Case study of Water2REturn Project

Wastewater Treatment and Nutrients Recovery in *Matadero del Sur* slaughterhouse, Salteras, Seville, Spain

Fig. 1: Project location

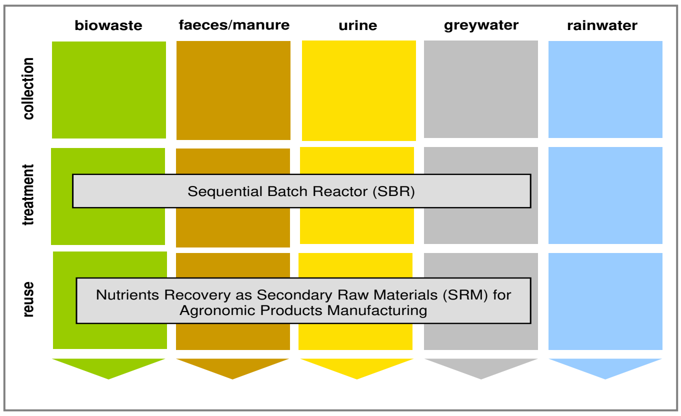

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:

Treatment of industrial wastewater from a slaughterhouse and nutrients recovery for further agronomic use (pilot scale)

Project period:

Project kick-off: July 2017

Start of construction: December 2018

Start of operation: June 2020

Project end: March 2022

Project scale:

Population covered: 4,173 (estimated according to the organic load of the raw wastewater)

Water flow: 54 m^3/day (out of the 162 m^3/day produced by the slaughterhouse)

Size of treatment plant: 375 m^2 of land footprint for the wastewater treatment unit, 2,000 m^2 for the complete Water2REturn system)

Address of project location:

Matadero del Sur S.A.

Carretera Nacional 630 Km. 803,5

41909 Salteras, Seville

Spain

Planning institution:

BIOAZUL S. L. (Spain)

Executing institution:

BIOAZUL S. L. (Spain)

Project ID:

Grant Agreement: 730398

REcovery and REcycling of nutrients TURNing wasteWATER into added-value products for a circular economy in agriculture (**Water2REturn, W2R**)

Project coordinator:

BIOAZUL S. L. (Spain)

Supporting agency:

European Commission (EC)

Total budget:

7,075,919.87 €

EC contribution:

5,871,895.76 €

2 Introducing the problem

'The wastewater generated in the EU by the slaughtering industry: around 750,000 m³/year.'

'The range of water consumption: between 1.5-40 m³ per ton of animal processed'

'Wastewater generation: typically, 80% of thewater consumption'

'High energy consumption in the meat industry: refrigeration: 90-1,094 kWh/t cattle, heating of water: 110-760 KWh/t pig'

'Agricultural demand on chemical fertilisers: around 13.6 Mt/year, 9.1 billion expected in 2050'

'Wastewater management costs: up to 25% of total production costs in the slaughtering industry'

Agricultural demand for chemical fertilisers is increasing due to the rising world population. The importance of nutrient recycling is crucial in Europe, where the general absence of nutrients represents a **considerable threat to EU food security**. This tension between resource scarcity and growing demand will continue to **push the prices of nutrient resources higher in the near future**.

Chemical fertilisers can have negative effect on human health, especially when they contain nitrogen, potassium, phosphorus and heavy metals. On the other hand, expansion in the animal production industry is resulting in the generation of **nutrient rich wastewater and waste**, in addition to **high energy consumption**. Pollution of water bodies and limited arable land because of the disposal of solid waste increase environmental concern.

Large quantities of wastewater and waste are, consequently, emitted into the environment with a high content of easily methanisable organic matter and nutrients, that can potentially be transformed into energy, fertilising and biostimulant products, but they are environmentally dangerous if discharged with no treatment.

The Ellen MacArthur Foundation described the [circular economy concept]() as a **new economic model** which addresses mounting resource- related challenges for business and economies, and **could generate growth, create jobs, and reduce environmental impacts,** including carbon emissions. In line with this perspective, the **circular economy would avoid landfilling/emissions and try to extract maximum value from slaughterhouse wastes.**

3 Proposed solution

Water2REturn proposes an **integrated solution** for slaughterhouse wastewater treatment, as well as for the recovery of valuable nutrients with a high market value in the agriculture sector.

Water2REturn technology adopts a **circular economy approach** where **nutrients (and energy resources) present in wastewaters are safely and efficiently recycled** in different forms, then **injected back into the agricultural system as new raw materials**.

Wastewater is, therefore, a **source of nutrients, energy and water**, and no longer a waste; wastewater treatment facilities become "**bio-refineries**". Water2REturn's business model is based on a **viable, cross-sectoral and integrated perspective for recovering resources** from the water cycle, while considering the relevant **legal, societal and market challenges**.

