# ANAEROBIC-AEROBIC TREATMENT OF DAIRY WASTEWATER WITH NATIONAL TECHNOLOGY IN MEXICO: the case of "El Sauz".

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## ABSTRACT

A short term solution for the treatment of dairy waste water is discussed. Discharge rate is 500 $m^3$/day with a high organic load (2,750 Kg COD/day). Low capital investment (US $ 330,000) and operational (US$ 0.55/$m^3$) costs were required which ought to be competitive with current market prices but within the official environmental norms imposed by the national agency SEDESOL.
The problem was solved by remodelling existing lagooning facilities which were operating below the official norm. Local technology was used with the exception of aereation equipment. The system was made of: a clarifier, an anaerobic lagoon, an intemediate aerobic lagoon and an effluent polishing lagoon with water hyacinth. Design and supervision was done by UAM-Iztapalapa personnel. Construction and operation by the cheese factory "El Sauz, S.A. de C.V."

## KEYWORDS

Dairy industry, anaerobic digestion, lagoons, aereation, stream segregation, water hyacinth,

## INTRODUCTION

Cheese waste problem in Mexico:
A brief presentation of the milk factory in Mexico will show the perspectives of the work done at "El Sauz" since a similar process can be adopted for all this industry.
The processing of milk and derivates represents 10 % of the gross internal product of the food industry and 1.8 % of the total manufacturing industry. There are 5 million milk cows which produce around 7,288 x $10^6$ liters of milk per year (national consumption being 9,500 x $10^6$ l/year). 15% of the milk national consumption is imported (145,000 tons of powdered milk). 48% of the national production is used for direct consumption while 52% is processed. Of this latter fraction, 46% is pasteurized, 12% is used for the production of dried, condensed, low fat and skimmed milks and 42% for the production of derivates (cheese, cream and butter).

The milk industry generates between 3.739 and 11.217 million $m^3$ of wastewater per year (1 to 3 times the volume of milk processed). In average this wastewater contain 1000 to 4000 mg/l of $BOD_5$ (Biological Oxygen Demand) corresponding to 2 to 5 g of BOD per kg of processed milk (table 1) That kind of wastewater contain all the organic compounds present in milk which are easily biodegradable and generate a high BOD as well as other substances used during the cleaning of equipment (acids, bases and detergents).
The different operations of the cheese production industry (reception of raw milk, filtration, cooling, coagulation, fat and protein separation, moulding, pressing, salting, packing and storage generate from 1800 to 2000 mg $BOD_5$ per liter of milk. In summary the pollution contributed by the milk industry is shown in table 1.

Table 1 Waste generation by the dairy industry

| PARAMETER | UNIT | DAILY AVERAGE | RANGE |
|---|---|---|---|
| Volume | $m^3/m^3$ of milk | 1 - 2 | 0.5 - 4.0 |
| $BOD_5$ load | Kg/ $m^3$ of milk | 1.8 - 2 | 0.3 - 0.5 |
| $BOD_5$ | mg/l | 500 - 2000 | 1 - 50,000 |
| COD/ $BOD_5$ | - | 1.4 | 1.1 - 2.8 |
| settleable solids | ml/l | 1 - 2 | 0 - 250 |
| TSS | mg/l | 280 | 220 - 340 |
| VSS | mg/l | 250 | 200 - 300 |
| pH | | 9 - 10.5 | 1 - 13 |
| $NH_4$-N | mg N/l | 18 | 13 - 23 |
| Organic-N | mg N/l | 70 | 93 - 50 |
| Total P | mg P/l | 100 | 75 -125 |
| Total S | mg S/l | 520 | 425 - 615 |
| $SO_4$ - S | mg S/l | 481 | 341 - 621 |
| Na | mg/l | 850 | 720 - 980 |
| $Cl^-$ | mg/l | 2,580 | 1730 - 3430 |
| $Ca^{2+}$ | mg/l | 740 | 530 - 950 |

Production of wastewater by the cheese factory "El Sauz S. A. de C. V."

