Ramses: Enhanced reclaimed water quality through mainstream anaerobic treatment using supported biomass growth

Autores/Authors: **B. Porras[2], P. Simón Andreu[1], C. Lardín Mifsut[1], J. Martínez Peñas[2], J. Solano Martos[2], A. Rancaño Pérez[2], P.Pérez[2]**

1 Entidad Regional de Saneamiento y Depuración de aguas residuales de la Región de Murcia (ESAMUR). Complejo de Espinardo - Ctra. N-301; C/Santiago Navarro, 4 1ª Planta. 30.100 Espinardo (Murcia)

2 ACCIONA Agua. Avda. De Europa, 22. Parque empresarial La Moraleja. 28108 Alcobendas Madrid

Abstract:

In the European Union only 1-2% of the potentially reclaimed wastewater is reused, besides nowadays only 40% of the sludge generated by WWTPs has the appropriate quality to be used in agriculture.

The solution proposed in RAMSES is based on the use of an anaerobic digestion with supported biomass growth as pre-treatment of the biological treatment of urban wastewater. The anaerobic digestion process is based on a UASB reactor but with an own design. It has also been feed with organic waste collected from different industries in the area, mainly from canned food industries. This organic waste act as co-substrate of the digestion process and it is treated together with the water in a process in which organic substances (phosphate, nitrate, etc) are extracted from the water and incorporated into the co-substrate in order to form a nutrient-rich organic sludge which can be used as fertilizer. This process also produces biogas that can be used in the digestion process, making the overall system more sustainable in terms of energy.

The results obtained to date present significant advances; organic matter eliminations of up to 90% have been obtained and values close to 70% of elimination of contaminants. With the start of the production of biogas, the consumption of aeration of the process has been reduced, and finally the volume of sludge generated has been reduced, expecting a reduction of up to 30% at the end of the project.

In summary, the Ramses project has achieved high eliminations of pollutants and reduction of produced sludge, thus achieving better reuse of wastewater for irrigation and agricultural purposes and improving the sustainability of the process with self-consumption of biogas and the use of the generated sludge as fertilizers.

1 INTRODUCTION

In Spain reused water only accounts for a small percentage of the total Spanish water demand, but in some areas, such as the Canary islands, Valencia or the Region of Murcia, this percentage is quite high, meaning that water has become a strategic non-conventional resource.

Specifically, the Region of Murcia leads the national and European Outlook on wastewater treatment and reuse, with state-of-the-art technologies for water treatment that are implemented in their 97 WWTP. In 2012, the 97 WWTPs treated 109,406,674 m^3 of wastewater. The 96% of the treated wastewater is reclaimed in an indirect or direct way, being this number the 25% of water reuse in Spain. The uses of reclaimed water in Murcia are; Indirect reclamation (the treated water is discharged to a riverbed and captures downstream for irrigation purposes (49% of the overall reclaimed water), direct reclamation (the reclaimed water is used mainly for irrigating orchards, citrus fruits and horticultural plantations (44% of reclaimed water) and discharged it cannot be reclaimed (4%).

Regretfully, the situation in Europe differs significantly from that of Murcia. In the European Union only 1-2% of the potentially 18,000 hm^3 reclaimed wastewater is reused. Therefore, it is necessary to implement water treatments that are able to reduce the amount of chemical-biological parameters below the minimum established by law and at lower possible cost. Indeed, there are some specialized treatment techniques that remove contaminants efficiently but sometimes, the Price of reclaimed water raise up to almost twice the cost of conventional drinking water, preventing it from using.

Besides the necessity of technologies that enhance the proportion of wastewater to be reused, it is important to consider the amount of sludge generated by WWTPs has the appropriate quality to be used in agriculture, according to the Sludge Directive. The remaining fraction is disposed in landfills or incinerated, with the associated negative environmental impact. Moreover, existing sludge sterilizing technologies are expensive due to energy requirements and are not prepared to deal with directives in progress, much restrictive in terms of:

1- Guaranteeing the biological stability of the residue.
2- Guaranteeing the absence of microbiologic contamination (<1000 CFU of E.coli/g solid matter, 4 log reduction and <3000 spores of Clostridum perfringens/g.m.s and absence of Salmonella in 50 g.m.f)
3- Removing emergent contaminants
4- The amount of metals

RAMSES technology is expected to generate 30% less sludge tan currently existing technologies, with lower energy requirements since wastewater will arrive “cleaner” to the biological treatment (and thereby less energy consumption from aeration is envisaged), and will have the quality foreseen in sludge directives in progress (proposal for a directive of the 30^{th} April 2003).

