UNIVERSITAT ROVIRA i VIRGILI

Facultat de Química Tarragona

Depuration process and monitoring assays of the Tarragona Wastewater Treatment Plant

Mia Climent Cerdà

Academic tutor: Carme Aguilar
Professional tutors: Francisco Oliva, Javier Recio

June 2024

AKNOWLEDGMENTS

First and foremost, I would like to extend my deepest gratitude to my academic tutor, Came Aguilar, for guiding me through my final year of the degree. Her unwavering support, insightful feedback, and numerous corrections have been invaluable in completing my bachelor's thesis.

I would also like to express my sincere thanks to Javier Recio, Francisco Oliva and the rest of the depuration team at Tarragona Wastewater Treatment Plant. Their acceptance of me as one of their own and their willingness to share their extensive knowledge and experience have significantly enriched my learning experience.

A special thanks goes to Yolanda Cesteros and the other DUAL mention organizers. The DUAL program has provided me with an exceptional opportunity that has been both enjoyable and incredibly beneficial. I am grateful for the chance to participate.

I am also immensely thankful for my classmates Mar, Sandra, Paula and Andrea, who have been a constant source of support inside and outside the classroom. Their encouragement and camaraderie have made this journey more manageable and enjoyable.

Lastly, I owe a heartfelt thank you to my family for their unwavering support and for keeping my and their spirits high at some turning points. I owe them a special meal to make it for my second/third-chance tuition fees.

Thank you all for being a part of this journey.

INDEX

1. Abstract

In this bachelor's thesis, a study is conducted on the various parameters analyzed at the Tarragona Wastewater Treatment Plant from September 2023 to April 2024.

First, the operation of a wastewater treatment plant is explained, highlighting the necessity of having a monitoring and control program for the treatment process, in compliance with the current legislation.

Secondly, the function of the new ammonia probe installed in the biological reactor is explained, along with a summary of the theoretical foundations of the nitrification and denitrification processes.

Next, the methods and frequency of plant sampling are described, along with the analyses performed on each sample. Following this, the results obtained from the tests are presented. The treatment efficiencies, over 90%, are compared with the average catalan data and the fulfilled requirements from the discharge permit are discussed, demonstrating Tarragona WWTP operates correctly and explaining the necessity of each analysis and the information they provide.

Finally, the thesis concludes by discussing whether the proposed objectives have been achieved.

En aquest treball de fi de grau es realitza un estudi dels diferents paràmetres analitzats en l'Estació Depuradora d'Aigües Residuals de Tarragona des del setembre de 2023 fins a l'abril del 2024.

Primerament, s'explica el funcionament d'una depuradora i s'exposa la necessitat de tenir un programa de vigilància i control del procés de depuració, seguint la legislació actual.

En segon lloc, s'explica la funció que tindrà la nova sonda d'amoni instal·lada al reactor biològic i un breu resum dels fonaments teòrics dels processos de nitrificació i desnitrificació.

A continuació, es descriu com i amb quina freqüència es fa el mostreig de planta i quines anàlisis es realitzen a cada mostra. Seguidament, s'exposen els resultats. Es discuteix l'eficiència dels tractaments, que està per sobre del 90%, comparant-la amb la mitjana de rendiment catalana i el compliment dels requeriments del permís d'abocament, demostrant que l'EDAR Tarragona funciona correctament i explicant la necessitat de dur a terme cada anàlisi i quina informació ens aporten.

Finalment, el treball es conclou explicant si s'han complert els objectius platejats inicialment.

2. Introduction

Water is an essential resource for human life, available only in certain locations and in varying amounts. Furthermore, water is involved in numerous industrial activities. Unlike many natural resources, fresh water renews continuously through the hydrological cycle. If water is used at a rate lower than its natural renewal rate, reserves should theoretically remain stable. Historically, this has led humanity the false sense that water is inexhaustible, resulting in its abuse and thoughtless use.

Over the past decades, humanity has begun to perceive the first signs that this resource is being dangerously overused. This overuse manifests in both quantitative issues (such as scarcity and restrictions in some areas and populations) and qualitative issues (including pollution from untreated agricultural, industrial, and domestic wastewater discharges threatening natural water bodies). Protecting water against contamination is a crucial issue in the hydraulic economy, with wastewater treatment being one of the most effective measures.

In Catalonia (Spain), regulations such as Royal Decree 849/1986 and Resolution MAH/285/2007 have been implemented to ensure efficient water use and treatment.[1,2] Given the importance of wastewater treatment, it is essential to understand how these processes operate in practice. This study focuses on the Tarragona Wastewater Treatment Plant (WWTP), managed by Ematsa and located within the harbor area. Ematsa is the municipal water company of Tarragona and it is responsible for managing the water supply services in that area. All my experimental work was conducted at Ematsa facilities, specifically in the WWTP, which provided the necessary tools and expertise for conducting monitoring assays. This internship allowed for in-depth analysis of the functioning and control of a WWTP.

2.1. Operation of the depuration process

Domestic wastewater flows into the sewage system, which collects both wastewater and rainwater from Tarragona, as well as industrial wastewater from the Francolí and Riuclar industrial areas, channeling it to the Tarragona WWTP. Water is pumped to the treatment plant using two main pumping stations: Francolí and Entrevies. These stations receive water from another five smaller stations that are part of the system: Canonja, Miracle, Carrer Barcelona, Serrallo, and Bonavista. Francolí and Entrevies stations are equipped with preliminary screening to remove large solids.