The plant of "El Sauz" at Cortazar in the state of Guanajuato, Mexico, produces an average of 1500 tons of milk derivates per month and 500 $m^3$ of wastewater per day. Some of its characteristic parameters are shown in table 2 which indicate that the organic pollution generated by "El Sauz" is higher than average (table 1).

Table 2. Waste water characteristics at "El Sauz" dairy industry.

| **Parameter** | **Mean** | **Min** | **Max** |
|---|---|---|---|
| COD (mg/l) | 4,430 | 1,000 | 7,500 |
| TSS (mg/l) | 1,110 | 500 | 2,500 |
| O&G (mg/l) | 754 | 200 | 1,800 |
| $PO_4$ - P (mg/l) | 14 | 6 | 23 |
| $NH_4$ - N (mg/l) | 18 | 9 | 60 |
| pH | 7.32 | 5.5 | 9.5 |

Existing wastewater treatment facilities. In december 1991, "El Sauz" had a treatment system consisting of a degreasing tank and three lagoons with the dimensions shown in table 3.
The quality of water achieved by this treatment system is presented in table 4 together with the discharged limits imposed to the factory by the mexican ministry of ecology in december 1985. As shown, several parameters ($BOD_5$, fat and grease, settleable solids, nitrogen and phosphorus) were not within the norm

because both the anaerobic lagoon and the maturation lagoon were not performing well. The problem was possed to several engineering firms gaving different answers which did not satisfied "El Sauz "requirements like the use of preexisting installations and low operating and investment costs. So "El Sauz" decided to build their own treatment plant.

Table 3 Dimensions of the existing waste water treatment plant at "El Sauz"

| | WIDTH (m) | DEPTH (m) | VOLUME ($m^3$) | HRT (d) |
|---|---|---|---|---|
| Pumping well | | | 6 | |
| Grease and oil | 16.2 | 2.4 | 62 | 0.124 |
| Anaerobic pond | 28 | 7 | 400 | 8 |
| Facultative pond | 28 | 7 | 400 | 8 |
| Maturation pond | 24 | 6 | 200 | 5 |

Table 4. Specific discharge conditions and effluent characterization at "El Sauz" before the anaerobic-aerobic treatment plant was commissioned.

| Parameter | PDC | | | Effluent | Treated |
|---|---|---|---|---|---|
| | Mean | Max | Cmax | | |
| $BOD_5$ (mg/l) | 90 | 100 | 7 | > 4,000 | > 393 |
| COD (mg/l) | - | 300 | - | 4,500 | |
| TSS (mg/l) | 90 | 100 | 7 | 1,000 | 65 |
| O & G | 10 | 15 | 0.7 | 1,000 | 56 |
| T (°C) | | 35 | | 28 | 24 |
| pH | > 6 | < 9 | | 9.2 | 7.5 |
| Sett Solids(ml/l) | | 1 | | | > 1 |
| Color (Pt-Co) | | 100 | | | 58 |
| Conductiv (µS) | 2,000 | | 3,400 | | 2,600 |
| Org - N (mg/l) | | 3 | | | 22 |
| $PO_4^{3+}$- P(mg/l) | | 5 | | 61 | 35 |
| Total Coliforms (NMP/100 ml) | 10,000 | 20,000 | | | |
| SAR | | 6 | | 27 | 20 |
| Materia Flotante | | Nil | | present | Nil |

**Mean** is the monthly mean of four samples taken at different days which should not exceed:
**Max** is the maximun value any sample can contain. **Cmax** is the maximum load in Kg/d.
**PDC** particular discharge conditions imposed by the ecology authorities.

## DESIGN OF A NEW TREATMENT SYSTEM FROM THE OLD INSTALLATIONS:

Four treatment steps were considered to redesign the plant:

1. Reduction of wastewater pollution by:

- *Segregation of plant effluents.* It was decided to recycle the acids and bases ($H_3PO_4$ and NaOH) used for cleaning the tanks and the pasteurization equipment in order to avoid their discharge. This introduced three advantages: reduction of chemical consumption, stability of wastewater pH, reduction of SAR and conductivity.
- *Removal of salts from effluent.* Concentration and drying of the brine produced during the regeneration of the ion exchange resins.
- *Substitution of cleansing chemicals.* Commercial detergents were changed to reduce the concentration of phosphorus in the wastewater as well as the formation of foam.

