The Best Practices Handbook

WETWINE

The WETWINE project (SOE1/P5/E0300) was approved in the First Call for Proposals in the 2014 - 2020 Interreg Sudoe Programme and is co-funded by the European Regional Development Fund

WETWINE project consortium

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PRESENTATION OF THE BEST PRACTICES HANDBOOK

Presentation of the Best Pratices Handbook

BASELINE SCENARIO

The **wine industry is of great importance in Europe**, particularly in the Sudoe area (Spain, Portugal and southern France), due to its socio-economic impact as an agricultural and productive activity, but also from an environmental and sustainability perspective.

From this **environmental and sustainability** perspective, we can consider a myriad of key issues to be taken into account in the industry, such as sustainable agronomic practices, biodiversity, the impact of climate change, generational change and many other issues that are currently being discussed and dealt with in depth by the industry and the scientific community.

However, it is very striking that many wineries currently have not wastewater treatment systems, have systems that are not adapted to the special features of their waste types and seasonality, or simply do not work due to lack of maintenance.

This is why the **WETWINE project** focuses on a key issue directly related to the environmental impact of winemaking, namely the **recovery and reuse of effluents generated in the winery**, which brings grape production and winemaking closer to a more sustainable **circular economic model.**

The WETWINE project thereby aims to achieve this objective by focusing on two key points:

1. WATER CONSUMPTION AND EFFLUENTS MANAGEMENT PRODUCED BY THE WINERY PRODUCTION PROCESS.
2. SLUDGE RECOVERY AS FERTILISER FOR THE VINEYARD AND REUSE OF TREATED WATER FOR IRRIGATION.

FIND OUT MORE ABOUT THE WETWINE PROJECT

WETWINE is a project from the **Interreg Sudoe transnational cooperation programme, co-funded by the European Regional Development Fund (ERDF)** and implemented in 12 wine regions in South-West Europe, involving **8 partners and 3 associated wineries from Spain, Portugal and France.**

The main objective of the WETWINE project is to promote the rational use of resources and their recovery, limiting the generation of waste and soil and water pollution in South-West Europe.

To achieve this, the **WETWINE project promotes a treatment and recovery system for waste from wine production, based on low-cost natural technologies.** WETWINE promotes a model for the management of wine effluents through constructed wetlands that allows both the treatment of wastewater for reuse as irrigation and the recovery of the resulting sludge by obtaining a fertilizer.

To validate this treatment and recovery system, **WETWINE has built a pilot plant at the Santiago Ruiz Winery, located in southern Galicia (Spain).** It is based on the combination of an anaerobic system and constructed wetlands system for water and sludge treatment, which will allow the design and operation strategies for constructed wetland systems to be adapted to the characteristics and special features of winery's wastewater

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OBJECTIVE OF THIS BPH

The objective of this **Best Practices Handbook** is to widely disseminate the model for the management of wine effluents proposed in the WETWINE project, focusing on the different stages of the process and emphasizing environmental impact reduction through the WETWINE global recovery system.

The WETWINE BPH directly contributes to the **transfer and dissemination of the project's results and to environmental awareness of all agents involved in the wine system value chain in the South-West European region.**

All the information gathered and the results achieved in this project development phase, such as data obtained from the construction, commissioning and operation of the WETWINE pilot plant, information gathered in the different tasks and activities carried out within the scope of the project, as well as the extensive experience and technical knowledge in effluents treatment and in agronomic aspects related to the recovery and reuse of wine production waste belonging to the participating partners, have enabled the drafting of this **WETWINE BPH** first version.

This BPH will be used in the activities for the transfer and dissemination of results planned for the last phase of the WETWINE project. Eventually, at the end of the project, a WETWINE BPH final version will be produced that includes the improvements identified and proposed by end users and incorporating the latest results and progress achieved in the project.

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INTRODUCTION TO WINERY EFFLUENT MANAGEMENT

WATER CONSUMPTION AND WASTEWATER GENERATION

The greatest water consumption at wineries is associated with different tasks in the production process, the following standing out: cleaning, refrigeration systems and filter beds preparation. Nevertheless, it is estimated that **90% of a winery's water consumption is directly related to the tank, equipment, machinery and facility cleaning tasks.**

As regards the different stages of the production process, it has been observed that most of the wine effluents pollution load and volume (about 60%) are concentrated in the 5-week period after the harvest start. Approximately 40% of the total corresponds to the harvest itself and the rest corresponds to the first racking, with daily peaks that can be as much as 2% of the annual volume (Pirra, 2008).

It should be pointed out that there are also **significant differences according to the type of wine.** For example, there is a great difference between the production of red and white wine, both in terms of pollutant load and water consumption. It is estimated that the organic matter load can be five times higher in red wine production and the volume of wastewater generated can amount to up to twice that generated by white wine production.

Water consumption in wineries generally ranges between 1 and 6 litres for every litre of wine produced. This ratio depends on several factors, such as facilities, ground type, cleaning equipment and technology, cleaning habits, water supply and treatment costs.

Achieving 1:1 ratios, **consuming 1 litre of water per litre of wine produced** without compromising any of the stages or tasks, or the hygiene levels of the production process, **are perfectly viable today.** Nevertheless, until now legal and economic issues associated with water consumption and effluent treatment have not had enough impact on the industry to archive the desired reduction.

This information establishes that **waste from a winery can vary greatly**, both **quantitatively and qualitatively**, according to the time of year, the operation that generates the waste, the type of wine(s) produced by the winery or other key elements, such as how concerned winery staff are with saving water and effluent management.

This is why it is practically **impossible to determine the "typical" effluent** from a winery, both in terms of volume and characterization of waste parameters.

WASTEWATER CHARACTERISATION

In the harvest period, pollutants mainly come from leftover must and leftover solids (seeds, skins and stems), as well as fermentation residue in tanks (lees). As a general rule, the waste is characterised by its low pH, high suspended solid concentrations, and high organic loads which are readily biodegradable.

Other winery operations **outside the harvest season** include a host of processes with a very diverse pollutant composition, influenced by the organic products and cleaning products used. This waste can generally be considered to have high pH variability depending on operation and suspended solids and organic loads lower concentration.

Winery effluents characterisation is essential in order to limit variability in terms of a properly designed effluent management system, check proper functioning of an operational plant or wastewater quality monitor after treatment.

The most common parameters for wastewater characterisation and control of the treatment system are detailed below. Although these parameters are highly variable, the range into which each of these values usually have is given in brackets as a guide:

pH: a measurement of acidity and alkalinity which indicates hydrogen ions concentration present in specific solutions. The pH scale varies from 0 to 14. Solutions with a pH below 7 are acids, those with a pH above 7 are alkalines, and those with a pH of 7 are considered neutral. The pH is a fundamental parameter in the development of bacteria in biological treatment systems [4 - 6.5].

TKN - Total Kjeldahl nitrogen: Reflects the total amount of nitrogen in the water being analysed, the sum of organic nitrogen in its various forms and the ammonium ion NH_4^+. It is an important parameter in wastewater treatment plants that measures the total nitrogen that can be nitrified to nitrites and nitrates. Nitrogen is necessary for the growth of microorganisms, but it also contributes to oxygen depletion and the eutrophication of water when it is found in high concentrations [20 - 200 mg/l].

P_{total} - total phosphorous: total phosphorous: Total phosphorous is the sum total of the three forms of phosphorus-containing compounds: soluble orthophosphates, inorganic polyphosphates and organic phosphates. It is expressed in milligrams per litre (mg/l) and is another component of wastewater that is important for the biological growth of microorganisms. Both TKN and P_{total} are representative parameters for the measurement of nutrients in the eutrophication (excessive growth of algae and other plants) of the receiving waterway [10 - 50 mg/l].

TSS - Total suspended solids: indicates the amount of solids that are suspended and which can be separated by mechanical means, such as liquid vacuum filtration or centrifugation. It is expressed in milligrams per litre (mg/l) and is a common parameter in water quality rating and in wastewater treatment. It quantifies the impact of the solids on the receiving waterway, the accumulation of which causes turbidity and the formation of sludge [1,000 – 2,500 mg/l].

