JET-LOOP SYSTEM ©®

A NEW ENERGY EFFICIENT AND NEAR ZERO SLUDGE EXCESS PRODUCTION FOR AEROBIC WASTEWATER TREATMENT USING ATMOSPHERIC OXYGEN DRIVEN TO THE EFFLUENT BY EJECTOR(S)

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ABSTARCT

The **Jet-Loop System©®** applies for aerobic wastewater treatment using ejector(s) as the mechanical system for aeration.

The ejector(s) are installed outside and above the effluent, and the air aspirated at the air inlet is conducted with the effluent in circulation to the bottom of the aeration bioreactor, by a draft tube.

The design and engineering of the ejector(s) is unique, since it is able to introduce air against a dept of liquid not less than 7,5 m, and at the same time, keeps the volume of aspirated air and the consumption of energy between limits that turn the system the most efficient in oxygen transfer to the effluent and the one among all other processes that spent less energy in the aeration process.

The **Jet-Loop System©®** doesn't produce any significant amount of excess sludge (MLSS), since it combines together three innovative features:

One- The ejector was designed to perfection, for creating the maximum sudden chock pressure and stress to the activated sludge (MLVSS) passing in the ejector.

Two- The age of the cells inside the Biorector were increased into a maximum, by total recirculation of MLSS to the bioreactor from the filtration devices at the output of the process.

Three- The loop created between the ejector and the bioreactor is made in a way that keeps the bottom and parts of the biorector closed to the MLSS sedimentation.

In terms of energy consumption and due tho the high global oxygen transfer coefficient, the system can operate to levels of electricity consumption , below 50% any existing process.

The **Jet-Loop System**©® is well adapted for the treatment of very high charged organic loads, as industrial biodegradable effluents, as well as less contaminated effluents, as in municipal wastewater treatment. It can be installed in any size from small communities, up to the biggest cities, depending only in the size of the bioreactor(s) all together with the number of ejectors to be installed and operated. The installation is fast and competitive, especially if it applies for the prefabrication in the main tanks for the bioreactors.

The operation of the system is very simple and reliable due to the well designed technology, and also without any special maintenance, since it is composed by no moving mechanical parts with the exception of the centrifugal pump(s) that driven the effluent throw the ejector(s).

KEYWORDS:

COD (Chemical Oxygen Demand); BOD (Biological Oxygen Demand); $K_l a$ (global coefficient for oxygen mass transfer);SOTR(Standard Oxygen Transfer Rate);DO (Dissolved Oxygen).

INTRODUCTION:

The **Jet-Loop System**©® is a new and revolutionary process for biological wastewater treatment, in using atmospheric oxygen as source for oxidation of the raw organic loads, driven to the effluents by ejectors devices specially designed and assembled in an innovative matter.

Due to is specific building and operation, the **Jet-Loop System**©® can deliver up to 20-30 m3 air/ KW to the effluents, works without excess sludge, and can be designed for most of the effluents containing COD and BOD in rations up to 3,5 (COD/BOD), as in many industrial and hazardous wastewater as the case of leacheate. The **Jet-Loop System**©® , covers all the effluents from domestic wastewater to industrial high charged organic effluents.

The **Jet-Loop System©®** is dimensioned as small as to operate with hydraulic retention times as low as 4-8 hours, thus reducing significantly the volumes and construction costs.

Since the **Jet-Loop System**©® can operate within the new and advanced concept of "Near Zero Sludge", it is extremely competitive in terms of the operation.

The effluent in the bioreactor is continuously recirculated in a loop between the ejector(s) the bioreactor, from the top of the bioreactor to a degasification tank, and from this tank

the feeding to the centrifugal pump(s) that drives the effluent through the ejector(s). Fig 1.

The ejector(s) discharge through a draft tube to the bottom of the bioreactor, and at this point the air is released, flowing up freely, due to the difference of gravity.