2. Pretreatment:

The existing grease and oil trap consisted of 4 sections. To increase its capacity , the three compartments of the first section were filled with rocks of differents diameters (3", 2", 1") to provide the mechanical deemulsification of grease . In the two following sections grease separation is obtained by flotation using fine bubble diffusers. Additionally, the fourth section is equipped with baffles to enhance grease separation. The pretreatment tank was designed to obtain an effluent with an oil and grease concentration of 300 mg/l.

3. Secondary biological treatment.

Anaerobic lagoon: Four examples of milk plants with pollution levels similar to "El Sauz" and using anaerobic treatment exist in the literature. Data on these treatment plants are given in table 6. Pfeiffer et al. (1986) and van Den Berg and Kennedy (1982) have shown that a Chemical Oxygen Demand (COD) removal of 60 to 95% is possible for Hydraulic Retention Time (HRT) between 5 and 25 h and organic loading loads of 0.5 to 18 Kg COD/m3.d. This indicates that with a high rate reactor such as the Upflow Anaerobic Sludge Blanket (UASB) it is possible to treat effluents from the milk industries at loading rates as high as 10 kg/m3.d with 80% efficiency. For eliminating nitrogen (N) and phosphorus (P) a $BOD_5$ /N/P ratio of 700/5/1 is necessary Actually the wastewater of "El Sauz" present a COD/N/P ratio of 700/13.2/3.15, this excess of nutrients (3 times more than the required) shows that a high loading rate can be applied.

TABLE 5. Anaerobic treatment experiences in the dairy industry.

| Reactor type | V ($m^3$) | So (gCOD/l) | F ($m^3$/d) |
|---|---|---|---|
| UASB | 400 | 3.8 | 765 |
| FFR | 500 | 3.8 | 765 |
| FA | 382 | 2.8 | 100 |
| Dig | 11,356 | 3.8 | 1,493 |

Bough *et al* (1987), Clanton *et al* (1987).

Calculations indicate that after the anaerobic step it is possible to obtain a water with 800 mg COD/l , 13 mg N/l, 100 mg of fat and grease/l and 11 mg P/l.

The experience obtained by the research group of the Universidad Autónoma Metropolitana in the design of UASB reactors and the search for an economical solution by "El Sauz" oriented the work towards the modification of the existing anaerobic lagoon. The modification consisted in optimizing the wastewater distribution to obtain a better contact between biomass and organic pollutants. The design is based on an homogenous distribution of the wastewater flow at the bottom of the lagoon as in UASB reactors (Lettinga and Hulshoff Pol 1991). Because of the large size of the lagoon and the absence of purging facilities, it was decided to build two steel bridges over its surface to support the distribution boxes and the PVC pipes.

Aerobic lagoon. Based on the designed effluent COD concentration from the upflow anaerobic lagoon, it was decided to add three surface mixer-difusers in the aerobic lagoon with a total capacity of 95 HP consumming 1700 kWh. In a first step, it was decided to operate the aeration system at 100% of its capacity during the necessary time for the upflow anaerobic lagoon to achieve its design efficiency (80% of COD removal). In a second step it is expected to put one of the motors in stand-by thus reducing the energy consumption by 37%; The aerobic lagoon was designed to reduce the water COD concentration from 800 mg/l to 112 mg/l (86% removal) using an aeration capacity of 60 HP at an energy cost of 1073 kWh. This capacity was calculated to maintain a mean dissolved oxygen concentration of 2 mg/l and a MLSS (mixed liquor suspended solids) of 1.2 g/l which gives a F/M (Food to Mass) ratio of 0.2 kg COD/kg MLSS.d. Being 7 days the HRT of the lagoon, the Solids Retention Time (SRT) was also 7 days which resulted in an adequate reactor stability without requiring recirculation as in the activated sludge process. With respect to N, P and fat and grease the actual design would allow to obtain 1, 7 and 10 mg/l in the effluent respectively.