BOD - biological oxygen demand: a parameter that measures the quantity of oxygen consumed in the organic matter breakdown in a liquid sample. It is expressed in milligrams of oxygen per litre (mg O_2/l) and is an interesting parameter in water samples that contain a large amount of organic matter [1,500 – 6,000 mg O_2/l].

COD - chemical oxygen demand: measures the quantity of substances susceptible to oxidation by chemical means that are dissolved or suspended in a liquid sample. It is expressed in milligrams of oxygen per litre (mg O_2/l) and, like BOD_5, it mostly allows for the measurement of organic matter concentration, while taking into account inorganic substances susceptible to oxidation. As with BOD_5, it is very useful for the design and control of treatment systems and a measurement of the impact that the wastewater would have on the oxygen levels of the receiving waterway [2,000 – 10,000 mg O_2/l].

SAMPLE COLLECTION

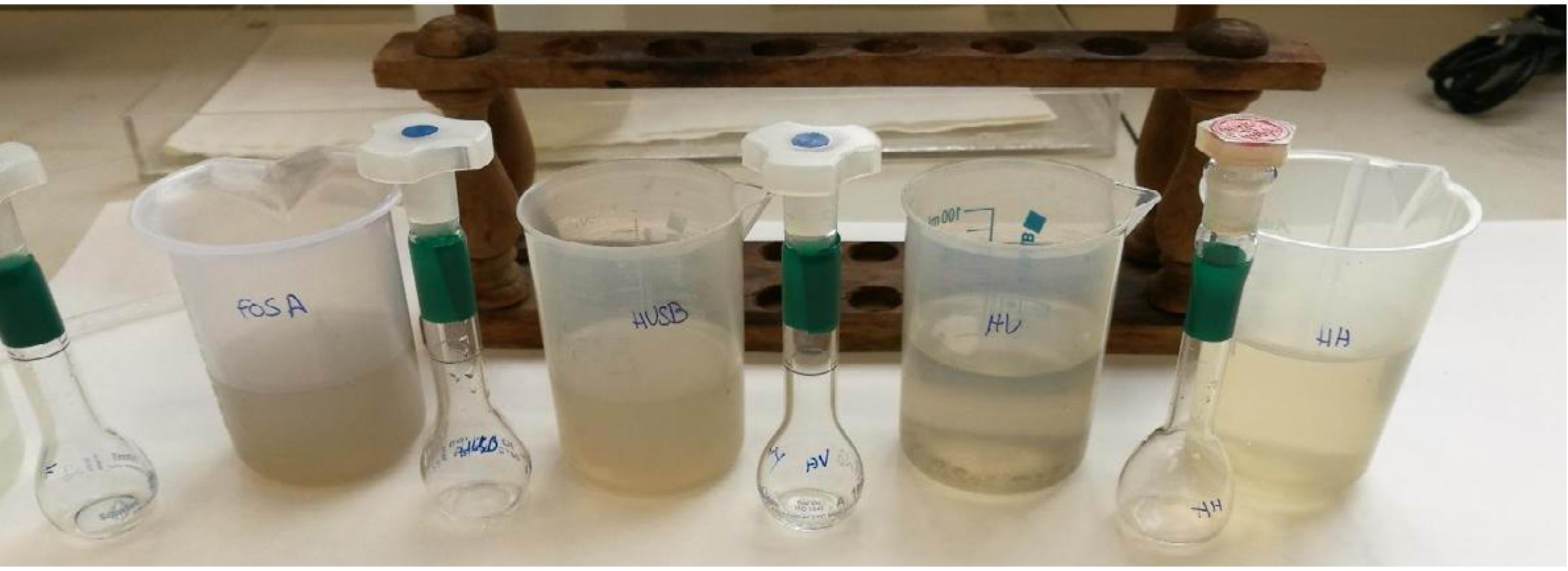
The sampling process is also **a critical task in effluent characterisation.** Sampling must follow a collection protocol so that it does not affect to final result.

As general sampling recommendations: clean 1-2 litre containers should be used, samples should then be refrigerated to avoid physical-chemical and microbiological alteration, and finally they should be analysed within a maximum of 48 hours.

Sampling systems **can vary depending on how the sample is collected**: it may be a grab sample, a composite sample or proportional to the flow rate (the last of which is the most representative).

Season and frequency is also decisive: the highest frequency of sampling is recommended in the harvest season, an intermediate frequency in periods before and after the harvest, and a lower frequency for the remainder of the year.

The procedures and frequency of sample collections **should in any case be adapted to the characteristics and special features** of each winery and treatment system.



LEGAL FRAMEWORK FOR EFFLUENT MANAGEMENT

The applicable legislation in the field of effluent management is very broad and complex, depending on the respective drainage basins and various municipal, regional and/or national regulations.

Council **Directive 91/271/EEC** is the basis for policy development and the transposition into national law of the various member states. The **Water Framework Directive** (**Directive 2000/60/EC**) is another reference regulation, which establishes a framework of Community action in the field of water policy.

In addition, **all those regulations that apply to water reuse** from treatment processes or to **sludge use as a fertilizer** should also be considered.

Given the complexity, the objective of this BPH is not to compile all the applicable legal references, which are available in detail in the WETWINE Guide to Public Policy and, according to the location of each winery, in the **WETWINE simulator**.

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WINERY EFFLUENT TREATMENT

WASTEWATER TREATMENT PROCESSES

Wastewater pollutants can be removed by physical, chemical and biological methods. A treatment system (or process phase) is normally a combination of all of these. For classification purposes, it is considered to be the predominant process.

Physical processes: treatment methods in which physical phenomena predominate (application of gravitational, centrifugal and physical retention forces, etc.). Filtration, degreasing, desanding, sedimentation, evaporation, disinfection and absorption can be included in this group.

Chemical processes: treatment methods in which the removal of pollutants is produced through chemical products addition or other chemical reactions. These include flocculation and coagulation, neutralisation, oxidation, reduction, ion exchange, absorption and disinfection (chlorine, ozone).

Biological processes: treatment methods in which pollutants are removed by means of a biological activity. Biological treatment is principally used to remove biodegradable organic substances (colloidal or dissolved) which are present in the wastewater. Basically, these substances are transformed into gases which can escape into the atmosphere and into biological cellular tissues, which can later be removed through sedimentation. This group includes: a sequencing batch reactor (SBR), bacteria beds, treatment in wetlands, lagooning, biodiscs and land application systems.

WASTEWATER TREATMENT STAGES

All effluents, originating from wine as well in this case, are managed in an orderly and sequential way through different stages that provide adequate treatment. **Effluent management processes, as well as the different possible combinations, are very diverse. The ones which are most widely used can be grouped into the following stages:**

Pretreatment: Physical and mechanical operations which separate the elements that damage the following treatment stages (solids, sand, oils, etc.). Among the different pretreatment types, the most common ones are:

—Roughing filters: Interception of wastewater using grids and/or sieves in order to remove solids varying in size between large and small.

—Desanding: Separation of solids (sand, gravel, etc.) in order to reduce sedimentation in the pipelines and to protect subsequent mechanical elements from abrasion.

Homogenisation: caims to achieve a more or less constant flow. It usually takes place in a tank.

Primary treatment: also known as primary sedimentation, this involves the removal of as many sedimentable and floating solids as possible, and part of the organic matter. Among the different types of primary treatment, the most common ones are

— **Primary clarifiers:** A circular or rectangular tank where gravity is used to decant solids.

— **UASB Digesters**: *(Upflow Anaerobic Sludge Blanket)* A biological anaerobic (absence of oxygen) reactor which operates continuously in an upward flow in which organic matter in the form of floccules and granules is easily decanted. Biogas can also be generated.

— **Septic tanks**: A tank where the separation and physical-chemical transformation of organic matter contained in wastewater takes place.

Secondary treatment: A process through which dissolved or colloidal biodegradable organic matter is removed, as well as the remaining solids and components that are present, and the treated water is clarified.