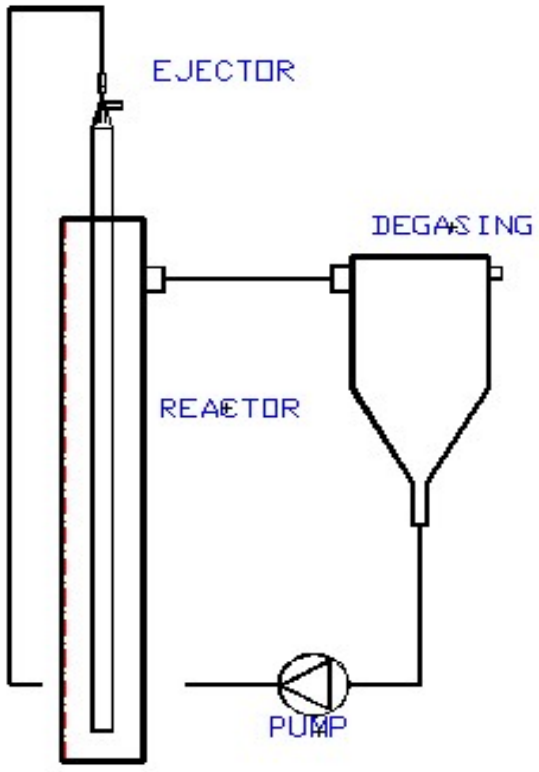

Fig. 1. JET-LOOP SYSTEM ©® simplified process diagram.

DISCUSSION:

In the **Jet-Loop System**©® The organic charged effluents , COD(Chemical Oxygen Demand) , and BOD5 (Biochemical Oxygen Demand) are highly oxidized by atmospheric oxygen, witch is diffused into the effluent in an enhanced way as a consequence of three major conditions of operation created by the innovative system:

-One: The air is micronized in the ejector into the most small size bubbles possible, as low as 2micron air bubbles. In addition, larger sized air bubbles are also produced, to facilitate good agitation for the wastewater, promoting the perfect mix of air-activated sludge.

-Two: the oxygen content in the micro-bubbles is in contact with the effluent for the time spent in flowing 7,5-8,5 m down to the bottom of the bioreactor and again 7,5-8,5 m up to the top of the bioreactor.

- Three: the high volume of air introduced into the effluents creates an holdup of gas greater than most of the known cases using other forms of aeration.

As consequence of these operational and innovative design, the **Jet-Loop System**©® is able to perform in higher DO concentrations than any other system without the need for any exceptional consumption of energy/Oxygen. In the **Jet-Loop System**©® case, we have observed in some industrial full operational plants permanent levels of DO between 45-55% of the maximum saturation level. Those levels were obtained in full scale operation, with consistent deliver of 17,5- 20,0 m3 Air to the effluents, per Kwh energy spent in the pumps used for driving the effluents to the ejectors.

The holdup volume of air in the effluent, achieved in full operational **Jet-Loop System**©® was measured as maximum as 6,6% volume of the total aeration designed volume.

The most innovative feature included in the **Jet-Loop System**©® is the installation of the ejector(s) outside and above the effluent. The ejector(s) where designed and developed to perform against the minimum dept of effluent of 7,5-8,5 m, thus their development was critical , due to the counter pressure (back-pressure) observed in such dept. In this aspect, the geometry of the ejector(s) is unique in several aspects, like the ratio of compression chamber / length of the " *vena-contracta*"; the size an aspect of the nozzle parts, and the angles and shapes in the several parts of the ejector(s). Once verified the capacity for the ejector(s) to work against the minimum dept of 7,5 -8,5 m, and verified the high efficiency in the ratio of pumped volume of air per energy spent, (M3 air/Kwh), the**Jet-Loop System**©® performance was verified in terms of the SOTR and Kla. The observed and measured values were obtained in real high charged industrial effluents, with concentrations in COD up to 17.000 mg / L.

The tests were made in field, with one DO sensor measuring the DO as percentage of the saturation level.

The measured temperature of the effluent were 24º C and the estimated salinity of the effluent were set as 5 parts per thousand. The barometric pressure were assumed as 760 mmHg. At this conditions, the saturation dissolved oxygen in water is 8,01 mg/L.

The Kla for the **Jet-Loop System**©® was determined considering the microorganisms uptake of oxygen:

$$\frac{dC}{dt} = Kla\,(Cs - C) - rM$$

Where Kla is the overall oxygen diffusion transfer coeficient to the liquid, Cs is the dissolved oxygen saturation concentration, and rM is the rate of oxygen consumed by the microorganisms.

To determine the rM (Rate of Oxygen used by the microorganisms) we should use the Warburg laboratory apparatus and know exactly the MLVSS concentration. As

alternative, we measured the consumption of oxygen in the process (fig. 2) , as function of the time.