Currently, the plant receives an average wastewater flow of 24,000 m^3/day, although its maximum design capacity is 35,000 m^3/day, which is equivalent to approximately 175,000 residents. The treatment process of the WWTP is divided into two main lines: the water line and the sludge line. The water line consists of a pretreatment, a primary treatment and a secondary treatment, whereas the sludge line involves thickening, digestion and dehydration of the sludge. [3]

The following figure provides a diagram of the depuration process followed at the Tarragona WWTP, illustrating both the water and sludge line components.

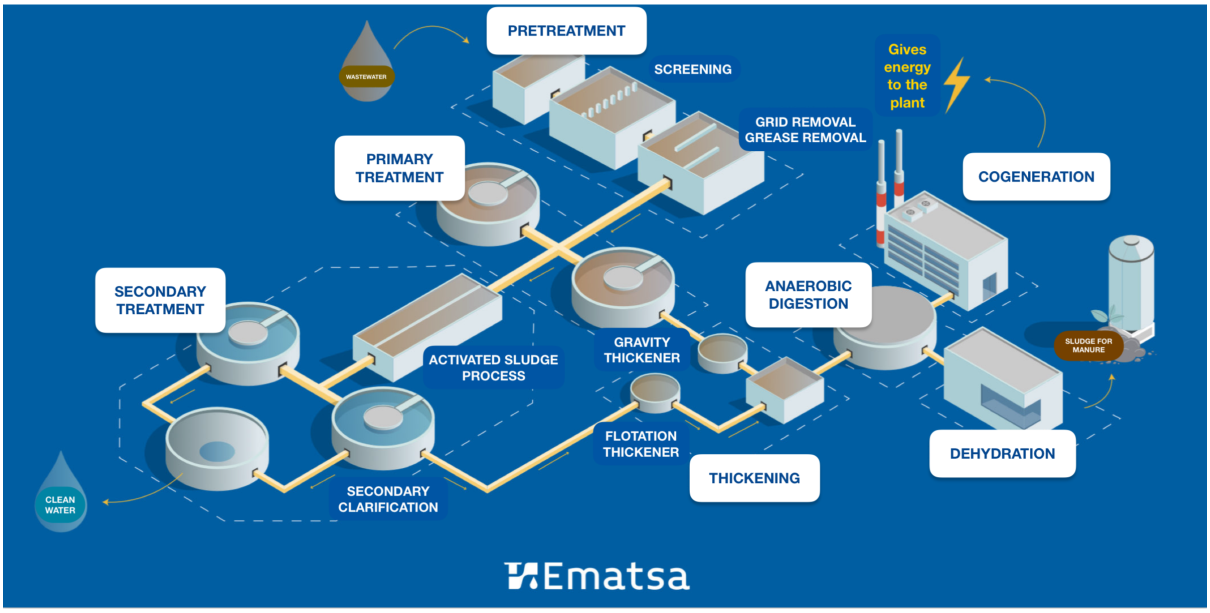


Figure 1. Tarragona's WWTP diagram showing the different stages of the depuration process.

The following subsections describe in more detail the different stages involved in each line.

2.1.1. Water Line

The water line starts with pretreatment, involving bar screening to remove large solids. There are three screening channels, each comprising two different screening sections (5 mm and 3 mm openings). The screens are cleaned by an automatic rake, which drags the solids onto a conveyor belt, depositing the waste into a container.

Subsequently, the wastewater enters the grit and grease removal unit, which is composed of two sections. In the grit section, sand settles at the bottom and is removed by a suction pump. The wastewater then passes through an aeration channel, facilitating the rise of grease and oil to the surface, and both are removed by a rubber brush.

Successively, the wastewater flows to the primary treatment stage, where the colloidal matter settles at the bottom of the tank. These solids are extracted from the bottom via pumps and directed to the sludge treatment line.

The clarified water flows to the secondary treatment, where activated sludge biodegrades organic matter. Water, after being in contact with the activated sludge for a determined hydraulic retention time, is transferred to the secondary clarifier, where the treated water is separated from the biomass by gravity. The settled sludge is extracted by a pump into a distribution chamber. Some activated sludge is recirculated back to the aeration tank to maintain a stable community of microorganisms essential for the biological process. The excess activated sludge is sent to a gravity-thickening tank for further treatment.

2.1.2. Sludge Line

Primary sludge and secondary sludge are processed through the WWTP sludge line to convert them into dehydrated sludge, which can subsequently be reused. The sludge treatment line consists of three main stages: thickening, digestion, and dehydration.

In the thickening phase the water content is reduced. There are two distinct types of thickeners: the gravity-thickener for primary sludge and the dissolved-air flotation thickener for secondary sludge. The gravity thickener operates based on the density difference between the solids and the water. Heavier solids settle to the bottom, forming a layer of sludge that is removed with a suction pump, while the clarified water from the top is returned to the plant's inlet for further processing.

Conversely, the dissolved-air flotation thickener pumps air into the water from the bottom of the thickener. This causes the lighter solids and fats present in the wastewater to adhere to the air bubbles and rise to the surface. The sludge is then removed with a scraper, while the clarified water is returned to the plant's inlet for additional treatment.

The next stage is an anaerobic digestion, in which the organic matter in the sludge undergoes processes such as: liquefaction, gasification, and mineralization, resulting in an inert final product and the release of gases. The biogas generated during the anaerobic digestion of the sludge is stored in a gasholder. This gas has a high calorific value, due to its methane content, and is thus used to produce thermal energy (via boilers to heat the digester) and electrical energy (via the cogeneration plant to reduce costs).