Among the different types of secondary treatment equipment, the most common ones are:

— **Biological reactors (aeration tanks)**: A tank where organic matter is assimilated and released by bacteria inside the reactor under aerobic conditions. There are several types of reactors (complete mix, plug flow, etc.)

— **Secondary clarifiers**: A circular or rectangular tank where a process of clarification of the influent is used to separate the suspended solids.

— **Aerated lagoon:** A reactor constructed by excavating an artificial pond in the ground in which there is an external mechanical oxygen input to break down organic matter.

— **Constructed wetlands:** Excavations in the ground in which a granular medium is placed, vegetation is planted and a series of pipes are installed. The wastewater circulates through the medium while a series of physical, chemical and biological mechanisms and processes take place that purify the wastewater.

Tertiary treatment: A process in which the treated water is sanitized and adjusted so that it can be discharged in areas with more demanding requirements or to be regenerated for a specific use. This stage generally aims to eliminate nutrients and pathogens. Some of the main types of tertiary treatments are:

— **Lagoons**: Artificial ponds dug into the ground, with or without the presence of algae. They can be aerobic, anaerobic or facultative.

— **Sand filters**: A reactor filled with granular material that allows solids and particles to be separated by the influent circulating through the reactor.

— **Disinfection:** A physical or chemical process that inactivates potential pathogens present in the water using reagents (e.g. chlorine).

Sludge treatment: its objective is **the thickening, stabilisation, conditioning and dehydration of the sludge generated during the treatment process for subsequent agricultural use.** Sludge contains 40-80% of organic matter, as well as nitrogen and phosphorus, nutrients that are essential for their fertilising potential.

CONVENTIONAL VS UNCONVENTIONAL TREATMENTS

In the biological (secondary) treatment stage, a distinction can be made between conventional and unconventional treatment technologies.

Conventional treatments

Conventional technologies are characterized by high construction requirements and specialisation required for their operation.

Pollutants biological transformations usually occur in concrete, plastic or iron containers and operate by prolonged aeration, mechanical mixing and a great variety of chemicals.

Due to the high intensity of these reactions, the physical space required in these processes is much smaller than in the processes that take place naturally, i.e. an intensive use of energy causes these systems to be compact.

There are different types of conventional treatments:

- Extensive Biological Ventilation Systems,
- Activated Sludge Treatment Stations,
- Biodiscs (RBC),
- Continuous Sequencing Batch Reactors (SBR),
- Membrane Biological Reactors (MBR)

Sequencing Batch Reactors (SBR) are one of the processes commonly used in wineries. This is an activated sludge treatment system operated in the filling and emptying phases. In this type of system, the roughened effluent is introduced directly into the aeration system without the need for prior decanting, so they are generally designed without primary sedimentation tanks, which is a cost-saving factor in their installation.

It is a competitive technology from an economic point of view and simpler to handle than other conventional processes, which makes it **an alternative for wineries among the conventional technologies available on the market.**

During operation, there are however several problems caused by complex and costly maintenance operations, need for qualified operators or costly repairs. This means that when they are not properly maintained, these treatment systems do not often perform as expected and do not meet the objectives for which they were designed.

Unconventional treatments

Unconventional systems, also called natural systems, **are characterised by the simplicity of their construction and operation.** In the case of these technologies, wastewater is treated by **the interaction of natural components (soil, plants, water).**

Natural treatment uses and maximizes a series of **processes that occur naturally in the environment, at a controlled site.** It aims to create a space in which a series of ecosystems can be developed to allow for the recovery of wastewater.

It is therefore **a natural process that does not require an external supply of chemicals and requires zero or low energy consumption** (only present in the case of pumping at head). The reduced manpower required for maintenance is another advantage.

This has all led to a gradual increase in the use of these natural systems, since these characteristics make them a competitive investment.

Natural systems can be classified into t**wo categories depending on where treatment takes place**:

— **On land:** Surface or subsurface application, sand filters, filter trenches and beds, green filters and subsurface flow constructed wetlands.

— **In a water body:** Floating plant systems, natural lagooning and surface flow constructed wetlands.

The most important limitation of unconventional treatment systems is the increased time that the wastewater must spend in the system to achieve adequate purification, causing these systems to require **larger surfaces for their operation compared to conventional technologies.**

CHOOSING THE MOST SUITABLE TREATMENT SYSTEM

Based on the above and considering the **specific characteristics of many wineries** (volumes of waste, location in natural or protected environments, limitations on access to public or collective sanitation networks), when deciding on the most appropriate solution for the wastewater treatment, **the following aspects should be prioritized:**

Selection of **systems that allow the treatment of the influent in situ, avoiding transport and dependence on external managers** that generate a higher operating cost and environmental impact.

Selection of **systems with low energy consumption**, avoiding – or minimising as far as possible – the use of pumping and electromechanical devices in favour of the use of natural oxygenation systems.

Selection of **systems with low maintenance and simple operation tasks,** avoiding the need for chemicals or other consumables, as well as specialised personnel for proper operation.

Selection of systems that guarantee **efficient and stable operation to combat peaks in the flow and pollutant load of the wastewater** that are associated with the harvest period, guaranteeing the required **quality of the wastewater** according to the destination or receiving environment.

Selection of systems that **simplify the management of sludge generated in treatment processes, allowing its recovery and reuse** as far as possible, favouring the circular economy in winery management.

Selection of systems that have a **low environmental impact, do not produce noise or odours**, do not attract mosquitoes and are **well integrated into the natural environment.**

Based on the above criteria, **the WETWINE system has been launched as an interesting alternative** for the management of wine-related effluents from wineries.