Water2REturn aims to recover **three high-value agronomic products**: nutrients concentrate, hydrolysed sludge fermented with *Bacillus spp.* and algal biomass, and to produce energy.

Fig. 3: Water2REturn concept *(source: BIOAZUL, 2017)*

Water2REturn system is composed of four interlinked treatment lines:

WATER LINE

The water line consists of a wastewater treatment and nutrients recovery system. After removal of solid particles and fats in a preliminary treatment unit, wastewater is treated in a Sequential Batch Reactor (SBR), and afterwards in a filtration unit, consisting of microfiltration + ultrafiltration + reverse osmosis. Then, the reclaimed water is discharged to the receiving environment, in accordance with national regulations.

The first secondary raw material (SRM1) obtained after this treatment is a nutrients' concentrate. However, it is not commercially feasible to formulate a product out of SRM1, due to the low Nitrogen concentration in *Matadero del Sur* slaughterhouse wastewater, but it is a good candidate for the direct fertilisation of local fields near the slaughterhouses.

Fig. 4: Water2REturn water line

SLUDGE LINE

The sludge resulting from the water line goes through a first pre-treatment process where pathogenic microorganisms are eliminated. Subsequently, it enters the fermentation unit, where the sludge is fermented with *Bacillus spp.* As a result, a hydrolysed sludge is obtained, which is the second secondary raw material (SRM2). The second agronomic product (AP2) is formulated and manufactured from this raw material: a biostimulant.

Fig. 5: Water2REturn sludge line

ENERGY LINE

Part of the hydrolysed sludge from the previous treatment line is upgraded in the energy line through an anaerobic digestion process, within which organic matter is transformed into biogas, composed mainly of CH_4 and CO_2. The biogas is turned into energy in a cogeneration unit. The energy generated can be used to either power the slaughterhouse or the system itself.

Fig. 6: Water2REturn energy line

ALGAE LINE

The AlgaBioGas (AGB) technology used in this algae treatment process is based on an algae ponds system. The digestate from the energy line contributes to algal biomass growth in the algae line. The third secondary raw material (SRM3) obtained after this treatment is an algal biomass. Eventually, the third agronomic product (AP3) is formulated and manufactured from this raw material: a second biostimulant.

Fig. 7: Water2REturn algae line

4 BIOAZUL engineering: water line

Water2REturn water line is composed of an SBR + a filtration unit (microfiltration + ultrafiltration + reverse osmosis). It treats a daily flow of 54 m^3/day (out of the 162 m^3/day produced by the slaughterhouse), covering a population of 4,173 people (estimated according to the organic load of the raw wastewater). It has 375 m^2 of land footprint for the wastewater treatment unit out of the 2,000 m^2 for the complete Water2REturn system.

Treatment description:

Solid separation. The solid separation operation begins when the wastewater is collected from the slaughterhouse. It is then pumped to the rotary screen, which removes the bigger bodies from the wastewater, which is directed to the first buffer tank. The solid waste is stored in a different tank for its valorisation or discard.

Fig. 8: Water2REturn solids separation unit (rotary screen)

Dissolved Air Flotation (DAF) unit. When water is demanded by the second buffer tank to feed the SBR, it is pumped from the first buffer to the DAF unit, which clarifies the wastewater by removing the fats, oils and other waste that float to the surface after dissolving pressured air in the water and de-pressurising it. As in the solid separation operation, the wastewater continues to the second buffer tank while the waste is moved to a separate tank.

Fig. 9: Water2REturn DAF unit

Sequential Batch Reactor (SBR). The SBR is the system that carries out the treatment process. It operates in cycles consisting of the following stages:

Filling: Wastewater is introduced into the sequencing reactor in a way that facilitates growth of suitable microorganisms.

Reaction: The organic matter and nutrients contained in the wastewater are degraded. Intermittent aeration can be provided, thus, combining different conditions (aerobic, anoxic and anaerobic).

Settling: Aeration and mixing in the reactor are interrupted so as to create favourable conditions for the settling of the activated sludge.

Emptying: Once the clarified wastewater has been separated from the sludge blanket at the end of the settling process, it is removed from the reactor.

Inactive phase (optional): Sludge removal can take place at the end of the reaction stage or during the settling, emptying or inactivity stages.

The duration of each stage and of the complete treatment cycle are programmed according to the water purification objectives pursued. Likewise, the operational cycles can be modified according to the characteristics of the influent and the quality requirements imposed on the effluent.

In this case, as Water2REturn approach pursues concentrating nutrients in the effluent, only nitrification is promoted, and not denitrification. This way, farmers will have access to a guaranteed and constant source of irrigation water, which is a huge benefit in arid regions.