Finally, the dehydration process, carried out through centrifugation, involves removing the water contained in the thickened and digested sludge to achieve a high dryness percentage. This process facilitates the removal and reuse of the sludge, while the clarified water is returned to the plant's inlet.

The aforementioned process enables the Tarragona WWTP to obtain an effluent water that complies with legal requirements, achieving with outstanding treatment efficiency.

2.2. Control and monitoring programs

Effective WWTPs operation is crucial to ensure that the treated effluent meets the legal and the environmental standarts. In Spain, Article 7 of the current Order of July 13, 1993, mandates that each discharge of wastewater into the sea, must include a Surveillance and Control Program (SCP).[2,4]

2.2.1 Surveillance and Control Program (SCP)

The SCP addresses two complementary aspects:

1. Structural quality of the pipeline. Ensuring that the discharge infrastructures remain in optimal condition and function correctly is essential. This is achieved through regular inspection and maintenance, durability assessments (verifying that construction materials can withstand long-term conditions), structural integrity monitoring (detecting problems before they become critical), corrosion control, and upgrading or renewing the pipelines when necessary.
2. Environmental monitoring. This includes monitoring both the discharged effluent and the receiving waters to prevent any adverse environmental impacts. The frequency of sampling, as well as the type and number of parameters to be analyzed, depend on the nature and significance of the discharge.[2,4]

Tarragona's WWTP is directly responsible for its discharged effluent. In the SCP of the discharged effluent, the monitored parameters include:

- **Biological Oxygen Demand (BOD):** quantifies the dissolved oxygen required by microorganisms for the aerobic oxidation of biodegradable organic matter present in water during a 5-day incubation period.
- **Chemical Oxygen Demand (COD):** quantifies the oxygen required to completely oxidize the organic and inorganic matter present in a known volume of sample.
- **Suspended Matter:** determines the total solids of mineral, vegetal, and animal origin present in the sample.
- **pH:** measures the concentration of hydrogen ions present in the water and is expressed in pH units.
- **Flow rate**

For areas at risk of eutrophication, the SCP of the discharged effluent may also include the determination of:

- **Kjeldahl nitrogen:** measures the total nitrogen concentration in the form of organic nitrogen and ammonium.
- **Oxidized nitrogen:** measures the total nitrogen concentration in the form of nitrate (NO_3^-) and nitrite (NO_2^-).
- **Total phosphorus:** measures the total phosphorus concentration.

2.2.1.1. Monitoring frequency, reporting and discharge permit

The frequency and the reporting requirements for the SCP are crucial for ensuring compliance with environmental regulations and for monitoring the efficiency of wastewater treatment processes. The mandatory monitoring frequency of the discharged effluent depends on the discharge type. Tarragona's WWTP discharge is classified as type III[4]: sewage pipes serving urban agglomerations that represent more than 50,000 population equivalents. The minimum annual number of analyses for a type III discharge is eighteen simplified analyses and six complete analyses, with sampling carried out at regular intervals throughout the year. The results of these SCPs must be compiled in an annual report that the discharge owner must submit to the Administration.[4] Although there are only twenty-four mandatory analyses per year that must be submitted to the Administration, Tarragona's WWTP conducts daily analyses to ensure the proper functioning and early detection of anomalies.

Each WWTP has its discharge permit, depending on the influent water, the amount of the treated water per day, and the receiving waters. Tarragona WWTP permit is in force until 2027/06/02 and states that the effluent water must have a BOD_5 equal to or lower than 25 ppm, a COD equal to or lower than 125 ppm, a SS equal to or lower than 35 ppm. In addition, the maximum amount of treated water that can be discharged per day is 35,000 m^3.

2.2.1.2. Technological advances

Tarragona's WWTP receiving environment is not considered an eutrophication risk area, so it isn't mandatory to include the Kjeldahl nitrogen, oxidized nitrogen, and total phosphorus in the Surveillance and Control Program. However, regulations become stricter over time, and it is suspected that in the following years the determination and reduction of the total nitrogen and total phosphorus will become mandatory. In this sense, and to stay ahead of regulatory requirements, Ematsa has implemented advanced monitoring technologies, including an ammonium probe in the aeration tank. This probe continuously measures pH, temperature, and nitrate, potassium and ammonium concentrations. The primary function of this probe is to quantify ammonium reduction occurring in the aeration tank and to optimize the cessation of air blowers in summer, through the denitrification process, thereby reducing the electrical costs of the plant and avoiding uncontrolled denitrification in the clarifier. The following section provides a theoretical background of the nitrification and denitrification processes, for a better understanding of the intended use of this ammonium probe.

2.3. Nitrification and denitrification processes

Nitrogen removal from wastewater can be accomplished through a variety of alternative processes. The most popular approach is by a biological nitrification-denitrification, which has the additional advantage of returning nitrogen to the atmosphere in its natural form. During the nitrification phase ammonia (NH_4^+) is oxidized to nitrate (NO_3^-) in presence of oxygen through a two-step oxidation process by specialized nitrifying bacteria. The first step is carried out by bacteria known as *Nitrosomas*. These bacteria oxidize NH_4^+ to nitrite (NO_2^-). The chemical reaction can be represented as follows:

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad (1)$$

This reaction produces H^+ ions which have an important role on pH and can contribute to a decrease on this magnitude and for that is an important parameter to monitor during nitrification.