4. Tertiary biological treatment.

Water Hyacinth lagoon. Previous experiences with this type of lagoon (Monroy and Sarquis, 1990) have shown that it is possible to reduce the concentration of nutrients to 1 mg N/l and 1 mg P/l. The TSS (Total Suspended Solids) coming from the aerated lagoon are pumped to the anaerobic lagoon for stabilization. Water hyacinth must be harvested every week to maintain a density of 8 kg (as fresh weigth)/$m^2$ with a high growth rate (O.24 kg/m2.d) in order to avoid its decay inside the lagoon.

## OPERATION RESULTS OF THE REDESIGNED PLANT

Figure 1 shows the flow diagram of the treatment system as well as the estimated water quality of the different streams. Figures 2 to 5 present the evolution of the final discharge of the treament plant from January 92 to January 93. The improvement of the plant performances after redesigning can be easily appreciated. The concentrations of oil and grease (Fig. 2), COD (Fig. 3 and 4) and TSS drastically decreased to the consent limits.
Both the actions of effluent segregation at the source and the water hyacinth lagoon allowed the significative reduction of the SAR (Fig. 5).
In summary, the new treatment plant performed adequately producing an effluent acceptable by the Ministry of Ecology. Table 7 the final quality of the water.

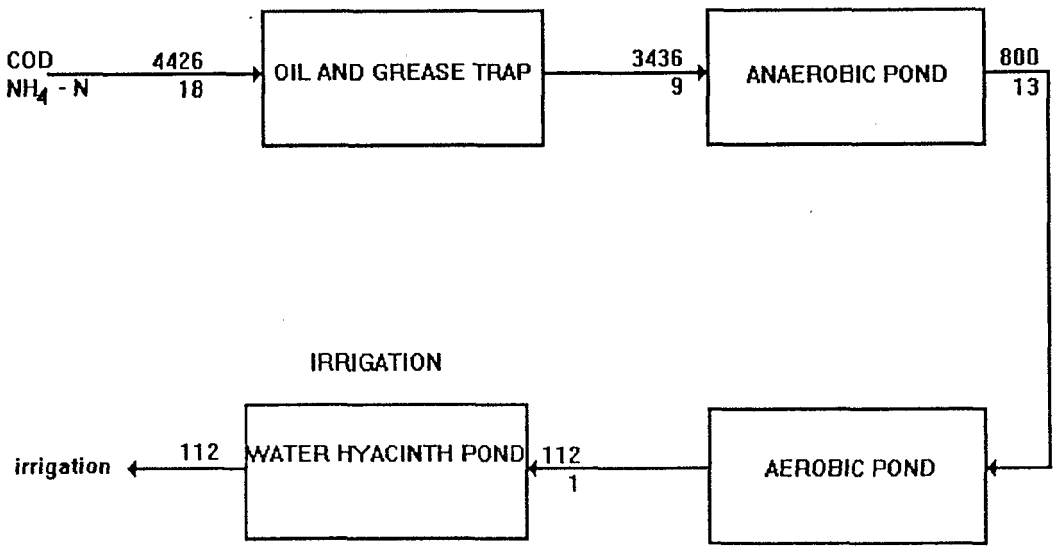


Figure 1. Flow diagram of the projected wastewater treatment system with the expected values of COD and $NH_4$ - N

## CONCLUSIONS

The estimated operation cost is aproximately US$ 0.55/$m^3$ with a total investment, considering the preexisting installations, of US$ 330,000.
These costs represent an increase of US$ 6.7 per T of processed cheese which represents a 0.4 % increase in the total operating costs.
These economic results show the feasibility of a wastewater treatment process for the dairy industry. This process consisted of a water management scheme to reduce flow rate and pollutants and an integrated physical-anaerobic-aerobic-water hyacinth process to avoid the use of chemicals and reduce operating costs.
This project was succesfully developed due to close cooperation between industry and university.