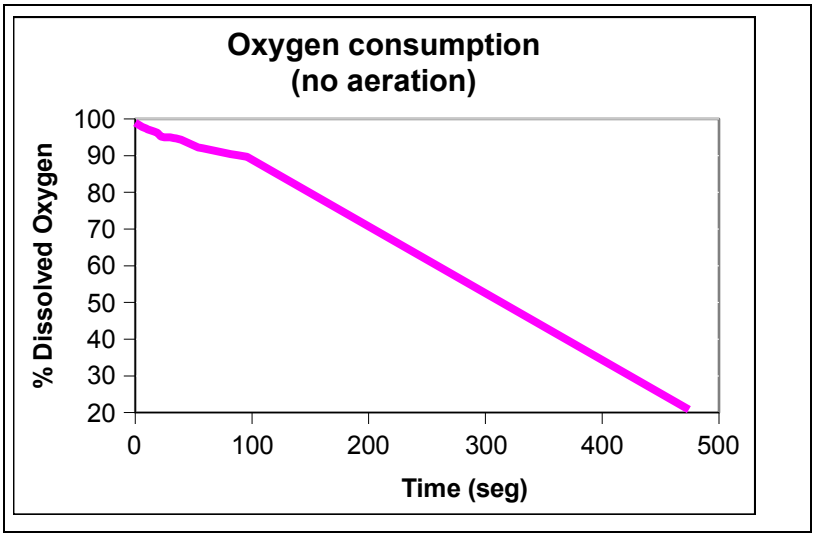

Fig. 2: Dissolved Oxygen (DO) in the **Jet-Loop System**©® as function of time, for total absence of aeration. The measurements were performed by INETI, at Dois Portos wastewater installation, during Set-2005.

Since the reduction of DO observed was constant and equal to 2,96 mg/L O2, in 200 seg., rM is equal to 1280 mg O2/day.L

The aeration of the process, from 0% DO, for a reactor with 60 m3 volume, with one ejector delivering 65 m3 air /h produced the following results. Fig 3.

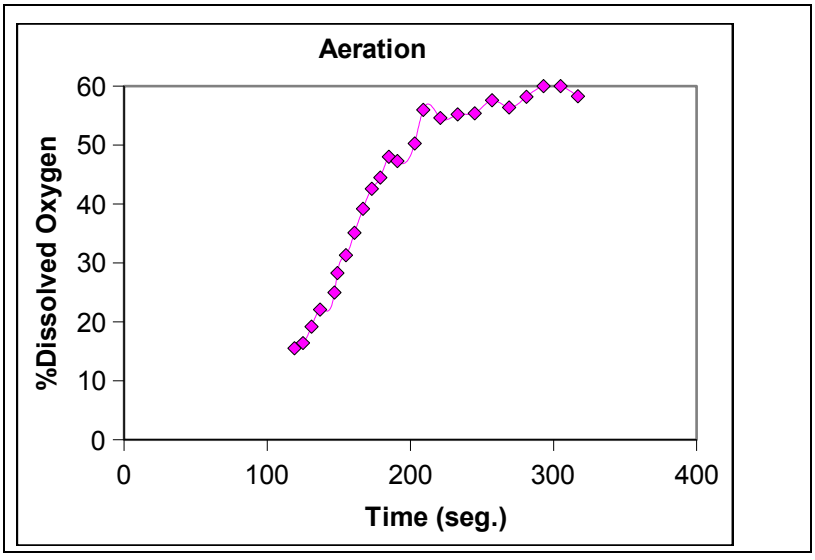

Fig. 3. Aeration of the process: Volume 60 m3. Air: 65 m3/h. The measurements were performed by INETI, at Dois Portos wastewater installation, during Set-2005.

The measurements, indicate a mass transfer of oxygen to the effluent of 2,88 mgO2/L.min, or 172,8 mgO2/L.H. Thus, the total Oxygen transferred to the system, was:

172,8x 60.000 = 10,368 Kg O2/H.

The average mass of oxygen per m3 of air is 0,25 Kg. Considering the air introduced in the liquid, the total Oxygen supplied to the liquid was 65x025=16,25 Kg.

From this calculation, we can determine the SOTR (Standard Oxygen Transfer Rate) and the SOTE (Standard Oxygen transfer efficiency) for the effluent. Since the system were operated by one ejector delivering 65 m3air/H and the pump that was driving the ejector was consuming 4 KWH, we obtain:

SOTR = Mass of Oxygen supplied to the system/ power spent in the process

SOTR = 16,25 / 4 = 4,06 Kg O2/ KWH

The SOTE will be determined as a % of the O2 transferred to the effluent:

SOTE = 10,368/ 16,25 = 63,8 %

Both SOTR and SOTE are roughly double or triple the respective values for general applications of aeration in systems with aerated turbines, submerged membrane or ceramic disks, and other equipments, operated in tanks up to 4 m deep. As known, the SOTE increases with dept, and for the case it confirms the general knowleadge about subject. The choice for deeper applications on the traditional 4 m, is normally avoided from engineers because the existing equipments for air compressing (blowers, root compressors, etc) loose their capacity and efficiency above the pressures of 0,5 bar.