2 Objectives

The aim of the project LIFE RAMSES is to demonstrate that a process consisting of an anaerobic digestion using supported biomass growth followed by a biological treatment is able to enhance the quality of the reclaimed water, thus making possible its reuse for irrigation and agricultural purposes. In order to improve the overall sustainability, a co-digestion process using organic residues can be coupled with the anaerobic reactor so that the biogas production is improved, leading to a self-sufficient energy process.

To fulfil this objective, the following specific objectives are defines:

1. To improve the quality of treated water, thus increasing the amount of reclaimed water available for reuse and reducing the amount that is discharged. It is expected that > 90% of the organic matter and suspended solids of the wastewater are removed before the biological treatment.
2. To increase the value of organic waste coming from nearby industries so they can be reuse as co-substrate for co-digestion.

3. To reduce CO2 emission since the biogas produced by co-digestion is used to cover the energy demand of the WWTP. Once the co-digestion is properly optimized, it can even lead to a self-sufficient plant in terms of energy consumption.
4. To reduce in 30% the current volume of sludge produced in the biological treatment, and to increase the value of this sludge (actually consider a waste) enabling its reuse as fertilizer due to the high organic content that it has (it will content the organic matter removed).
5. To improve the stability of the process by means of using supported biomass growth. In this way, the supported biomass is highly specific, resulting in a process that it is better prepared in front of inhibitor events that could bring the water to be treated.
6. To decrease in 25% the volume of the reactor in newly built facilities, as the amount of biomass involved in the process (for the same volume) in increased and highly specialized. Likewise, the capacity of existing reactors can be increased, which is very useful in case the technology is implemented in existing WWTP, where space is a critical issue.
7. To transfer the acquires knowledge to stakeholders by means of specific education and dissemination strategies and platforms as well as recommendations to policy makers.

3 METHODOLOGY

The innovation of this project has been to use a proprietary design of an anaerobic reactor using supported biomass as pre-treatment of a biological process for urban wastewater treatment. Moreover, the anaerobic digestion is assisted adding co-substrates that are waste from the food-processing industries, making the process suitable for not only for very warm areas but also with warm climate (20-30ºC). To end, the biogas produced in the co-digestion process has been supplied to the WWTP.

For a first approximation, the UASB digestion module has been configured in the GPS-X program of Hydromantis, with the operating conditions pf the project reactor, located in the Blanca (Murcia) WWTP.

Once the simulation has finished and the results have been analyses the prototype has been installed before the biological treatment, by remodeling a homogenization tank before the pre-existing biological treatment (which is currently out of service). This way, it has been possible to take advantage of civil works and electrical connections available, as well as pipes connected with the biological treatment.

The prototype has consisted on the following parts: a conical tank; filled anaerobic reactor; annexed deposit for organic waste; metering and injector for the reactor; gas line for biogas; cogeneration engines; and auxiliary equipment and materials (cables, insulation, etc).

Figure 1. Anaerobic treatment unit

Figure 2. Cogeneration unit and gas line

Figure 3. Prototype implementation

Concerning the methodology of gathering and storing the biodegradable waste as well as the way to distribute the organic sludge as fertilizer, the RAMSES project has proposed and innovative implementation procedure:

1. ***Procedure to gather and store biodegradable wastes***

In order to deal with this project, 30 companies located within the WWTP area were contacted. Some previous findings were concluded with organic wastes from different origins provided by 15 companies located in the region.

2. ***Valorization and distribution of valorized organic sludge: eco-fertilizer***

The sludge obtained will be analyzed to check it fulfils the chemical-biological requirements to be used as fertilizer. In order to distribute the fertilizer with a powerful fertilizing potential among the farmers located in the area, it has been subcontracted an authorized waste manager, who has been the responsible of avoiding the plot saturation and to fairly distribute the sludge obtained (Royal Decree 1310/90 concerning the WWTP sludge management for farming purposes).