The second step is carried out by bacteria known as *Nitrobacter*. These bacteria oxidize nitrite (NO_2^-) to nitrate (NO_3^-). The chemical reaction can be represented as follows:

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad (2)$$

The total reaction is as follows:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \quad (3)$$

The denitrification is the subsequent process that removes nitrate (NO_3^-) from wastewater, converting it to nitrogen gas (N_2), which is released to atmosphere. This process is anaerobic, so it occurs with the absence of oxygen as is facilitated by heterotrophic bacteria that utilize nitrate as an electron acceptor in the degradation of organic matter. It involves the reduction of nitrate to nitrite to nitric oxide to nitrous oxide to nitrogen gas, as shown in the chemical reaction below:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO + N_2O \rightarrow N_2 \quad (4)$$

The total reaction is as follows:

$$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O \quad (5)$$

The combined nitrification-denitrification process remove nitrogen from wastewater.

3. Objectives

The aim of this bachelor's thesis is to comprehensively understand the operation of the Tarragona WWTP and conduct the required control analyses to ensure regulatory compliance according to the discharge permit. Additionally, the thesis aims to compile and analyze data from the newly installed ammonium probe, focusing on quantifying ammonium in the aeration tank and the parameters affecting nitrification and denitrification processes.

4. Experimental part

In the following subsections the reagents used, the plant sampling schedule and the procedure followed for each analysis are detailed.

4.1. Reagents and equipment used

In this section, the reagents, kits, and equipment used to perform the different analyses during the Bachelor's Thesis are classified in different tables, including detailed information for each one.

The following table contains all the reagents used to perform the analyses, the analyses in which each reagent is used, the brand and safety information.

Table 1. Reagents used to perform the analyses.

REAGENTS	ASSAY IN WHICH IS USED	BRAND	HAZARDS	PERSONAL PROTECTION MEASURES
Buffer solution pH 6,88 (pH standard)	pH daily verification	VMW Chemicals (Barcelona, Spain)	Non Hazardous	safety googles, lab coat, suitable gloves
COD Standard Solution 100ppm (COD standard)	COD weekly verification	Merck (Darmstadt, Germany)	Non Hazardous	safety googles
Conductivity Standard 1413 µS/cm @25ºC (conductivity standard)	Conductivity weekly verification	VMW Chemicals (Barcelona, Spain)	Non Hazardous	safety googles, lab coat, suitable gloves
BOD Standard Solution Ampule for Manometric Method 3000ppm Glucose; 3000ppm Glutamic Acid (BOD_5 blank)	BOD_5 weekly blank solution	Hach (Düsseldorf, Germany)	Non Hazardous	safety googles, lab coat, suitable gloves
Microcrystalline Cellulose (suspend solids standard)	Suspend solids monthly verification	Merck (Darmstadt, Germany)	Non Hazardous	safety googles, lab coat, suitable gloves
BOD Nutrient Buffer Pillows (BOD_5 standard)	BOD_5 monthly verification	Hach (Düsseldorf, Germany)	Non Hazardous	safety googles, lab coat, suitable gloves
Nitrification inhibitor (N-Allythiourea)	BOD_5 assay	EMATSA (prepared solution)	Non Hazardous	safety googles, lab coat, suitable gloves
Sodium Hydroxide pelletes >98% purity	BOD_5 assay	Merck (Darmstadt, Germany)		safety googles, lab coat, suitable gloves
Sodium Hydroxide 0,1M volumetric solution	Digestor's ratio determination assay	Panreac (Barcelona, Spain)	Non Hazardous	safety googles, lab coat, suitable gloves
Sulphuric acid 0,05M in aqueous solution	Digestor's ratio determination assay	VMW Chemicals (Barcelona, Spain)	Non Hazardous	safety googles, lab coat, suitable gloves

The following table contains all the kits used in some of the plant monitoring analyses performed during this bachelor's thesis.

Table 2. Kits used to perform the analyses

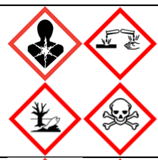
KITS	KIT'S CONTENT	ASSAY IN WHICH IS USED	BRAND	HAZARDS	PERSONAL PROTECTION MEASURES
COD Cell Test 10-150ppm	sulfuric solution of potassium dichromate, silver sulfate (catalyst)	COD effluent water assay	Merck (Darmstadt, Germany)		safety googles, lab coat, suitable gloves
COD Cell Test 25-1500ppm	sulfuric solution of potassium dichromate, silver sulfate (catalyst)	COD influent water assay	Merck (Darmstadt, Germany)		safety googles, lab coat, suitable gloves
Ammonium Cell Test 4,0-80,0ppm NH_4-N	alkaline solution, NH4-1K (solutions that contains Sodium Nitroprusside troclosene sodium, dihydrate)	ammonium determination assay	Merck (Darmstadt, Germany)		safety googles, lab coat, suitable gloves

Table 3 contains all the equipment used to perform the different plant monitoring analyses carried out.

Table 3. Equipment used.

