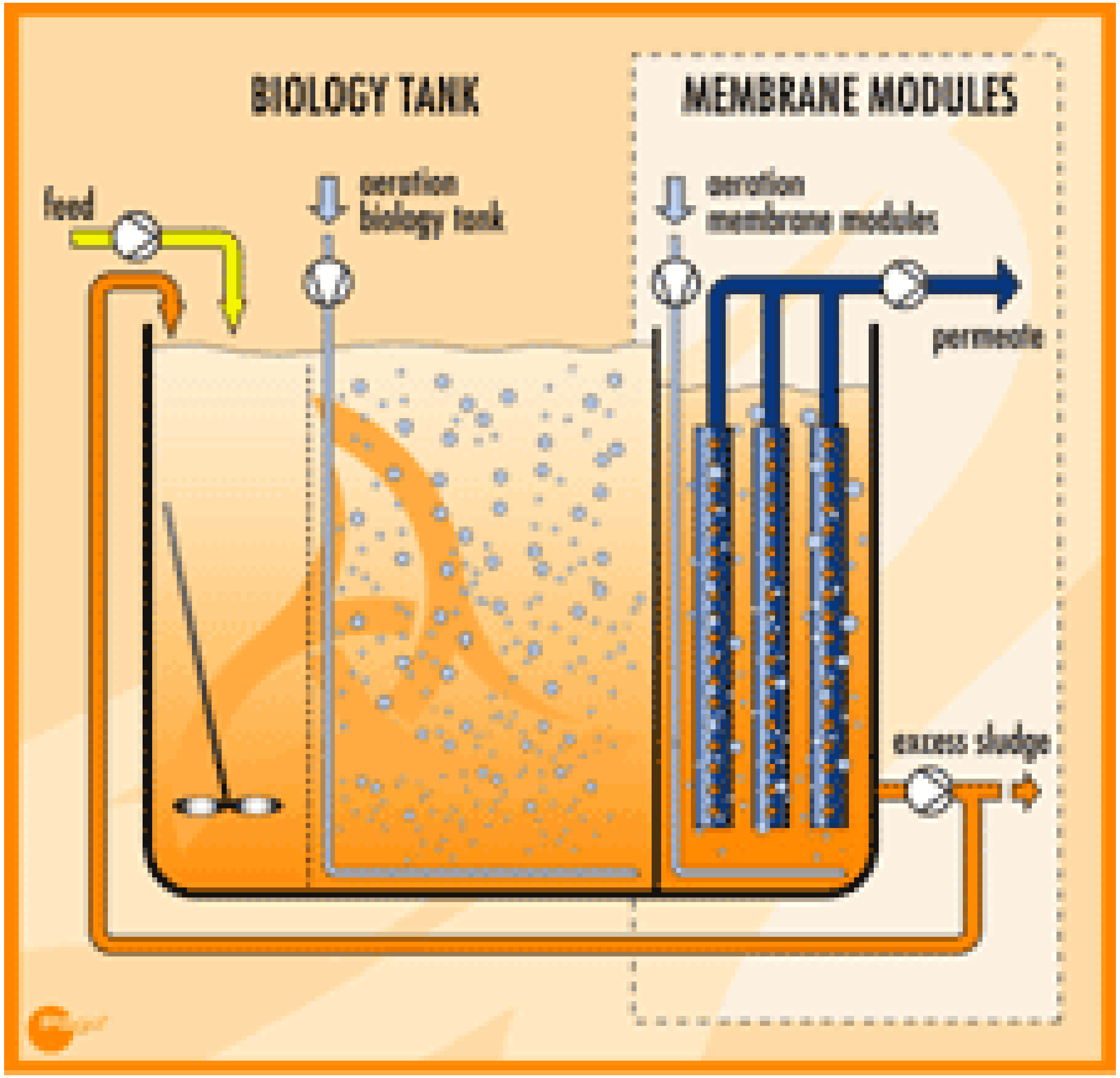
- *Ligninolytic fungi*; C. Novotny et all, *J.Biotechnology*, **2001**, *89,* 113-122, P.R. Moreira et all, *J.Biotechnology*, **2001**, *89,* 107-111, I. Mielgo et all, *J.Biotechnology*, **2001**, *89,* 99-106, I. Darah, C.O. Ibrahim, *Annales Bogorienses*, **1998**, *5*, No 2, M. Adosinda et all, *J.Biotechnology*, **2001**, *89,* 91-98, D.S.L. Balan et all, *J.Biotechnology*, **2001**, *89,* 141-145
- *Laccases*; R.Campos et all, *J.Biotechnology*, **2001**, *89,* 131-139, E. Abadula et all, Applied and Environmental Microbiology, **2000**,66*, 3357-3362.*
- *Cocktail of oxidoreductases;* M.C. Costa-Fereirra, G. Soares, M.T. Pessoa de Amorim, *Electronic Journal of Environmental Agriculture and Food Chemistry*, **2002**.