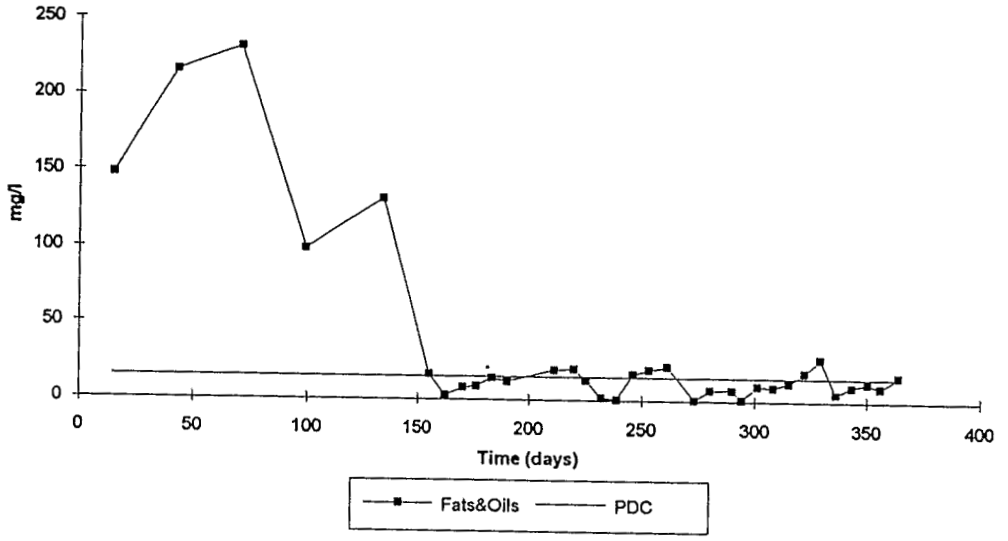


Figure 2 Grease and oil evolution during the commisioning and start up of the wastewater treatment plant at "El Sauz".

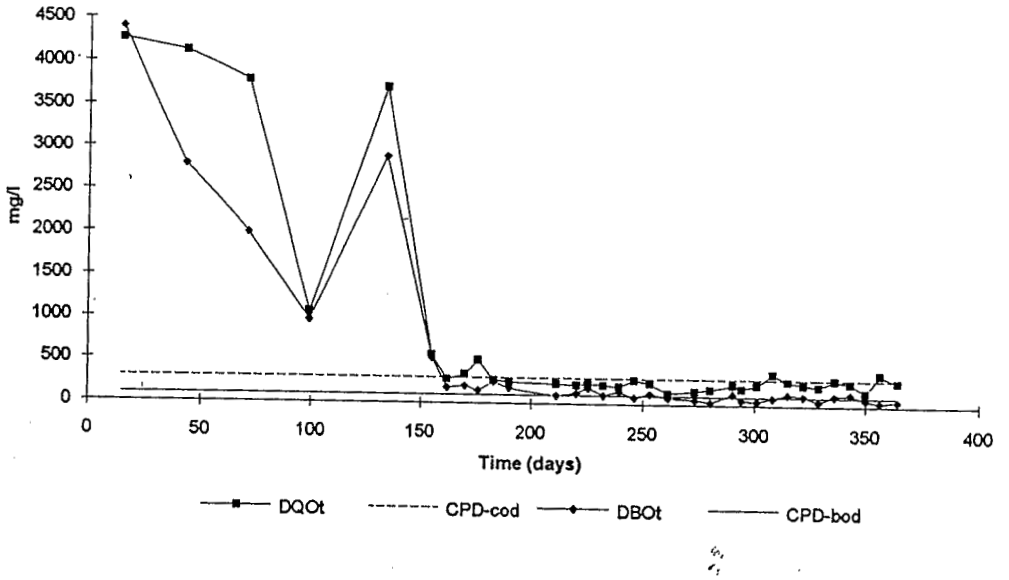


Figure 3. Effluent COD and BOD during the stabilization process of the waste water treatment plant at "El Sauz".