EQUIPMENT	BRAND
Analytical balance PIONEER	OHaus (Parsippany, New Jersey, USA)
Microscope DM2500	Leica (Wetzlar, Germany)
Centrifuge CENTRONIC BLT	JP Selecta (Barcelona, Spain)
Stove CONTERM	JP Selecta (Barcelona, Catalonia, Spain)
Heating stirrer	LLG Labware (Meckenheim, Germany)
Thermoreactor	Macherey-Nagel (Düren, Germany)
Desiccator	OHaus (Parsippany, New Jersey, USA)
Muffle Furnace	Hobersal (Barcelona, Spain)
pH meter 80 PRO	XS Instruments (Milan, Italy)
pH electrode	Hamilton (Reno, Nevada, USA)
Spectophotometer Prove 100	Merck (Darmstadt, Germany)
Conductimeter	Thermo Fisher (Waltham, Massachusetts, USA)
OxiTop BOD_5 heads	WTW (Weilheim, Germany)
Vacuum filtration equipment	-

4.2. Sampling of the plant

Sampling of both water and sludge lines is performed weekly. Basic monitoring control is conducted midweek. The sample schedule in Ematsa WWTP is as follows:

Table 4. Distribution of weekly analyses performed.

Monday	Tuesday	Wednesday	Thursday	Friday
Water line	Sludge line	Basic monitoring	Water line	Sludge line

The following tables (5,6 and 7) contain the information related to the samples taken for each line, in particular Table 5 shows the samples taken for the water line, Table 6 shows the samples taken for the sludge line and Table 7 show the samples taken for basic monitoring.

Table 5. Samples taken for water line monitoring.

SAMPLE CODE	DESCRIPTION	SAMPLING SPOT
IAE	internal inlet water	Grit and grease removal bridge's exit
IAD	internal settled water	Primary clarifier's exit
IAS	internal water outlet	Secondary clarifier's exit
IRB A, IRB B	internal biological reactors A and B	Aeration tank
IFS	internal secondary sludge	Distribution chamber
IDF	internal fresh digester	Mixing chamber (where gravity and flotation sludge are mixed)
IDR	internal recirculated digester	Digester
IDD	internal digested digester	Digester's exit
IFD	internal dehydrated sludge	Centrifuge

Table 6. Samples taken for sludge line monitoring.

SAMPLE CODE	DESCRIPTION	SAMPLING SPOT
IFP A, IFP B	internal primary sludge A and B	Primary clarifier
IFG	internal gravity sludge	Gravity thickener
IEG	internal gravity runoff	Gravity thickener's exit
IRB A, IRB B	internal biological reactors A and B	Aeration tank
IFF	internal flotation sludge	Flotation thickener
IEF	internal flotation runoff	Flotation thickener's exit
IDF	internal fresh digester	Mixing chamber (where gravity and flotation sludge are mixed)
IFC	internal centrifuge sludge	Centrifuge's entrance
IFD	internal dehydrated sludge	Centrifuge
IEA or IEB	internal runoff A or B	Centrifuge's exit

Table 7. Samples taken for basic monitoring.

SAMPLE CODE	DESCRIPTION	SAMPLING SPOT
IRB A, IRB B	internal biological reactors A and B	Aeration tank
IDF	internal fresh digester	Mixing chamber (where gravity and flotation sludge are mixed)
IFD	internal dehydrated sludge	Centrifuge

All samples are collected punctually, except for IAE and IAS (which correspond to the inlet and outlet water, respectively). For these a composite sample is taken using an automated sampler which collects one liter of water every hour over 24-hour period. The necessary milliliters of each sample are calculated based on the water flow rate each hour to produce a representative one-liter solution.

4.3. Monitoring analyses performed

This section details the different procedures followed to measure the different parameters and the samples used for each analysis.

4.3.1. Suspended Matter (SS)

This analysis quantifies the total suspended solids present for all the aqueous samples: including runoff, activated sludge, secondary sludge, influent water, post-decantation water, and effluent water. In brief, the followed procedure consists on:

1. Remove a clean Petri dish with a filter from the "clean material" stove and let it cool in a desiccator.
2. Weight the clean Petri dish on the analytical balance.
3. With a graduated cylinder, measure 10 to 25mL of the aqueous sample and filter using the filtration equipment.
4. Leave the Petri dish in the stove for twenty-four hours.
5. Weight the Petri dish on the analytical balance after cooling in the desiccator.
6. Subtract the clean dish weight from the final weight and divide by the volume.
7. Convert the units to mg/L.

4.3.2. Volatile Suspended Solids (VSS)

Volatile suspended solids are determined exclusively in the activated sludge to quantify the biomass present. The VSS determination follows the SS procedure, using a crucible instead of a Petri dish, to withstand the 550°C temperature required.

After determining the suspended solids, the following procedure is done.

1. Introduce the crucible containing the filter paper in the muffle furnace and heat it at 550°C for fifteen minutes.
2. After calcination, weight the crucible on the analytical balance after cooling in the desiccator.
3. Subtract the initial clean crucible weight from the calcinated weight and divide by the volume of the filtered sample.
4. Convert the result to mg/L and subtract the previously calculated suspended matter.

4.3.3. Macroscopic and microscopic analysis

Macroscopic and microscopic analysis are performed on the activated sludge to understand and predict its behavior. The macroscopic assay consists in performing a column settling test whereas the microscopic assay consists in observing the sludge under the microscope. In the next subsections a brief explanation on how each assay is performed is detailed.

4.3.3.1. Column settling test (V30)

1. Add 500mL of activated sludge sample to a 1L graduated cylinder.
2. Rinse it to the 1L mark with water.
3. After 30 minutes of decantation, multiply the sludge volume by two to obtain the V30 result. It is expressed in mL.