# *Problems and Solutions*

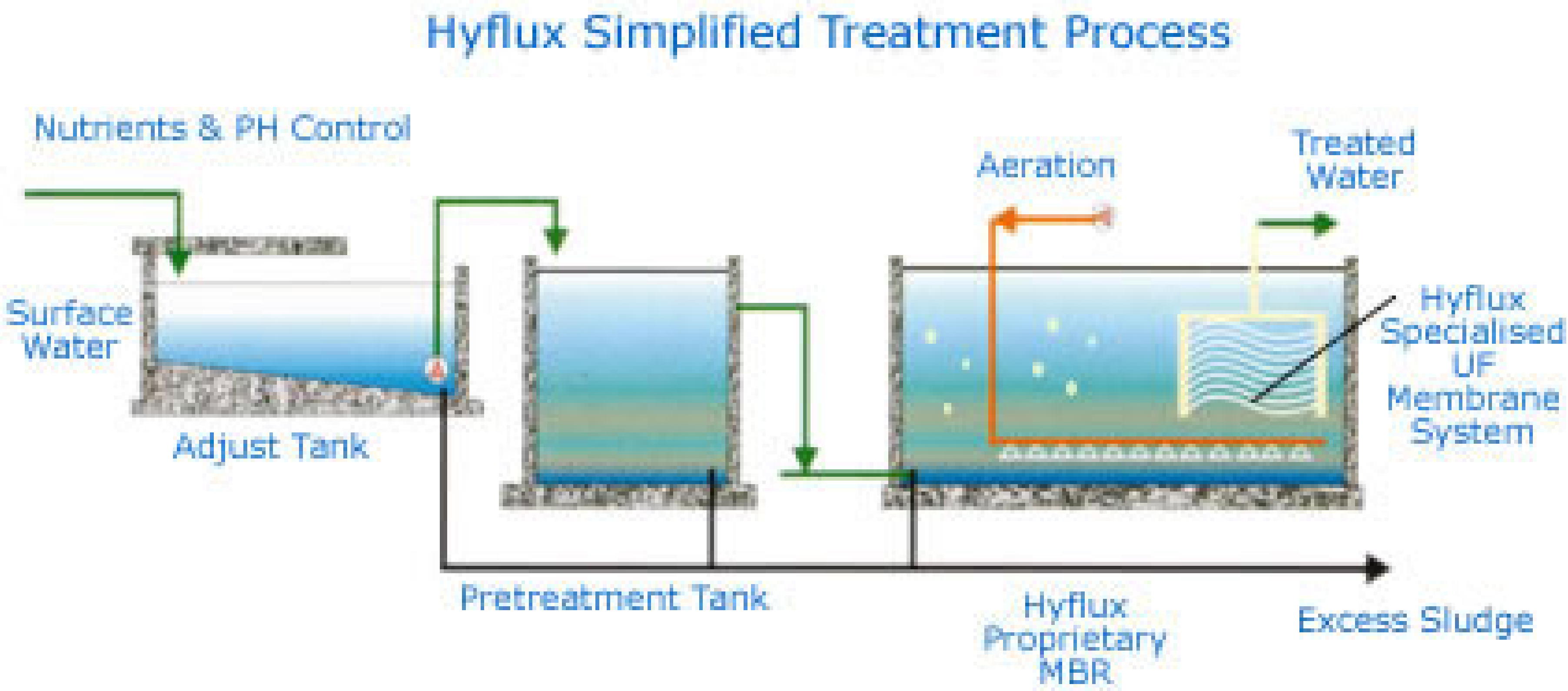
– Combined procedures:

- Biological anoxic decolorization, aerobic combined with O3 oxidation (azo dyes); R. Krull, D.C. Hempel, *Water Sci.Technol.*, **2001**, *44(5)*, 85-92.
- Activated sludge combined with membrane plant; G. Ciardelli, L. Corsi, M. Marcucci, *Resources, Conservation and Recycling*, **2001**, *31*, 189-197. C.W. Aurich, *JSDC*, **1995**, *111*, 179-181
- Absorption and coagulation combined technology; R. Reid, *JSDC*, **1996**, 140-141.
- Fungal laccase together with redox mediators; G.M.B. Sores, M.T. Pessoa de Amorim, M.C. Ferreira, *J.Biotechnology*, **2001**, *89*, 123-129.

# Complementary technology



# *Combined Processes*



# Concluding remarks

- Biotechnology offer a number of solutions for textile effluent treatments;
- The aerobic anaerobic biodegradation procedures may be improved by bioremediation (development of new microorganisms, enhancement of special types of microorganisms, etc.);

# Concluding remarks

- The use of commercial enzymes for segregated effluents seems practical;
- Combinations of biological methods with high technology procedures like: ultra-filtration, reverse osmosis, etc., give good results;
- Combinations of chemical with biological procedures improve the water quality;

# Concluding remarks

- There is no general solution for the textile effluent treatment each case has to be carefully analyzed to establish the best solution.

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