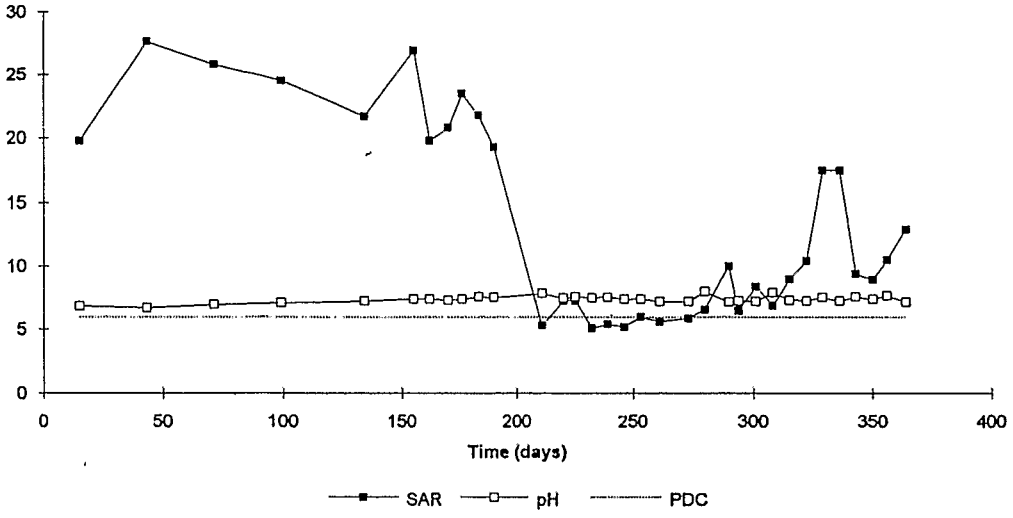


Figura 4 Effluent SAR and pH since the start up of the treatment plant at "El Sauz".

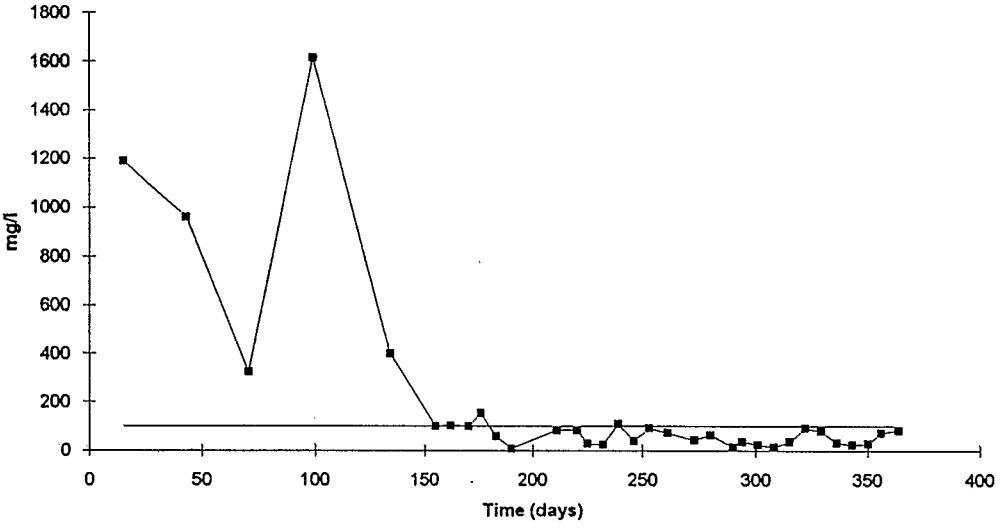


Figure 5. Suspended solids effluent concentration during the commisioning and start up of the treatment plant at "El Sauz".

Table 7. Effluent characteristics at "El SAUZ with the new treatment plant.

| Parameter | Inffluent | Effluent | % Remov |
|---|---|---|---|
| $BOD_5$ (mg/l) | 5,000 | 105 | 98 |
| COD (mg/l) | 5,500 | 224 | 96 |
| TSS (mg/l) | 1,000 | 24 | 98 |
| G & O | 1,000 | 1.7 | 99.8 |
| T (°C) | 28* | 24* | - |
| pH | 5.5-9.2 | 7.5 | - |
| Set Sol(ml/l) | 2,5 | 0.7 | 72 |
| Color (Pt-Co) | 90 | 50 | - |
| Conductiv (µS) | 2,500 | | |
| Org - N (mg/l) | 73 | 6.6 | 91 |
| $PO_4^{3+}$ - P (mg/l) | 61 | 17 | 62 |
| Tot Coliforms (NMP/100 ml) | $2.1x10^6$ | 10,000 | 99.5 |
| SAR | 20 | 16 | 20 |
| Floating Matter | Yes | No | - |

## REFERENCES


Bough WA, Burk ED, Bybee EC, Eckert RW, Clark-T D, "The Evolution of a treatment system for high strength dairy processing waste", *Food Processing Waste Conference* Sep 1987, Atlanta, GA, Georgia Tech Research Institute.