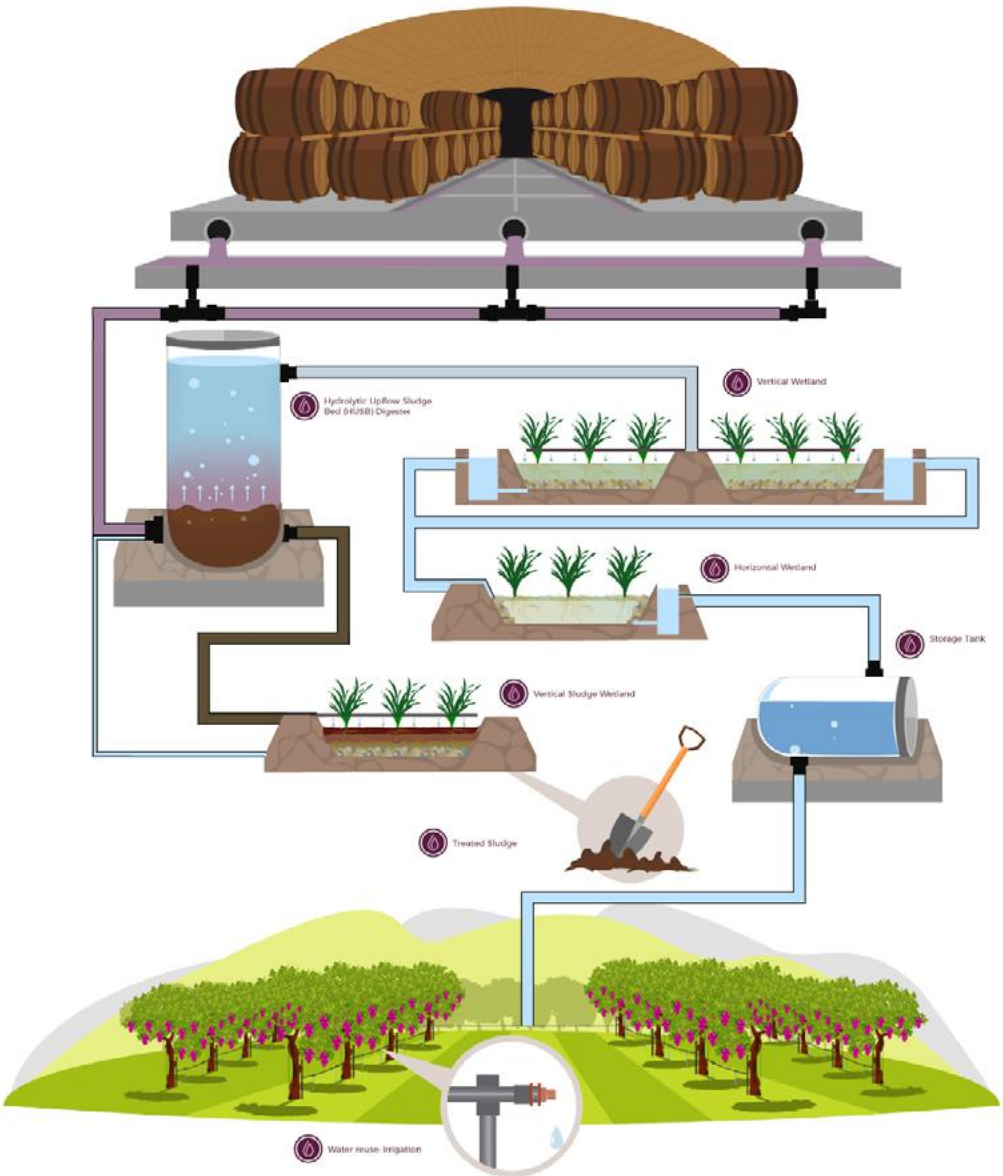
INTRODUCTION TO THEWETWINE SYSTEM

The **WETWINE project has adapted natural wastewater treatment technologies to the specific effluent needs of the wine industry.** A pilot plant has been built for this purpose in the Santiago Ruiz Winery, where the use of natural wetland technologies has proven to be an interesting alternative for the treatment of both wastewater and sludge.

The **WETWINE system basically combines an anaerobic primary treatment unit (HUSB reactor) with a series of subsurface flow constructed wetlands** for water and sludge treatment.

In the primary treatment stage, which takes place in the HUSB reactor, solids are retained and hydrolysed or broken down with 70-80% efficiency. The resulting water then circulates through a series of **vertical and horizontal wetlands planted** with reeds where, through various biological, physical and chemical processes that take place simultaneously, wastewater is treated and an effluent is obtained that has analytical parameters suitable for discharge or even for use as irrigation.

Meanwhile, the solids retained in the HUSB reactor are treated in **sludge treatment wetlands** where physical, biological and chemical processes reduce the volume of sludge. Stabilisation and mineralisation also occurs for subsequent use as a fertilizer in the vineyard.



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DESCRIPTION OF THE WETWINE SYSTEM

Description of the WETWINE system

GENERAL OVERVIEW

The first stage of the WETWINE system is **anaerobic treatment, where the waste will be separated into two parts:** a liquid part and a solid (sludge) part.

The liquid part will be treated using **subsurface flow constructed wetland** technology that allows wastewater to be purified by natural processes without the need for chemicals and with little or no energy consumption.

The solid phase will be treated in the **sludge treatment wetlands**, where it is stabilised through physical, biological and chemical processes to obtain a final product which is suitable for direct reuse as fertilizer.

Based on this distinction we can distinguish the main units that make up the WETWINE system:

1. PRIMARY TREATMENT THROUGH A HUSB (HYDROLYTIC UPFLOW SLUDGE BED) ANAEROBIC REACTOR.
2. A SECONDARY TREATMENT STAGE OF CONSTRUCTED WETLANDS, COMBINING VERTICAL AND HORIZONTAL SUBSURFACE FLOW WETLANDS, WHICH WILL BE CALLED THE WATER TREATMENT LINE.
3. A SLUDGE TREATMENT STAGE USING SLUDGE TREATMENT WETLANDS, WHICH WILL BE CALLED THE SLUDGE TREATMENT LINE.

Each stage of the WETWINE system is described in more detail below:

HUSB DIGESTER (HYDROLYTIC UPFLOW SLUDGE BED)

The primary treatment consists of **a hydrolytic upflow digester (HUSB)**, whose main functions are the **retention of solids and the hydrolysis or break down of compounds that are difficult to biodegrade into simpler ones.** The two parts will be separated in this treatment stage: the liquid phase will be treated in the constructed wetlands, and the sludge phase will be treated in the sludge treatment wetlands.

The main **physical processes** that take place in a HUSB reactor are **sedimentation, filtration and absorption.** In these reactors, the main aim is to retain suspended solids.

WATER TREATMENT LINE

The water treatment line is based on the combination of v**ertical and horizontal subsurface flow constructed wetland technologies.**

These are **natural treatment systems** designed to enhance the elimination of pollutants in wastewater with **mechanisms that occur spontaneously in nature**, both at a physical-chemical and biological level. In these systems, decontamination processes take place through **the interaction between water, a granular medium, microorganisms and vegetation.**

The WETWINE system's wetlands are subsurface flow wetlands, in which water circulates underground through a granular medium, in contact with the roots and rhizomes of plants. The biofilm that grows attached to the granular medium, as well as to the plants roots and rhizomes, plays a fundamental role in water decontamination processes.

Wastewater treatment in constructed wetlands is based on several principles, the most important of which are:

— **Organic matter removal** by sedimentation and particle filtration between gravel spaces and roots. This process involves various microorganisms (essentially bacteria), which can be aerobic or anaerobic.

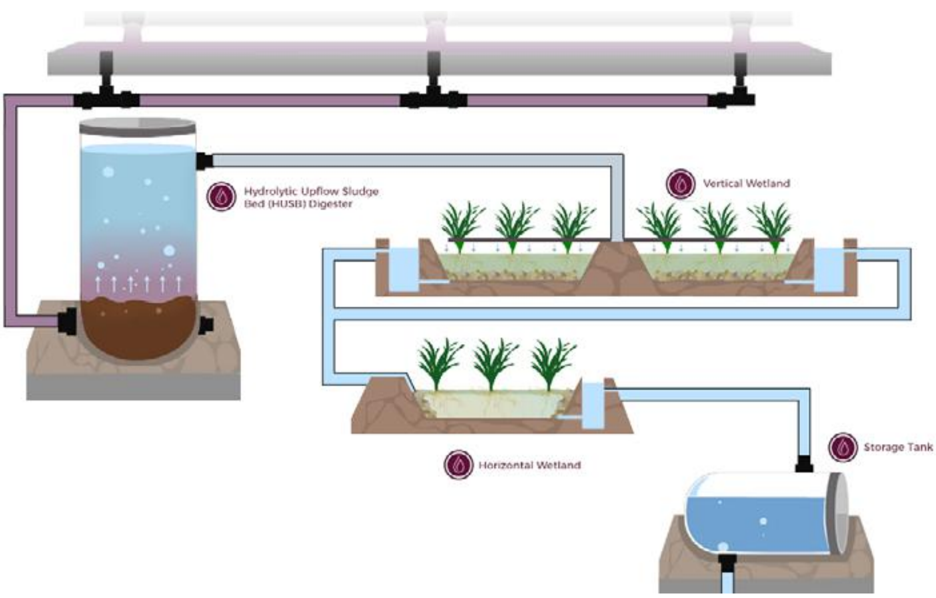
— **Suspended solids removal** by filtration between the substrate and the roots. Suspended solids are eliminated in the first few metres from the inlet.

— **Pathogenic organism removal** by adsorption on substrate particles. Bacteriophages and protozoa predatory action that inhabit the substrate is also involved.

— **Nitrogen removal**, which is normally in organic or ammonium nitrogen form. Under these conditions, nitrification-denitrification processes carried out by different microorganisms and other nitrogen transformation processes such as anammox are generated. Cutting back the wetland plants increases performance in this respect.

— **Phosphorus removal** that occurs when contact is made with the fluid containing phosphorus, influent, and substrate. In these circumstances, adsorption phenomena occur which phosphorus retain, even though this reduction is very low.

Two wetland types considered in the WETWINE system are distinguished by the type of circulating flow, being divided between vertical and horizontal subsurface flow wetlands.