The **Jet-Loop System©®** introduces an innovative and unique approach to the limitations observed in the existing aeration systems.

As a consequence of the innovative process developed, the result from the hold-up of air into the effluent, together with the perfect mixing of the extremely small micro bubbles of air with the liquid, creates the most effective and the highest diffusion coefficient of oxygen into the water until now known for processes using atmospheric oxygen.

As consequence of the high SOTR the **Jet-Loop System** ©®, can operate with a great energy economy. Since the majority of energy spent on a wastewater treatment plant is dedicated to the aeration process, and comparing our process with other standard processes, we can figure that the energy economy with the Jet-Loop System, can be situated above 65%.

This high SOTR combined with the high value for the SOTE, produces the capacity for the system to work above 55% saturation dissolved oxygen, representing this concentrations 5-6 mg/L DO (Dissolved Oxygen).

The values for the Kla (Global Coefficient for Oxygen mass transfer) were calculated in accordance to the experimental values.

The methodology applied follow the guidelines from Metcalf & Eddy for linear plot of the dissolved oxygen concentration versus the time.

The values used for the calculation were those from table 1:

Table 1: Observed values for the DO concentration in the aerated effluent as function of time.

(Cs-C) mgO2/L	Time (seg)
6,77	119
6,47	131
6,01	147
5,50	155

And plotted in semi-logaritm scale for obtaining a linear correlation, as:

Kla= 2,303 x(log 6,77-log 5,55)/(155-119) (1) = 0,0055 seg-1 = 0,33 min-1

The **Jet-Loop System©®** as been applied to the secondary wastewater treatment of domestic and industrial effluents. One of the cases of application is resumed below:

Table 2: Jet-Loop System ©® application to Domestic + Industrial effluents.

Parameter	Input	Output
COD (Chemical Oxygen Demand) mg/L	17 225	120
BOD5(Biological Oxygen Demand)mg/L	9453	40
TSS (Total Suspended Solids)mg/L	2128	35
PH (Sorensen scale)	4	7

The **Jet-Loop System©®** meets the limits in wastewater parameters standards for European Union. requirements. It is thus very effective in municipal wastewater treatment as also in industrial high loaded wastewater.

Due to this high DO concentrations, the system handles perfectly with VOC witch usually are released by wastewater effluents, like ammonia and H2S, oxidizing those components strongly and limiting is emissions below insignificant levels. This advantage is adequate for elimination of odors in the wastewater treatment plants and the near surroundings.

Table 3: Jet-Loop System ©® Operational main parameters.

Parameter	
HRT (Hydraulic Retention Time) H	6-7
COD specific input (Kg COD/ m3.d)	3-25
F/M (Feed/ MLVSS ratio) Kg/Kg	0,8- 4,2
COD efficiency reduction (%)	> 97

One very important advantage introduced by the **Jet-Loop System©®** is the fact that it works according to the principle of "NEAR ZERO EXCESS SLUDGE"

VALORSABIO as actually seven full scale plants installed with the **Jet-Loop System©®** applied to industrial and domestic effluents.

In all of those plants, some operating at more than three years, the excess sludge observed is practically near zero. In particular, a few installations has been monitoring closely since installation and operation, after 2005. We observed that in most plants, the excess sludge was practically zero.
The low or zero excess sludge is a consequence of the innovation introduced in the ejector design, since it was chapped to perform as the driving motor for the air uptake (as seen before) and as a mechanism for destruction of biomass. This is achieved in the section of the nozzles of the ejector, were the continuous application of high pressure followed by sudden expansion, is responsible for the damage of the biomass cells.
Knowing this advantage, the **Jet-Loop System©®** loop was developed in a way that only allows a partial recirculation of the biomass through the ejector, keeping the remaining and necessary biomass on the bottom of the bioreactor. This is achieved by the correct position of the pipe spool that feed the degasification tank, at the upper section of the bioreactor.

The biorector included in the **Jet-Loop System©®** is a round cylindrical form, with two essential parts or to ring concentric parts: the outer section, here the aeration and major COD, BOD5 is eliminated, and the inner section, dedicated to sludge concentration and pre-clarification of the treated effluents. Fig 4.

CONCLUSIONS:

The is similar to many existing processes in one aspect: it operates with oxygen taken from the air, and works on the principles of aerobic biological treatment.

On all other aspects, it is totally different from the existing technologies:

- It operates with "NEAR ZERO EXCESS SLUDGE", thus the process turns extremely competitive in terms of sludge handling and disposal costs.