Technology monitoring has been completed by daily measuring the intake and effluent waster features (flow, COD, BOD, N-total, nitrogen-, P-total phosphorous-, SST, conductivity, pH, etc)a part from carrying out a follow-up in terms of alkalinity and volatile fatty acids, as well as a daily verification of the sludge, biogas and electric energy produced and consumed in the installation.

4 RESULTS

The project started the 16th July 2015 and is expected to be finished the 15th July 2018.

The project has been divided in different parts in order to manage the entire project and study carefully of the getting results:

4.1 Parametrization of WWTP feed water characteristics and its annuals variability

In the very beginning of the project several analysis were carried out to allow to determine the variability of the entering water in the plant in a seasonal way and detecting possible factors that may influence both in the design and the correct operation of the prototype and the process.

4.1.1 Respirometric Analysis

This analysis allows knowing the biological mud behaviour and if the present bacteria in the mud have capacity enough to adapt it to the new conditions.

First of all it was taken samples of the intake water:

Table 1. Intake water characterization

	ENTRADA 17-05	ENTRADA 19-05	ENTRADA 23-05	ENTRADA 24-05	ENTRADA 25-05
pH	7.78	8.15	7.56	7.79	8.09
CE	2730	4150	3400	2270	1958
SS	278	544	612	530	377
DQO	3754	8811	1770	1505	2331

Respirometric analysis has been carried out during a year of experimentation. Throughout the year of experimentation, it was observed SOUR and UNFED close to 3 and 4, which indicate low affinity of bacteria for oxygen.

Percentage of elimination of organic matter and nutrient (N and P) at the output of the biological reactor it has been pretty good, **it can be conclude that the possible toxic contents in the intake didn´t affect to the process.**

4.1.2 Microscopic Analysis

Microorganisms existing in the biological reactor, morphology and activity, determines if in any time it has been inhibition of the species. The microbiology test carried out of the sludge determines variability throughout the year depending on the composition of the water entering the plant.

It has been observed that the bacteria population it is not seriously affected through the experimentation period (they have good structure and morphology).

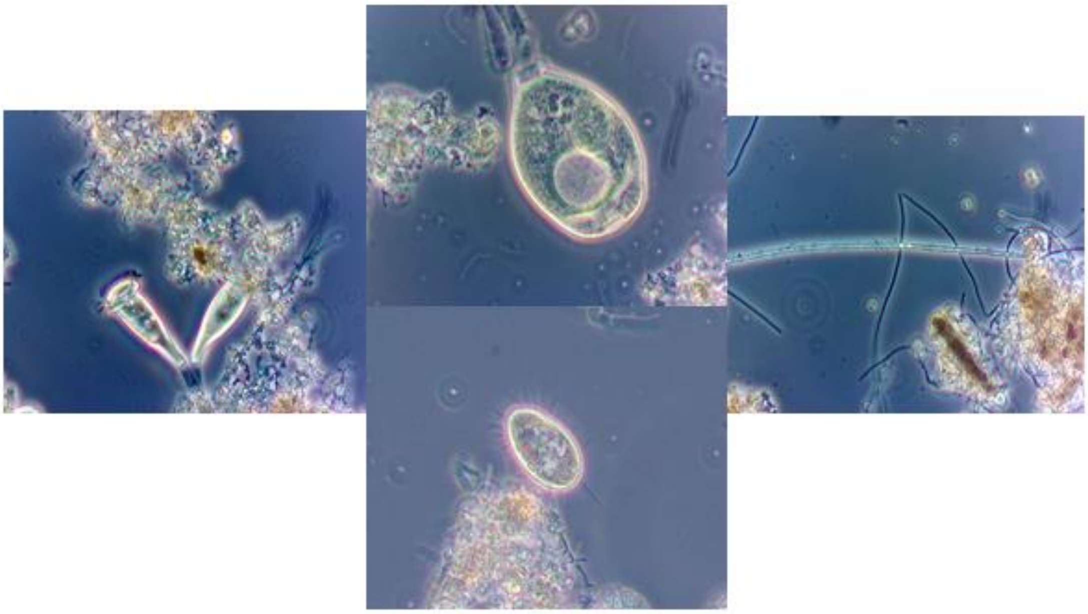

Figure 4. Bacteria population present in the Blanca WWTP

4.1.3 Analysis of physical-chemical parameters

It has been carried out analysis of the physical-chemical parameters in order to characterize the intake water.