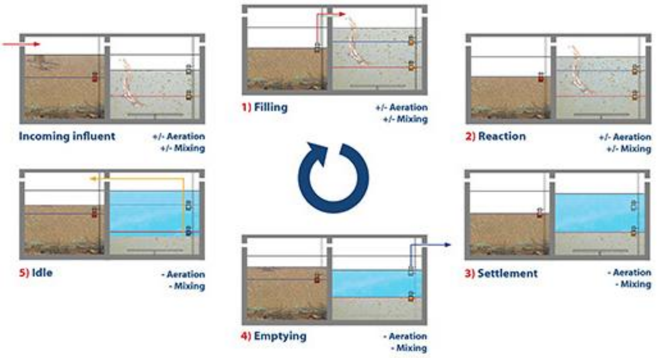

Fig. 10: Water2REturn SBR functioning

Fig. 11: Water2REturn SBR

Thickener. After the excess sludge is pumped from the SBR into the thickener, it settles on the bottom of the tank as water mixed into it leaves clarified by the upper part of the tank. The water on the top of the thickener leaves to the second buffer tank, while the sludge is drained from the bottom for its valorisation.

Fig. 12: Water2REturn thickener

Nutrients Recovery System. After the SBR operation, the water is full of nutrients that should be collected to increase the value of the treatment plant. To this end, the subsequent filtration steps are designed to obtain a nutrient concentrate as the water is usable again.

Microfiltration and Ultrafiltration. After being clarified in the SBR, the water undergoes two additional filtration processes to remove any solid smaller than 0.08 µm. Then, it is pumped to the Reverse Osmosis unit to finalise the treatment process.

Figs. 12 & 13: Water2REturn microfiltration (left) and Ultrafiltration (right)

Reverse Osmosis. The Reverse Osmosis is the last process before the water is usable again. It consists on a filtration plant that allows all the bacteria, viruses and multivalent and univalent ions to be eliminated, along with most of the contaminants that remain in the water. The water that comes out of this process is suitable for reuse. Two different flows exit the reverse osmosis unit: the fully reusable treated water and a nutrient concentrate by-product that can be used as a fertiliser.

Fig. 14: Water2REturn reverse osmosis

Once the system started up by June 2020, a protocol for analysing the SBR's treated water to evaluate the performance and the treatment efficiency rates in the process was established and applied during the rest of the project duration. This sampling program includes the parameters usually considered when evaluating the efficiency of wastewater treatment systems according to the Council Directive on May 21st, 1991 91/271/EEC: BOD5, COD, TSS, VSS. The contents of Nitrogen have been also checked by measuring the $N\text{-}NH_4$ and the $N\text{-}NO_3$ on a weekly basis in samples taken from different sampling points: the SBR influent (inlet pumping well), the SBR reactor, the treated effluent (the outlet pit of the treatment facility) and, from June, 2021, in the DAF.

Two types of samples have been taken on a weekly basis since September 2020: punctual samples and 24h-aggregated samples. All samples have been taken, conserved and transferred following the normalised standards for carrying out the activity. Results have been checked to find out if they fulfil the discharge limits permitted by the current legislation (Directive 91/271/EEC):

- Biochemical oxygen demand (BOD5 at 20 °C) without nitrification: concentration permitted, 25 mg/l O_2; minimum percentage of reduction required, 70-90%.
- Chemical oxygen demand (COD): concentration permitted, 125 mg/l O_2; minimum percentage of reduction required, 75%.
- Total suspended solids (TSS): concentration permitted, 35 mg/l; minimum percentage of reduction required, 90%.

All samples taken fulfill legislation applying ither the values for BOD5, COD and TSS concentration or for the established percentage of reduction, what means the treatment performed is satisfactory.

5 Location and conditions

The demonstration site is the real working slaughterhouse '*Matadero del Sur*'.

Matadero del Sur is a family business with nearly 40 years of experience in the meat sector. Since 1984 they have been established in the municipality of Salteras, 14 kilometres from the centre of Seville, Spain. It operates as a general refrigerated slaughterhouse, with cutting and packaging rooms, sausage factories and a drying room for Iberian hams.

The company, which has been operating nationally since 1978 and internationally since 1990, also has several extensive and intensive farms for the rearing and fattening of cattle and pigs.

This long business and industrial journey has made *Matadero del Sur* a true benchmark in the Andalusian meat production.