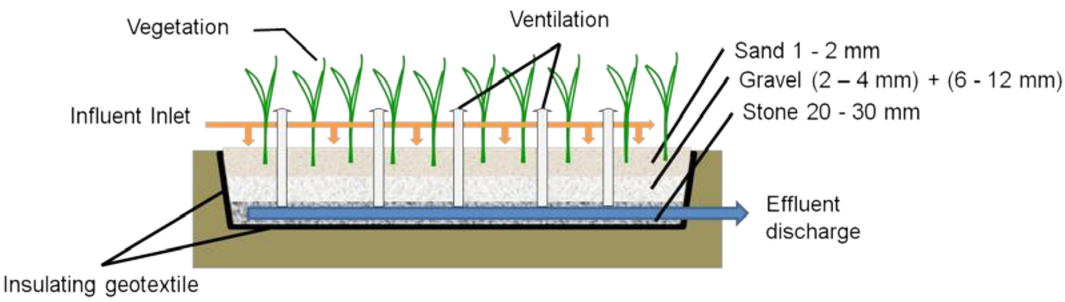


Vertical Wetlands

Vertical wetlands are **fundamentally aerobic and can take higher pollutant loads.** This is why the vertical wetland will be placed at secondary treatment head to receive the most polluted wastewater from the HUSB digester outlet. These systems consist of several cells that are fed intermittently and sequentially, alternating between feeding and rest periods.

This wetland type was originally developed as an alternative to horizontal wetlands to produce nitrified effluents. **Vertical systems are generally combined with horizontal systems (hybrid systems) so that nitrification and denitrification** processes take place gradually, thereby eliminating the nitrogen and obtaining a better quality effluent.

Water circulates vertically downwards and circulation takes place in pulses, so that the granular medium is not permanently flooded or saturated, thus allowing the decontamination processes in these systems to be mainly aerobic.

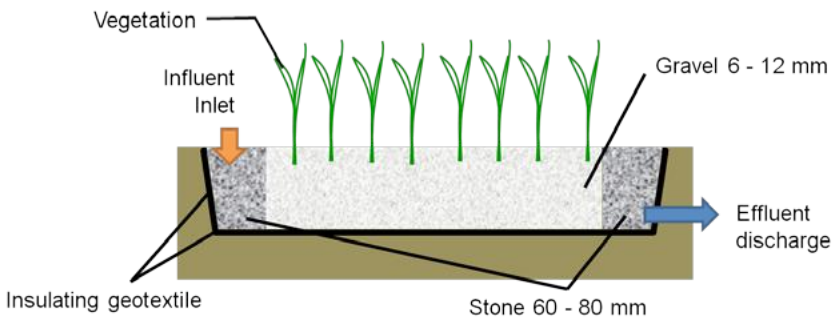


Vertical subsurface flow constructed wetland

Horizontal wetlands

A horizontal flow wetland, **with aerobic and anaerobic zones, is located afterwards so that a greater number of pollutants are degraded, through the combination of both environments.** This horizontal wetland will take on the treatment of the effluent from the vertical wetlands, which will already be partially purified and oxygenated.

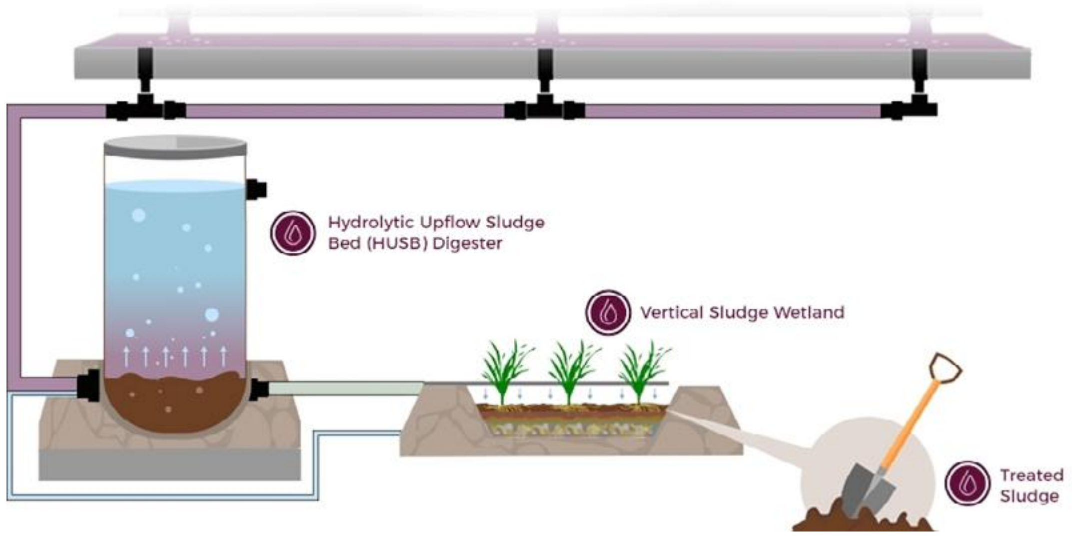
In this type of system **the water circulates horizontally through the granular medium and the plants rhizomes and roots.** Water depth is between 0.3 and 0.9 m and the wetlands are characterized by operating in a permanently flooded and saturated state.



Horizontal subsurface flow constructed wetland

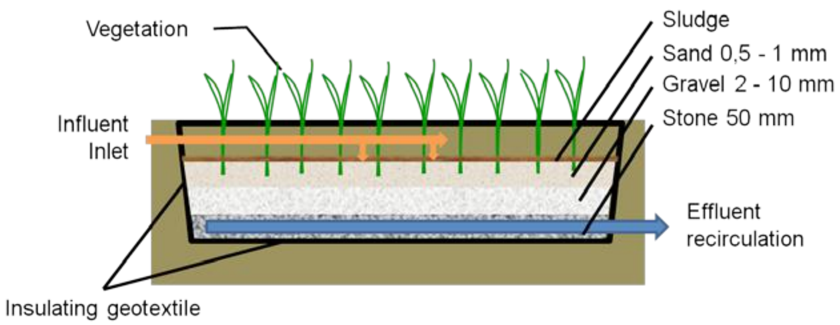
SLUDGE TREATMENT LINE

Sludge treatment wetlands **are a type of vertical wetland developed to treat sludge which comes from the HUSB digester.** These systems consist of several cells into which homogenised sludge is **intermittently and sequentially pumped**, alternating between periods of feeding and rest.



Rest periods will depend on design and climate conditions, but **intervals between feeding should be sufficient to allow the water contained in the sludge to drain.**

As the sludge accumulates at the top of the bed and the layer grows, plant rhizomes develop and penetrate the sludge layer, increasing dehydration through an evapotranspiration process.



Sludge treatment wetland

Once the sludge storage capacity is reached in the wetlands, and after **physical (drying) and biological (mineralisation) processes that allow its stabilisation, a final product is obtained with a dry matter content greater than 25% and suitable for direct reuse as fertilizer (taking into account the legal limitations of each region).**

ADVANTAGES AND DISADVANTAGES

The constructed wetlands constitute an interesting alternative for the wastewater treatment from wineries due to their low cost, low energy consumption and easy operation and maintenance compared to other "conventional" systems.

Generally speaking, it can be said that **conventional technologies treat wastewater intensively** through physical, chemical and biological processes that achieve **faster reaction and treatment speeds,** but with higher operating and maintenance costs, which translates into high energy consumption, chemicals and the need for specialized personnel. At the same time, conventional systems can **have problems adapting to high variability of organic loads and flow rates** that wine industries have throughout the year, so their performance and efficiency is limited.

On the other hand, **natural systems are characterized by low energy consumption; they do not require chemical products for wastewater treatment** (as they reproduce the treatment processes carried out in nature) and they **do not need specialised personnel** for maintenance. This is the reason why these systems have lower implementation, operation and maintenance costs; however, the time required to carry out contaminant removal processes is greater.