The following figure shows a prepared column settling test:

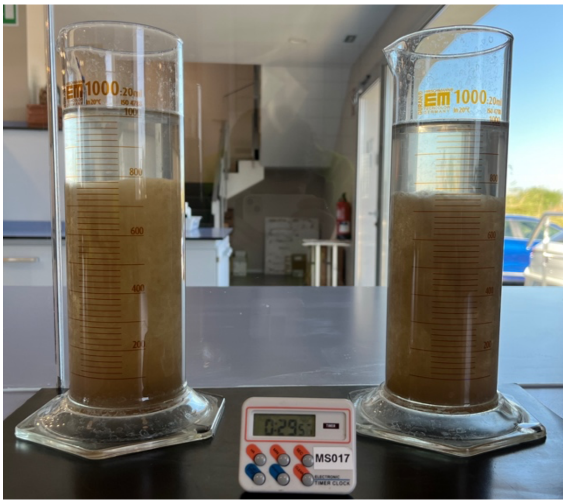


Figure 2. Column settling test.

4.3.3.2. Microscopic analyses

The observation of activated sludge under the microscope is performed to examine the flocs formation and structure.

As an example, the following figure shows flocs of an activated sludge sample using a x5 magnification.

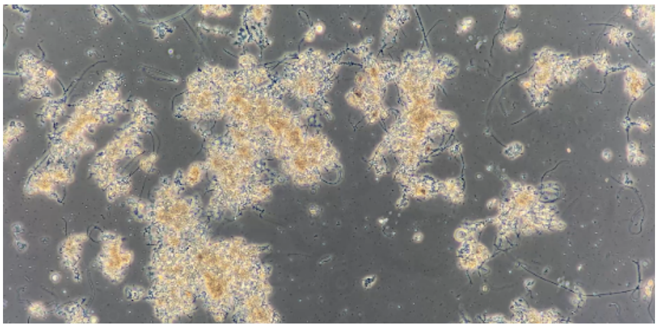


Figure 3. Activated sludge sample at a x5 maginfication.

4.3.4. Biochemical Oxygen Demand in Five Days (BOD_5)

This analysis quantifies the amount of biodegradable matter and is carried out for influent, post-decantation and effluent water samples in the water line. The followed procedure consists in:

1. Measure specified volumes for influent, post-decantation and effluent water samples using overflow measuring flasks.
2. Add the measured volume to a BOD bottle with a magnetic stirring rod.
3. Add three drops of the nitrification inhibitor to the BOD bottle.
4. Place a bung on top and add one sodium hydroxide pellet.
5. Close the bottle with the OxiTop head and turn it on.
6. Incubate the bottle for five days.

The following figure shows a BOD bottle for BOD_5 analysis

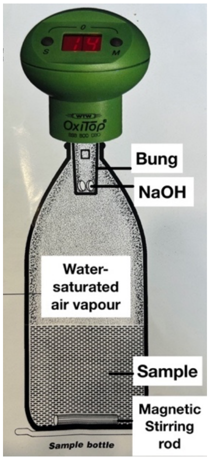


Figure 4. Prepared BOD bottle for BOD_5 analysis.

4.3.5. Chemical Oxygen Demand (COD)

This analysis quantifies the amount of inorganic and inorganic matter present and is carried out for of influent, post-decantation, and effluent water samples in the water line.

1. Suspend the bottom sediment in the reaction cell by swirling.
2. Measure 3 mL of the sample using a micropipette.
3. Add the measured volume into the reaction cell.
4. Tightly attach the screw cap to the cell and vigorously mix the contents.
5. Heat the cell at 148°C in the preheated thermoreactor for 120 minutes.
6. Remove the hot cell from the thermoreactor and allow it to cool down in a test-tube rack.
7. Perform the photometric measurement at 600nm. At this wavelength, the molar absorptivity (ε) is at its maximum for Cr^{3+} ions.

4.3.6. Conductivity and pH

Conductivity and pH are determined to detect abrupt changes that would destabilize the biomass present in the aeration tank and digestor. Conductivity is measured for influent water, to monitor its characteristics before entering the plant and pH is measured in several sample points, in particular for influent, post-decantation and effluent water samples, as well as IDF, IDR, and IDD sludge samples.

4.3.7. Digestor Ratio Determination

The digestor ratio determination is performed to obtain the alkalinity and total volatile acids ratio in the digestor, using the recirculated digestor sample. Briefly, the procedure consists of the following steps:

1. Perform three centrifugations with 25mL of the recirculated digestor sample
2. Measure the initial pH of the liquid.
3. Adjust the pH to 4 using 0.05M sulfuric acid.
4. Heat and stir the solution to 100°C and boil for five minutes.
5. Cool the solution.
6. Adjust to pH 7 using 0.1M sodium hydroxide.
7. Calculate the total alkalinity using the volume of acid needed to reach pH 4.
8. Calculate the total volatile fatty acids using the volume of base needed to reach pH 7.
9. Divide the total volatile fatty acids by the total alkalinity to obtain the ratio.

4.3.8. Dry Matter (DM) and Volatile Dry Matter (%VDM)

This analysis is performed to quantify the matter and volatile matter present in sludge samples. Briefly, the procedure to quantify DM consists of the following steps:

1. Remove a crucible from the stove and let it cool in a desiccator.
2. Weight the clean crucible on the analytical balance.
3. Add the sludge sample into the crucible.
4. Weight the crucible with the sample on the analytical balance.
5. Dehydrate in the stove for 24 hours.
6. The following day, weigh the crucible on the analytical balance after cooling in the desiccator.
7. Subtract the clean crucible weight from weights before and after dehydration.
8. Calculate %DM.