In the text table it is presented a summary with the results of the physical-chemical parameters measured throughout 2017.

Table 2. average results of the physical-chemical parameters measured throughout 2017

INTAKE WATER WWTP BLANCA 2017	unit	January	February	March	April	May	Jun	July	Average
pH		7,6	7,5	7,4	7,6	7,54	7,5	7,5	**7,5**
Conductivity	µs/cm	2.003	1.804	2.150	2.118	2.005	2.123	2.011	**2.019**
SS	ppm	245	215	344	331	264	253	299	**284**
DBO_5	ppm	435	345	769	778	610	495	624	**582**
DQO	ppm	667	634	1.123	1.138	941	734	985	**890**
N-NTK	ppm	55,7	76,6	77,3	74,8	69,2	63,1	62,4	**71,1**
$N\text{-}NH_4$	ppm	30,4	41,7	45,4	55,0	30,2	43,4	32,8	**43,1**
$N\text{-}NO_3$	ppm	0,6	0,8	0,7	0,9	1,0	1,2	0,6	**0,7**
$P\text{-}PO_4$	ppm	7,3	12,7	8,8	12,6	8,5	15,7	11,0	**10,3**

As conclusion of this first phase it has been observed that during certain period of the year, **special care must be taken with the process.** During the period of greatest load of material input to the plant, the hours of aeration have increased. **However, taking the appropriate measures and operating properly neither the**

process nor the prototype run any risk. This increase has helped to verify the correct operation of the prototype in conditions of overload.

4.2 Testing of different plastic supports for biomass growth

During the project it has been compared different plastic fillings which it has not been worked with until now, except for one of the filling with which one has experience working and it is known to produce good results.

Up to know it has been studied two different plastic fillings which a priori have presented good enough results to be implemented in the Ramses prototype.

Table 3. Studied plastic filling during the project

Company	Product	Protected area (m2/m3)	Total area (m2/m3)	Dimensions (L*diameter)
Anoxkaldnes	K3	500	600	12mm*25mm
Christian Stöhr	HXF13KLL (CR13)	806	955	13mm*13mm

STUDY 1. AnoxKaldnes (K3)

- In less than 10 days, a biofilm with yields that exceeds 70% of substrate removal has been obtained starting from clean fillings.
- In spite of obtaining certain instability in the yields with both fillings, it has been found a relation of ratios very close to 1.7 between the rates. This means that the RVT9 filler is using **76.9%** of its surface.
- After this study, when using the studied filler RVT9, it will be considered an active surface area of 540 m^2/m^3 approximately.

STUDY 2. Christian Stohr-AnoxKaldnes (K3)

- Up until now, it has been studied up to 50% the behaviour of the fillings and up to 35% the occupation.
- Preliminary results are that both fillings raise their nitrification rates with respect to those obtained working at 50% of occupancy.
- It is worth mentioning the superiority of the performance of the CR13 with respect to the K3.

Preliminary conclusions include the higher efficiency of the CR13 filling compared to K3. The ratio between both supports is 1.14 (average value), which means that the CR13 filling uses 87.7% of its protected surface.

However, it has begun to work with plastic filling K3, expecting to work later with the CR13 fillings, with which it will be possible to carry out a comparison at real scale.

4.3 Analysis of possible co-substrates for the anaerobic co-digestion process

The incorporation of substrates to the digestion can produce synergies so that it not only provides organic matter, but also contributes to the growth of the appropriate bacteria population for the process.