All in all, the main differences between natural and conventional systems are **lower or almost zero energy requirements for natural systems** (generally 5-10 times lower than conventional systems) and a retention time up to 100 times longer than conventional systems. This is why a larger area **is needed for the implementation of natural systems compared to conventional systems** for the treatment of the same volume of effluents. The WETWINE system also offers the added advantage of **being able to recover sludge for later use as fertilizer in the vineyard and reusing the treated water for irrigation.**

The main advantages and disadvantages that distinguish conventional technologies from WETWINE constructed wetland systems are as follows:

Conventional technologies	WETWINE technologies (unconventional system)
High energy consumption	Low or almost zero energy consumption
High chemical consumption	No chemicals required
High implementation and operational costs	Low implementation and operational costs
Complex operation and maintenance	Simple operation and maintenance
Odour problems	Odours and mosquitoes Drastic reduction of
Cost of sludge management by authorised companies	Sludge recovery as fertilizer in the same system
Destination of treated effluents: discharge	Possibility of reusing treated effluents for irrigation
Greater environmental impact	Reduced environmental impact by promoting the circular economy
Short treatment times	Longer treatment time
Require little surface area	Require a lot of surface area

5

WETWINE SYSTEM DESIGN AND CONSTRUCTION RECOMMENDATIONS

WETWINE system design and construction recommendations

In this section, specific recommendations are given regarding the construction details of the different stages of the previously described WETWINE System.

PRIMARY TREATMENT DESIGN - HUSB REACTOR

— Prior to the reactor, an accumulation tank must be installed to homogenise the composition of the wastewater and laminate discharge peaks.

— Reactor should have height/diameter ratios that increase hydraulic retention times. In the harvest season, retention times in the reactor will be between 40 and 50 hours. Outside harvest season, retention times are not limiting as reactor microbial activity is reduced. In any case, times of less than 40 hours are not recommended due to the design.

— The upflow velocity of the wastewater inside the reactor should be limited to 0.3 mph to favour the retention of solids and the correct formation of the sludge blanket.

— If pumps are being used to feed reactor, a frequency converter should be installed to limit the feed flow rate.

— The inlet pipe must be equipped with a check valve and divided into four H-shaped outlets at the base of the reactor to avoid excessive sludge agitation at the bottom.

— Have four outlet pipes at different heights. Lower pipe corresponds to the sludge outlet to feed the sludge wetland, the rest will be equipped with ball valves to check the sludge level or to empty the reactor.

— It can be installed using prefabricated concrete rings on a base and sealed with an epoxy paint primer or directly by installing a prefabricated cylindrical tank made of fibreglass or reinforced polyester.

— The reactor shall have a top cover to use for repair and maintenance.

LAND MOVEMENT AND WETLAND STRUCTURES

— Construction of vertical and horizontal wetlands and sludge wetlands through ground excavation, taking advantage as far as possible of the topographic slope to promote gravity flows.

— Wetland perimeters formed with marine board and with an external slope to balance the internal and external pressures, or directly on the slopes (in this case, the slope must be around 45º).

— Gradients of around 1% in the flow direction at the wetland base.

— Vertical and horizontal wetland length/width ratios of around 2/1 or 3/1. In the case of sludge wetlands the cells will have an approximate ratio of 1/1.

— Avoid ground seepage by using plastic sheeting. High-density polyethylene is recommended with a thickness greater than 1 mm.

— Avoid damage from stones, filter substrate or plant roots and rhizomes by reinforcing with two geotextile sheets (above and below the plastic sheet). Thicknesses between 150 and 300 g/cm_2 are recommended.

— Exhaustive inspection of plastic and geotextile sheet seams.

— Anchor plastic sheets by burying them in a perimeter trench or by using metal staples.

— There must be an adequate buffer around the wetland to prevent the entry of runoff water

PIPELINES: FEEDING, DRAINAGE AND VENTILATION

— Avoid preferred wastewater flow paths in wetlands through homogeneous surface feeding.

— Hydraulic design of pipelines, pumps and solenoid valves that take into account pumping needs at the head and intermediate levels allowing for intermittent feeding of the wetlands.

— Priority is given to hydraulic designs that take advantage of gravity flows between the different stages.

Vertical Wetlands

— Wetland feeding by means of perforated PVC or polyethylene pipes with a 40 mm diameter, located 1 metre from each other, which ensures an even discharge over the entire wetland surface.

— The supply lines shall be drilled in the frontal plane with 6 mm holes located at a distance of 0.5 m. from each other.

— The feed pipes must be useable at their ends through a screw cap for easy cleaning and maintenance.

— Supply pipes shall be connected to a general pipe with a comb-like distribution and equipped with solenoid valves allowing alternating supply between vertical wetlands. Intermittent feeding (alternating periods of rest and feeding) greatly improves oxygen transfer and the efficiency of purification processes.

- The feeding speed must be higher than the infiltration speed in order to achieve a better distribution over the entire wetland surface

— Vertical wetlands often present clogging problems as they operate at higher loads and have high load losses, so they will often require pumping at head.

— Arrangement of 75 mm diameter drainage pipes located 3 cm from the wetland bottom and at an equal distance of 1 m from each other. The drainage pipes shall be surrounded by a layer of medium thickness gravel (20-30 mm)

— Favour oxygenation of the substrate through the provision of vertical ventilation chimneys connected to the drainage pipes, made with PVC pipes or equivalent material with a 50 mm diameter and finished off at the end by a cap.

Horizontal Wetlands

— Distribution of the influent by means of a 75 mm diameter pipe in the head area that occupies the entire side of the wetland and arranged perpendicularly to the flow direction, and buried 90 cm from the bottom of the wetland.

— At the ends of the distribution pipe there will be 90° elbows that will rise up to 20 cm above the wetland surface, ending in screw caps that facilitate cleaning and maintenance.

— The distribution pipes shall be drilled in the frontal median plane with 2 cm diameter holes every 50 cm.

— These wetlands operate permanently flooded, although flooding level should be 5-10 cm below wetland surface to avoid problems with odours and mosquitoes.

— Water evacuation by means of a 75 mm diameter pipe located in the area opposite the head, arranged perpendicularly to the flow direction and buried in the lower part of the wetland profile. As with feed pipes, the ends of the pipe will be equipped with elbows and screw caps 20 cm above the surface.

— Evacuation pipes will have 3 cm diameter holes drilled at the front end every 50 cm.

— Provision of flexible piping or a useable elbow located in the outlet chamber to control the level of wetland flooding.

— The bottom of the drainage chamber should be at the same height as the wetland one.

Sludge Wetlands

— The sludge wetlands will be arranged in cells and sub-cells measuring approximately 10m^2 so that the homogenised sludge is pumped intermittently and sequentially, alternating between feeding and rest periods.

— The feeding will be carried out with 40 mm diameter pipes discharging into the central part of cell to evenly distribute the sludge over the whole surface.

— Sludge feeding must be carried out intermittently and with high flow rates so that sludge is distributed over the entire surface and to avoid preferential flow paths. Plates may be installed for this purpose on the wetland surface to prevent erosion at the discharge point.

— Once wetland has reached its capacity and after a final three-month rest period, sludge is considered to be stabilised.

— A leachate drainage system using PVC pipes measuring 75 mm in diameter and spaced 1 m apart, with 5 mm notches located every 25 cm. As with the vertical wetlands, a ventilation system is required.

— The drainage pipe will be connected to a chamber where there is a flexible pipe or a useable elbow for wetland moisture control in times when it cannot be fed with sludge.

FILTER SUBSTRATES

— The filter substrate must be sufficiently homogeneous in shape and size (low uniformity coefficient), clean (without the presence of fine particles) and adapted to the needs of each wetland type.

— A high content of fine particles could cause clogging problems which will shorten wetland life.

— Avoid damaging the waterproof sheets and the geotextile in the filling and distribution of the filter substrate in the wetlands.

— Avoid the movement of heavy machinery on wetlands to prevent compaction.

Vertical Wetlands

— Filter substrate with a thickness of 1 m and a profile formed by aggregates of different thickness.

— A 10 cm-thick surface layer with sand measuring 1-2 mm in diameter + a 60 cm-thick upper intermediate layer of gravel measuring 2-4 mm in diameter + a 10 cm-thick lower intermediate layer of gravel measuring 6-12 mm in diameter + a 20 cm-thick deeper layer of gravel measuring 20-30 mm in diameter (where drainage pipes will go).

Horizontal Wetlands

— A 60 cm-thick substrate with root and rhizome penetration profiles not exceeding 40 cm.