- It spent must less energy in the aeration process. The actual spent energy is one half to third of the equivalent aeration processes.

- The aeration equipment and system is unique and double or triple the usual design parameters: SOTR and SOTE are more than double the best existing systems.

- The Installation is fast, simple and smaller than any other existing system.

- The maintenance of the **Jet-Loop System©®** is practically inexistent, since in all the system, the mechanical an moving parts are resumed to the centrifugal pumps. All the other components and equipments of the system are static, thus with minimal or none maintenance.

The **Jet-Loop System©®** can be couple with either percolating filters for water discharge requirements, or with ultrafiltration membranes for total water reclamation and reuse. In this case, the water quality can meet the regulatory parameters for use in agricultural irrigation, industry, etc.

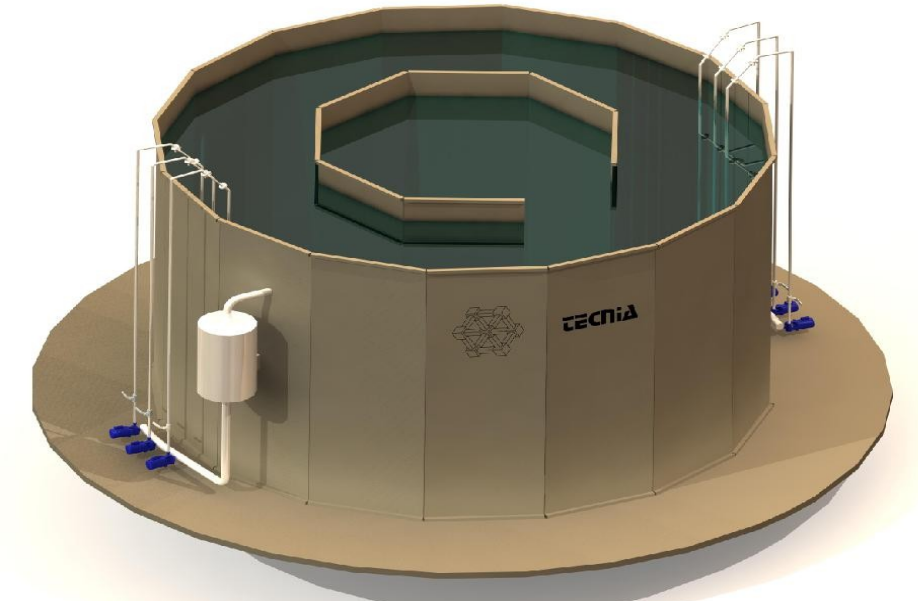

Fig 4: The Jet-Loop System configuration for medium municipal wastewater treatment. Bioreactor dimensions: Diameter= 14,7 m; H= 8,5 m, V= 1370 m3. Daily treated wastewater:4500-5000 m3/day. Population served: 20.000 – 30.000 habitants city. Six ejectors installed. Total power installed: 24 Kwh.

In terms of construction, the jet-loop represents a major economy in space and volume. The bioreactor(s) can be build applying the prefabricated principle, and can be made up from panels of reinforced concrete or pre-molded steel panels. The remaining construction consists of pipping , the degasification tank(s), centrifugal pump(s) and the ejector(s). All this elements can be specified in SS AISI 304 to 316L, depending on the effluents to be treated.

The Jet-Loop System is a registed know-how, with several industrial secrets involved at the operation level and fabrication of some specific parts.The system was develop from 1996 and continuously improved to the actual state of the art.

ACKNOWLEDGMENTS.

The development of the system was made possible due to the financial support achieved by the 5th EC Research Framework Program, and the LIFE 96.

The collaboration on the earlier research from INETI (National Institute for Engineering and Industrial Technology) was also a great contribution to the Jet-loop System.

All the Portuguese Industrial companies that from the beginning did select this technology for the treatment of their effluents, believing on the advantages of the system.

The JET-LOOP SYSTEM received several National and international awards such as the "Prémio Nacional de Ambiente" - 2006 and the nomination for European Environmental 10 best environmental solutions in 2006.

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VALORSABIO- Is a Leading Environmental Research Engineering Company in Europe, were have been conducting successful research projects, several of them under the EC approval and support. The approach that VALORSABIO has been given to the technological research in the main field of environment, connecting permanently to the scientific community, as in the case of Universities and Research Official Institutions, and also some companies, establishing consortium's for the innovation in the many important environmental areas, have been producing the highest results in terms of new solutions for solving the existing environmental issues. The Jet-loop System©® as it is today, was started from this kind of research partnership collaboration under the EC research program LIFE.