Volatile dry matter is determined for all sludge samples except for IFS and IFP. The following steps are performed after calculating %DM:

Introduce the crucible in the muffle furnace and calcine at 550°C for fifteen minutes.

1. Weight the crucible on the analytical balance after cooling in the desiccator.
2. Subtract the clean crucible weight from both the dehydrated and the calcinated weights.
3. Calculate %VDM

5. Results and discussion

This section discusses the results obtained from the monitoring analysis, conducted during my dual mention internship at Ematsa. The focus is on evaluating the performance and efficiency of the Tarragona WWTP, based on the different evaluated parameters. Emphasis is also given to the ammonium probe to understand its impact on the treatment process. The discussion provides insights into the operational status of the WWTP of Tarragona.

5.1. Suspended Matter (SS)

The analysis of suspended matter quantifies the total solids of mineral, vegetal and animal origin present in the samples. SS quantification is important to ensure the proper functioning of the plant's machinery, determining the amount of matter loaded into a unit, and ensuring compliance with SS effluent requirements specified in the discharge permit (SS ≤ 35 ppm). It is determined in the following samples:

- Runoffs: SS is determined to ensure the thickeners are working correctly. A high value of SS means that the thickeners are malfunctioning, and sludge is found in the "clarified water". The clarified water is returned to the plant's inlet, meaning sludge is being directly introduced into the plant.

- Post-decantation water: SS is evaluated to assess the primary clarifier efficiency and determine the amount of suspended matter entering the aeration tank.
- Secondary sludge sample: SS quantifies the active biomass in the distribution chamber. Maintaining a stable community of microorganisms in the aeration tank is essential for the biological process, so knowing the concentration of biomass in the distribution chamber is useful to determine the flow rate of the recirculated and excess activated sludge.
- Effluent water: SS ensures compliance with discharge permit requirements.

The table below presents the SS results of Tarragona WWTP for influent and effluent waters along with the treated water per day and the yields, which indicate the efficiency of the treatment process in removing the suspended matter.

Table 8. SS results for the influent and effluent waters and yields between September 2023 and April 2024..

	SS			
	Influent (ppm)	Effluent (ppm)	Yield (%)	Treated water (m^3/day)
September-23	264	21	92	22,691
October-23	276	18	94	24,029
November-23	305	19	92	22,584
December-23	275	22	90	20,343
January-24	302	18	94	22,850
February-24	327	17	95	23,488
March-24	263	16	94	24,217
April-24	316	21	93	22,821

As it can be observed through the reported data, the SS yield at Tarragona WWTP ranges from 90% to 95%, consistently accomplishing the discharge permit requirements. This demonstrates effective elimination of suspended solids. The SS values of influent water vary between 263 and 327 ppm, whereas effluent water ranges from 16 to 22 ppm.

For comparison, the following table (Table 9) contains data compiled by the "Institut Català d'Estadística" up to 2022. It includes the average SS yields and the average m^3 of treated water per day in the 545 catalan WWTPs.[6]

Table 9. Average treated water per day and yields of catalan WWTPs during the period 2019-2022.

	Average treated water (m^3/day)	Average SS Yield (%)
2022	1,673	95.7
2021	1,715	95.8
2020	1,935	95.1
2019	1,785	95.4

The Tarragona WWTP consistently meets the discharge permit requirements, achieving yields of 90% or higher. Although the SS yield at Tarragona WWTP is slightly below the catalan average, it is important to take into account that Tarragona treats approximately 1287% more water per day than an average catalan WWTP. This significant difference in the treated water volume demonstrates the efficiency and capacity of the Tarragona plant despite the slightly lower yield percentage.

5.2. Volatile Suspended Solids (SSV)

The volatile suspended solids analysis is performed in the activated sludge samples to evaluate the active biomass of microorganisms in the aeration tank. The following table presents the biomass values in the aeration tank for each month.

Table 10. Biomass present in the aeration tank between September 2023 and April 2024.

	MLSSV (ppm)
September-23	2666
October-23	2260
November-23	2460
December-23	2573
January-24	2263
February-24	2761
March-24	2479
April-24	1567

The optimal biomass working values are between 2200 and 3500 ppm. This range has been determined through historical records, comparing depuration efficiency and biomass. Each

WWTP has its own optimal biomass values influenced by differences in influent water, which affect the microorganisms' population.

The results from the MLSSV analysis will be further discussed in conjunction with the SVI and BOD_5 results in subsection 5.4.

5.3. Macroscopic and microscopic analysis

In the following subsections, the results obtained from the column settling test and the images taken from the microscopic observations are discussed.

5.3.1. Column settling test (V30)

The macroscopic analyses, determined through V30 testing, are useful for routine monitoring of the biological process. They allow for sludge flocculation and sedimentation, which is useful to predict its potential settling behavior in the secondary clarifier. The V30 test provides a visual estimation of the age and nature of the sludge, and the turbidity of the effluent water from the treatment plant.

The numerical results of the column settling test and the MLSSV of the biological reactor are used to calculate the sludge volume index (SVI). The SVI measures the ability of the sludge to settle and compact, and is defined as the volume in mL occupied by 1 g of activated sludge after settling for 30 min in a 1L graduated cylinder.[5]

The SVI results will be discussed further along with the MLSSV and BOD_5 results in subsection 5.4.