— 50 cm-wide stone sides (measured at wetland bottom) with a 60-80 mm diameter in the head areas (where feed pipe is located) and on the opposite side (discharge pipe location).

— Aggregates size depends on pollutant load of water to be treated. Aggregate sizes of between 6 and 12 mm are recommended

Sludge Wetlands

— Substrate thickness of 60 cm with a profile formed by aggregates of different thickness.

— A 10 cm-thick surface layer with 0.5-1 mm diameter sand + 30 cm-thick intermediate layer of gravel measuring 2-10 mm in diameter + 20 cm-thick deeper layer of stone measuring 50 mm in diameter (where the leachate drainage pipes will go).

— A 60 cm buffer for the accumulation of sludge layers through the successive feeding phases until final emptying.

VEGETATION

— Most suitable plant species for planting on wetland water line is the common reed (*Phragmites australis)*, although other species may be used (on the condition that they are fully adapted to the environmental and climate conditions prevailing in the wetlands).

— In these wetlands types, planting in densities of 4 plants per m^2 or 3 plants per m^2 arranged in alternate rows is recommended.

— In the case of sludge treatment wetlands, common reeds (*Phragmites australis*) and bulrushes (*Typha latifolia*) are recommended as the most suitable species.

— Planting density in sludge wetlands is 5 plants per m^2.

— Plant establishment can be carried out by the use of nursery plants or by vegetative propagation from rhizomes obtained in nearby natural wetland areas.

Phragmites australis

Typha latifolia

6

WETWINE SYSTEM USE AND MAINTENANCE MANUAL

CHECKS PRIOR TO START-UP

— Checking the correct operation of all the equipment and installations in the different stages (HUSB reactor, pumps, flow measurement systems, bypass valves, etc.).

— Checking the water tightness of the enclosures containing the filter substrates (wetlands) and the absence of leaks in pipes, connections and intermediate chambers.

— Once construction work and installation are complete, corresponding hydraulic tests will be carried out to validate the functioning of the equipment and to detect possible leaks and malfunctions in any of the items before starting up the plant.

START-UP

— Wetlands feeding will take place once planting has been carried out in order to promote plant growth.

— When wetlands starting up, recirculation is recommended at treated waters head to maintain water level in the wetlands (compensating for losses through evapotranspiration) and thus promoting the initial development of plants.

— If anaerobic sludge from other similar facilities (wineries) is available, it can be used for inoculation of the HUSB reactor.

— For sludge wetlands start-up, it is recommended to feed them only with water for the first 3 or 5 weeks to encourage the development of vegetation and subsequently add solids by feeding sludge.

— As soon as the wetlands start operating, their treatment function begins, initially based on filtering processes through the substrate.

— The bacterial biomass is then progressively developed while the plants retain the nutrients necessary for their growth.

— In horizontal subsurface flow wetlands, the water level will initially be located about 5 cm below the surface, and then the water level will be progressively lowered in order to encourage the deep root development of the plants. Finally, the water level will return to its initial position (5 cm below the surface).

MAINTENANCE AND USE OF WETLANDS

— Substrate maintenance. The substrate is a key part of the wetland, so compaction and saturation should be avoided. It is therefore advisable to tread as little as possible on the wetlands and monitor the interior through frequent inspections from the perimeter.

— Distribution systems periodic cleaning. A good distribution of wastewater will promote the regular growth of all plants in wetland and thus an increase in treatment performance. It will also extend substrate life.

— Distribution systems, located at the head in horizontal wetlands, and on the substrate in the case of vertical wetlands, must be cleaned periodically (in second ones, cleaning after cutting back vegetation is recommended).

— Attention should be paid to plants vegetative state to avoid pests and diseases. In this respect, early detection is essential in order to take action in the initial stages.

— During the reed growth phase, it is necessary to manually monitor development (never using herbicides) of other adventitious species that limit competition.

— Once a year, and always before the vegetation dries, in order to prevent retained pollutants discharge back into water any dry plants should be cut down and removed, although in cold climates this can be avoided, allowing the presence of vegetation as a wetlands thermal protection measure.

— Daily visits to the wetland system are recommended in order to detect possible anomalies that may alter its proper functioning.

— To properly monitor the process, flows of influents and the resulting treated waters must be determined. If flow meters are available, the measurements will be recorded, otherwise the corresponding measurements will be taken occasionally.

— Reading of influent and effluent analyses. Good wetland behaviour will imply adequate performance of BOD5, COD and suspended solids. Any anomaly in one of these parameters is an alarm signal for a possible problem in the wetland. Water sampling and analysis frequency must be included in the treatment system operation and maintenance plan.

— Puddles appearance of on the wetland surface (horizontal) is due to a substrate clogging problem. In order to solve this problem, wetland feeding must be suspended and wetland must be emptied.

— If stems and leaves death is observed outside the winter period and not caused by drought, it may be due to the presence of toxic substances in wastewater.

— In the case of vertical and sludge wetlands, emergence of preferential flow paths should be limited, leading to emergence of flooded and other non-irrigated areas. This is achieved by an even distribution of water over the entire wetland surface during feeding

— In the case of vertical wetlands, feeding periods of 3.5 days and resting periods of 3.5 days are recommended, in around 5-10-minute pulses (each particular case may be different in terms of pulse frequency and duration) every 3-4 hours. Solenoid valves are used for this purpose.

— Consideration should be given to recirculating water possibility from the horizontal wetland in the case of possible problems with twater quality arising from the treatment process or in periods of drought without sufficient water input to system.

— HUSB reactor will be fed in 4 daily pulses lasting from 6 to 15 min, depending on the organic load of the incoming wastewater.

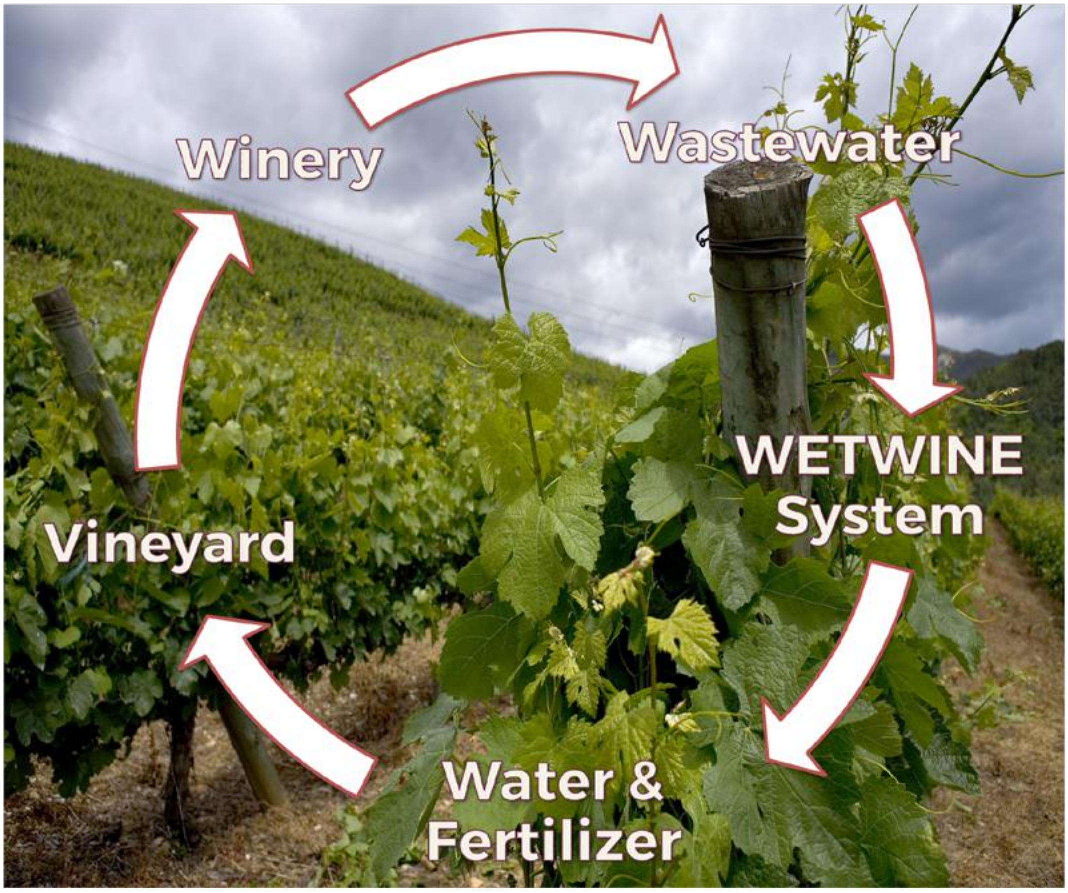
— An accumulation and homogenization tank will be provided for the correct feeding of the sludge into the corresponding wetland.