Clanton C.J., Backus B.D., Goodrich P.R.,·Fox E.J., Morris H.A., "Anaerobic digestion of cheese whey", *Food Processing Waste Conference* Sep 1987, Atlanta, GA, Georgia Tech Research Institute.

Lettinga G., Hulshoff Pol L.W., (1991), "UASB process design for various types of wastewaters", *Wat Sci & Tech* 24,8:87-107.

Monroy-H, O, Sarquis S, (1990), "Design considerations for waste water treatment with water hyacinth *E. crassipes*", *Environmental Technology* Vol 11:669-674.

Pfeiffer W, Temper U, Steiner A, Carozzi A, Bischofsberger W, "State of the Art of Anaerobic Waste Water Treatment in Various Industrial Branches", der Technischen Universitat Munchen E.V. (1986).

van del Berg, L., Kennedy K.J.(1982), "Use of anaerobic downflow stationary fixed film reactors for waste treatment and methane production", Avances en Digestión Anaeróbica *Memorias del II Simposio Panamericano de Combustibles y Productos Químicos Via Fermentación*, MIRCEN de BIOTECNOLOGIA-ICAITI-UAM.


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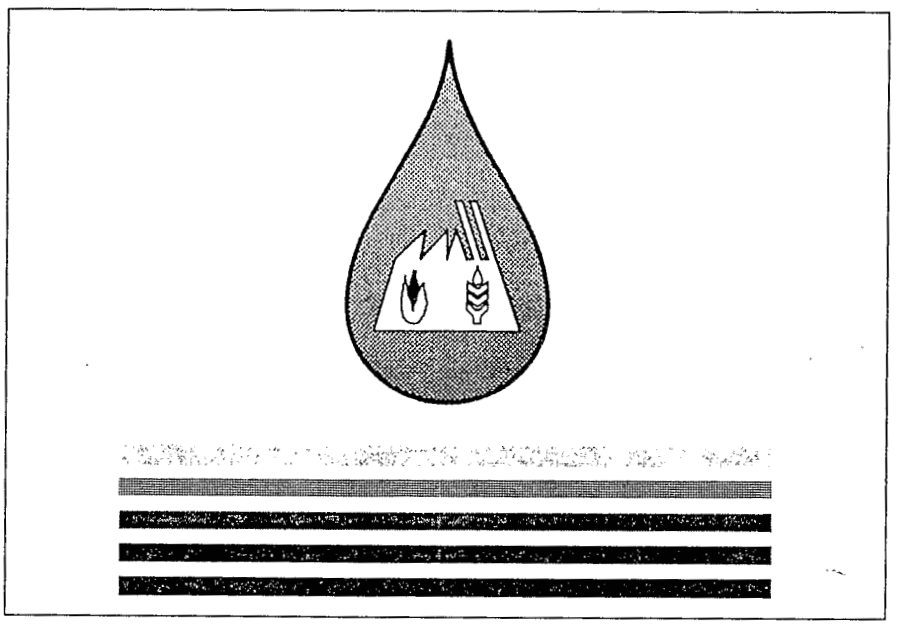
# PROCEEDINGS OF THE THIRD INTERNATIONAL SYMPOSIUM ON WASTE MANAGEMENT PROBLEMS IN AGRO-INDUSTRIES MEXICO CITY, 4-6 OCTOBER 1995

# MEMORIAS DEL TERCER SIMPOSIO INTERNACIONAL SOBRE MANEJO DE DESECHOS EN LAS AGROINDUSTRIAS CIUDAD DE MÉXICO, 4-6 DE OCTUBRE DE 1995



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