Best results are obtained with waste of methanolic origin; products coming from various industrial production processes and recovery activities of waste materials. The waste and by-products have the following composition:

Water: > 60%

Methyl alcohol: 5% to 40%

Other organic products (alcohols, acetone, light esters ...): <10%

Other inorganic products (salts): <1%

4.4 Obtained results with the prototype

1- Elimination performance COD around 50%
2- Elimination performance SS around 55%
3- COD elimination performance of the Blanca (Murcia) WWTP 97%

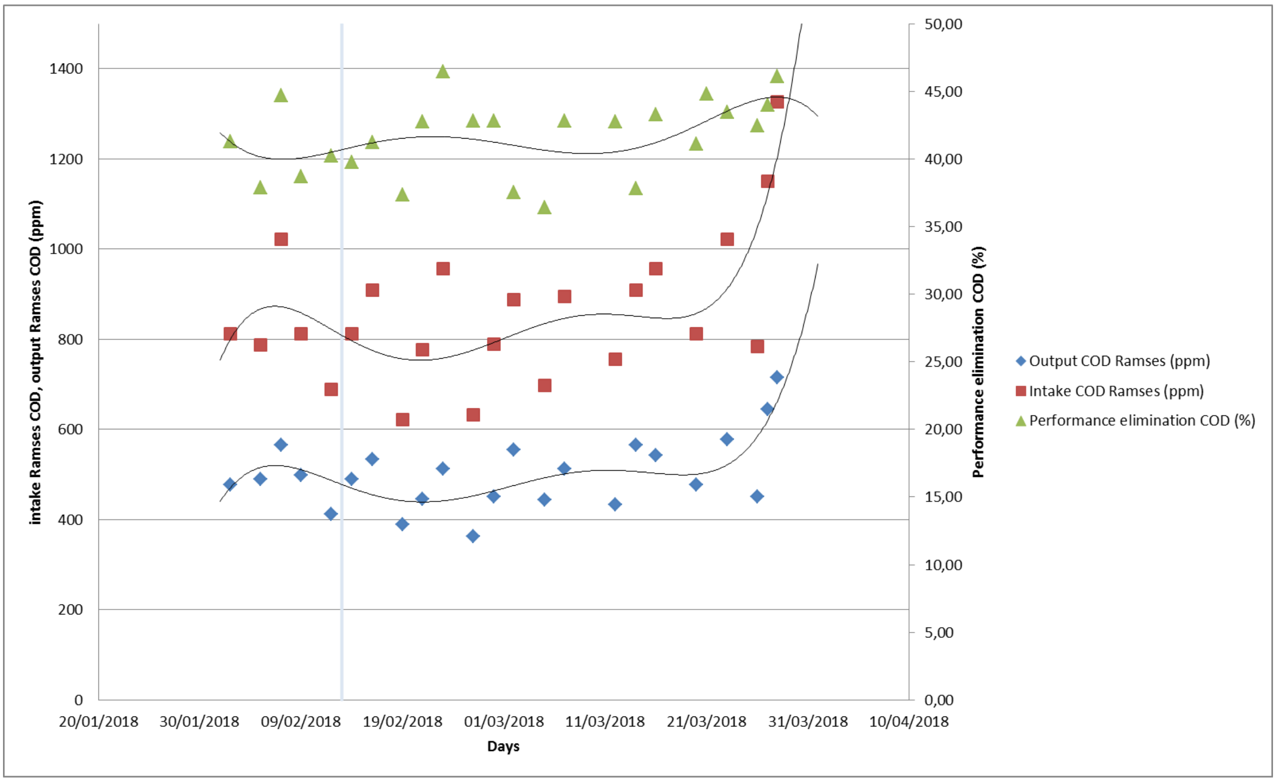

Figure 5. Obtained results with the prototype (II)