Fig. 15: Water2REturn system at *Matadero del Sur*

Fig. 16: Water2REturn system at *Matadero del Sur*

6 Slaughterhouse industry

The slaughtering process is highly demanding in terms of freshwater consumption. It is not easy to provide data on water and energy consumption as there are many factors at play, namely, types of technologies used by the specific plant, country-specific requirements, types of treatment and processing, etc. As an estimation, animal production requires about 2,422 Gm^3 of water per year, with animal feed being the most water-intensive component. This figure alone highlights the industry's needs for resource-efficiency technologies and leaves room for Water2REturn alike technologies. Water2REturn solution can **effectively save up to 20-40% of water in the industry** through its recycling for irrigation and cleaning purposes, as well as **recover up to 90% of nutrients from the slaughterhouse wastewater and discharge low nutrient content of reclaimed water, reducing the pollution of water bodies.**

During the slaughtering process, more specifically, water is required for many phases: carcass cleaning, sanitising equipment, cleaning stockyards, animal pens, cooling facilities and for the staff employed on site. Strict rules determine that during the slaughtering process, operators must use fresh water, as the food produced is meant for human consumption and health hazards must be ruled out.

7 Environmental, economic and social impact

The projected treatment capacity of Water2REturn system is 50 m^3 per day (out of the 150 m^3 of the slaughterhouse's daily flow). Taking into account this fact, the environmental, economic and social assessments considered two different scenarios.

The first scenario is based on the demonstrator for a treatment capacity of 54 m^3 per day (average capacity calculated with real data). The second scenario is an adaptation of the Water2REturn system for a full treatment capacity of 162 m^3 per day, as an average capacity of the slaughterhouse wastewater treatment plant according to the real data compiled.

Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) were run comparing both scenarios.

Different scenarios demonstrate that the production of biostimulants and the chemical fertiliser reduction have a significant role to determine the benefits of the Water2REturn system for both capacity scenarios.

LCA results have demonstrated that due to the nutrient recovery from raw wastewater, Water2REturn plant even without biostimulants has lower environmental impacts than the baseline situation for both capacities. If the chemical fertiliser reduction rate is higher than the environmental break-even point (1,4%), the Water2REturn plant becomes beneficial for the environment.

Due to additional units and a large energy consumption, the Water2REturn plant without biostimulants has higher life cycle costs in comparison to the baseline scenario. If the chemical fertiliser reduction rate is higher than the economic break-even point (2,3% for full capacity and 2,7% for reduced capacity), the Water2REturn plant generates economic savings.

Different scenarios demonstrate that the production of biostimulants and the reduction rate of the chemical fertiliser consumption have a significant role to determine the environmental benefits and economic savings of the Water2REturn system for both capacity scenarios.

In comparison to the baseline situation, all scenarios with a fertiliser reduction rate higher than the break- even point (1,4%), are beneficial to the environment. The economic break-even point is higher due to the large investment costs in the Water2REturn system.

The full capacity scenario (162 m^3/d) has a better environmental and economic performance than the reduced capacity scenario (54 m^3/d) due to scale effects of the impacts and benefits related to the construction and operation of the Water2REturn system.

The eco-efficiency results show that the environmental and economic performance go hand in hand. Chemical fertiliser reduction results in both environmental benefits and economic savings as long as both environmental and economic break-even points are exceeded, representing a win/win situation for the Water2REturn system.

Regarding the social footprint, results of the social LCA indicate that the construction of the plant plays a relevant role in the risk of the Water2REturn technology and this should be taken into consideration when it enters the market. For this reason, attention should be given to the selection of companies producing the elements for the different lines. The production of biostimulants represents an opportunity with a positive impact on the local communities and workers. Furthermore, the use of biostimulants allows a reduction in the use of fertilisers, with avoided risks for workers and local communities.

8 Financial analysis

The most economically and financially performing plant condition is the one with a treatment capacity of 162 m^3/d slaughterhouse wastewater with the production of the two agronomic products (APs) with their highest sales prices. The production of the two APs considerably increases the profitability of the plant for the highest sales prices of € 6,250.00 €/m^3 and € 11,200.00€/m^3. The average sales prices for APs also offers good prospects for the sustainability of the investment, while the scenario with the rock-bottom sales prices of the APs is the least sustainable, especially for the 54 m^3/d treatment capacity of the Water2REturn system.

Table 1: Financial analysis of the Water2Return system for two treatment capacities

Scenario	CAPEX (€/y)	OPEX (€/y)	Break-even point (€)	Payback period (y)
Baseline, 54 m^3/d	380,511.67	31,560.00	N/A	N/A
Baseline, 162 m^3/d	1,141,535.00	94,680.00	N/A	N/A
W2R+SRMs, 54 m^3/d	551,770.11	227,088.29	726,340.60	3.89
W2R+SRMs, 162 m^3/d	847,472.65	556,101.26	1,230,962.63	1.78
W2R APs, 54 m^3/d	726,340.60	802,730.54	1,324,945.51	1.54
W2R+APs, 162 m^3/d	847,473.00	2,251,893.43	2,464,626.37	0.89

8 Contact

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