— Sludge tank will be fed once a week with sludge from the HUSB digester.

— Once sludge tank has reached a set capacity, corresponding subcell of the sludge wetland will be fed. Feeding periods of 1 to 3 days and rest periods of 9 to 13 days will be established for each of the sludge wetland subcells.

—Fertilizer volume (mineralised and dehydrated sludge) produced by sludge wetlands varies greatly and depends on the total solid load of wetland sludge feeding. A production of 20 kg of fertilizer (expressed in TS) per m_2 of sludge wetland per year has however been calculated.

— The solenoid valves that will determine the wetland feeding periods will be monitored for greater precision in opening and closing times, being installed in prefabricated concrete chambers with drainage systems to avoid condensation problems.



7

ENVIRONMENTAL IMPACT OF THE WETWINE SYSTEM

Impact environnemental du système WETWINE

The WETWINE project is also working on **the environmental impact assessment of constructed wetlands** as a wine effluent management system.

To this end, a detailed analysis of various conventional effluent management technologies in several wineries in the Sudoe territory has been carried out, which compares their environmental impact with respect to the WETWINE system.

Life cycle analysis (LCA) methodology was used for this study, which identifies and quantifies both the use of raw materials and energy, as well as emissions released to the environment, and analyses the potential environmental impacts of each technology.

LCA is an important and interesting tool for decision making and allows environmental impact reduction strategies to be put into practice in order to improve the sustainability of production activities.

The following impact categories (environmental indicators) chosen for the LCA study are:

- Climate change
- Ozone depletion
- Soil acidification
- Freshwater eutrophication
- Marine eutrophication
- Formation of photochemical oxidants
- Formation of particulate matter
- Depletion of mineral resources
- Depletion of fossil fuels

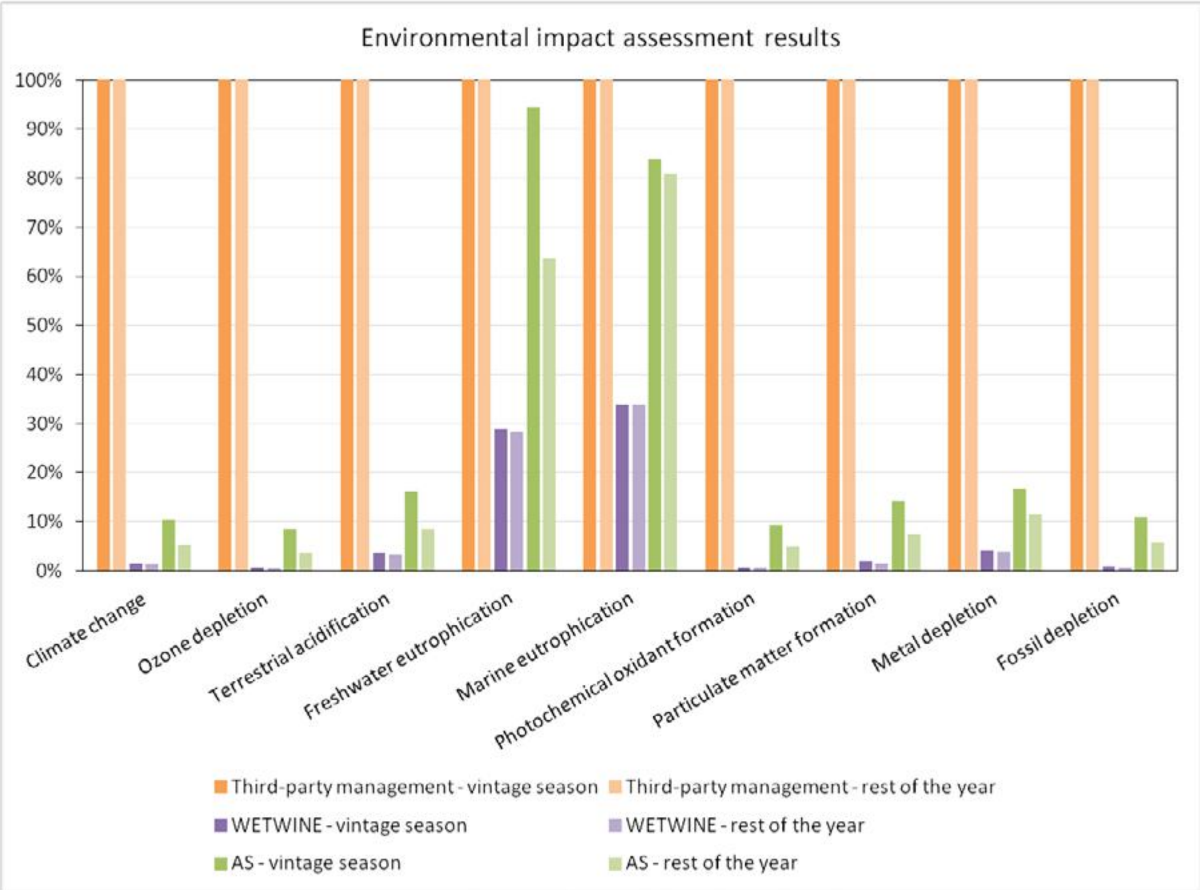
As an example, we present the **LCA results of three Galician wineries with three different effluent management scenarios studied** within the context of the WETWINE project environment. The following **three scenarios were analysed**:

- **Third-party management:** the wastewater is accumulated in a homogenising tank and is transported and treated by an authorised external manager.

- **WETWINE system:** treatment of effluents by means of an anaerobic reactor combined with wetlands for the treatment of water and sludge, with discharge of treated water into the aquatic ecosystem and reuse of treated and stabilised sludge as a fertiliser.

— **Activated sludge:** treatment of effluents by means of an activated sludge system (aerated reactor followed by a secondary clarifier) with discharge of the resulting water into the sewage system, where it will be also treated by a municipal treatment plant. The sludge is centrifuged and managed by third parties.

The following chart shows the results of the environmental impact assessment of these three scenarios during the harvest period and during the rest of the year:



In the chart it can be seen that the **WETWINE system is the best solution environmentally** in all the impact categories analysed.

In the case of third-party management, the high environmental impact is mainly due to wastewater transport and its treatment in a conventional treatment plant.

In the case of activated sludge, high impact is due to high chemicals consumption, additional treatment in a municipal treatment plant and third-party sludge management.

To conclude, it can be said that the **WETWINE system makes it possible to improve sustainability and reduce environment pressure derived from wine-industry effluents management**, due to the fact that this system limits transport, energy and reagents consumption during treatment, and avoids dangerous discharges emissions into environment, while at the same time recovering some by-products obtained from the process, such as sludge for use as fertilizer.

In addition to the environmental indicators mentioned above, other environmental points to be noted about the constructed wetlands:

— Visual, landscape and environmental integration, replacing facilities and buildings with green spaces.

— Low or no energy consumption, because water is treated through natural processes.

— Decreased odours. In subsurface flow wetlands, water is not in contact with the atmosphere, drastically reducing odours generation and mosquitoes appearance.

— Additives or chemicals incorporation in treatment process is not necessary under normal conditions.

— Possibility of using sludge as a fertilizer and reusing water for irrigation, promoting a circular economy.

Within the framework of the WETWINE project, **a calculation tool has been developed that allows the environmental impact of the WETWINE system in the specific case of each winery to be evaluated quickly and simply.**

You can try it out it by accessing the calculation tool on the WETWINE website: [**www.wetwine.eu**]

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