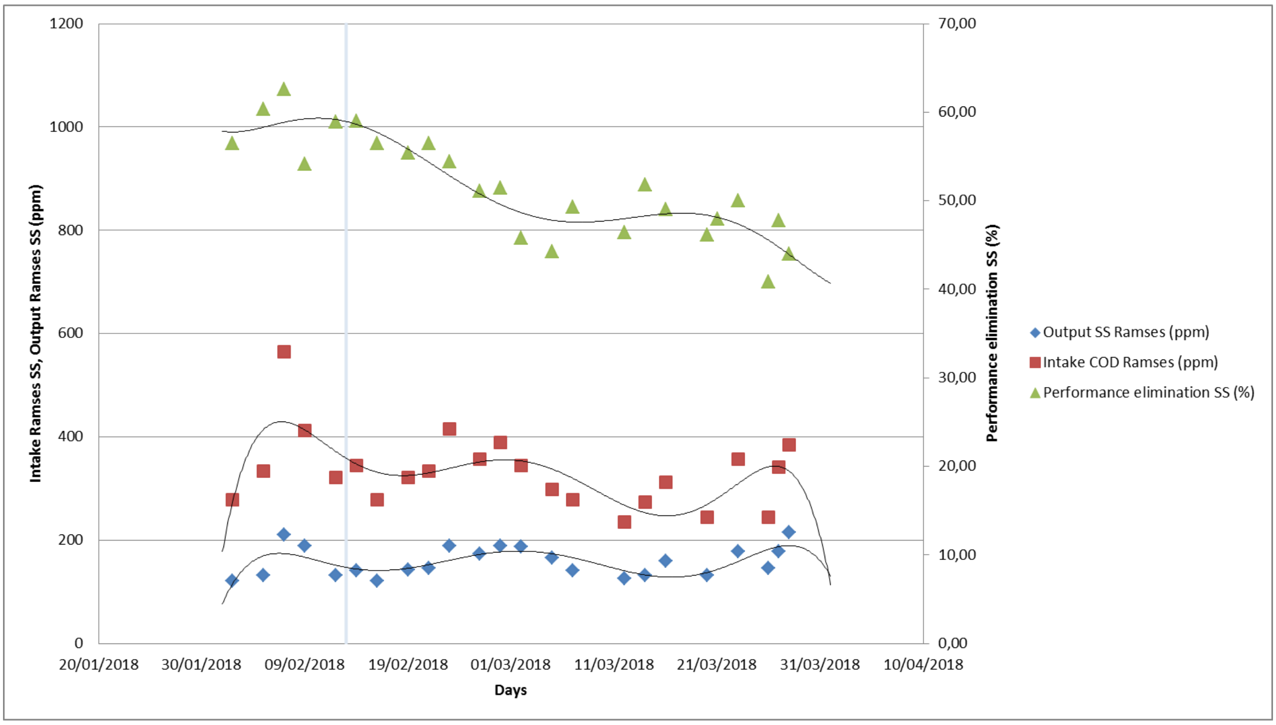

Figure 6. Obtained results with the prototype (III)

5 CONCLUSIONS

Main objectives of the RAMSES project have been targeted:

1- To Increase the amount of reused treated water for agricultural, recreational and other different uses, using a sustainable process.
2- To reduce the risk of eutrophication and other negative environmental impacts that can be caused by directly discharging treated water with high organic content.
3- To reduce the amount of sludge produced in the WWTP as well as to enrich it with nutrients, so it can be used as fertilizer.
4- To improve the stability of the process using supported biomass growth. In this way, the process can tackle feed water with different composition.

Throughout the execution of the Ramses project, the main milestones proposed in the project's objectives have been carried out, thus, the entrance water has been characterized, the possible fillings to be incorporated into the system have been studied, it has been incorporated the best co-substrate found among the nearby industries. In this way the eliminations of contaminants and expected nutrients have been achieved, leaving still time for the achievement of the project and for the improvement of these values.

References

Foresti, E., M, Zaiat, and M.Vallero. Anaerobic processes as the core technology for sustainable domestic wastewater treatment: Consolidated applications, new trends, perspectives, and challenges. Reviews in Environmental Science and Biotechnology, 2006, 5(1): p. 3-19

Gao, D.W., et al., Fate of organic carbon in UAFB treating raw sewage: Impact of moderate to low temperatura. Bioresource Technology, 2011. 102(3): p. 2248-2254

Liu, Y. and J-H Tay State of the art of biogranulation technology for wastewater treatment Biotechnology Advances, 2004. 22(7): p. 533-563.

Singh, K.S and T. Viraraghavan, Impact of temperatura on performance, microbiological and hydrodinamic aspects of UASB reactors trating municipal wastewater. Water Science & Technology, 2003 48(6): p 211-217

Uemura, S and H. Harada Treatment of sewage by a UASB reactor under moderate to low temperatura conditions. Bioresource Technology, 2000 72(3): p.275-282.

Walia, R. Polishing of effluent from UASB reactor: ORP as a monitoring parameter, in Indian Institute of Technology, 2007: Roorke, India