5.3.2. Microscopic analyses

Microscopic analyses involve observing activated sludge flocs under the microscope to evaluated their morphology and detect proliferations of bacteria, which are indicative of changes in influent water, and can cause sedimentation problems.

Activated sludge flocs are conglomerates of living and dead bacterial cells, often including filamentous strains, precipitated salts, trapped inorganic particles (sand) and organic fibers. They are held together by a slime matrix of polymeric compounds surrounding the cells, and by chemical bonding forces, in which divalent cations, such as Ca^{2+} and Mg^{2+}, play an important role. Free-living bacteria, protozoa, and occasionally higher organisms are present around the flocs and in the interflocular water.[7]

There are two structure levels in the activated sludge flocs, the macrostructure, composed of filamentous bacteria acting as a "skeleton", and the microstructure, formed by the aforementioned components, which bind to the macrostructure. Filamentous bacteria in low quantities are necessary to form the flocs. However, an increase in these bacteria causes serious turbidity problems if they are not associated with flocs, and sedimentation problems if they form interflocular bridges. The following figure is a representation of a floc in which the two mentioned structure levels are shown.

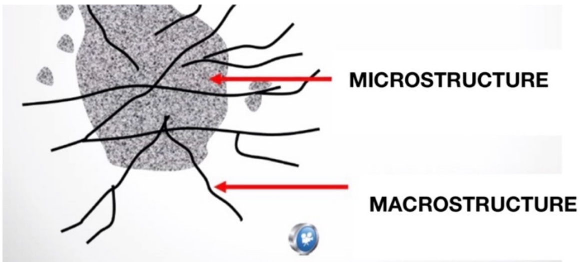


Figure 5. Macrostructure and microstructure representation in a floc.

The morphological characteristics of flocs determine its settleability:

- Shape: Regular flocs result in faster and better sedimentation.
- Structure: Compact flocs, where bacteria are closely stacked, settle faster than open-structured flocs, through which water can flow.
- Size: Compact flocs settle more rapidly if they are larger (>250 µm). Small (<25 µm) flocs are nearly always present.[7]

To illustrate how the flocs vary depending on their morphological characteristics, the following figures (6,7,8 and 9) are shown.[7]

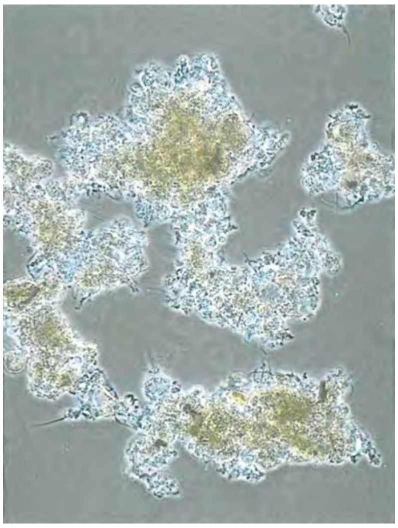


Figure 6. Regular shaped sludge flocs.

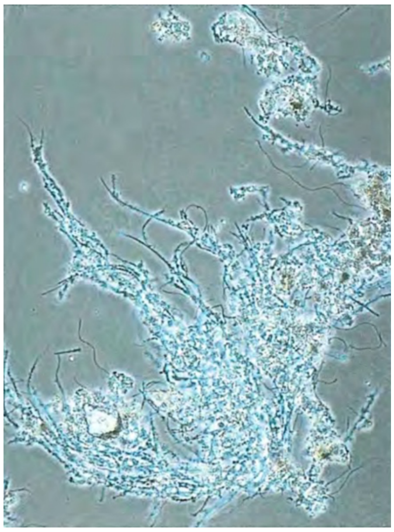


Figure 7. Irregular shaped sludge flocs.

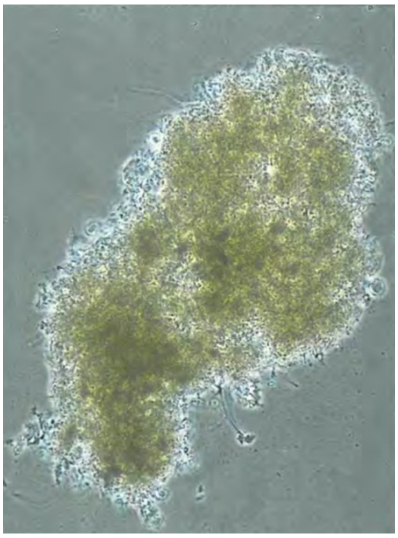


Figure 8. A compact sludge floc.

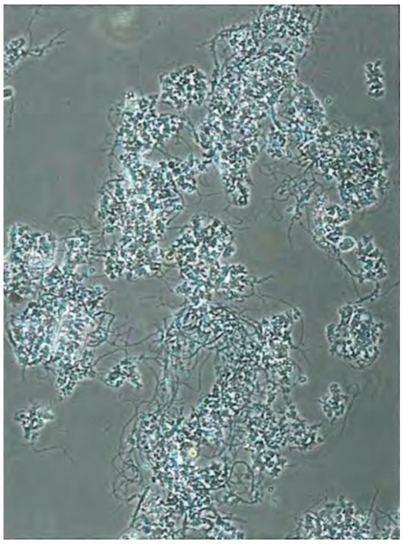


Figure 9. An open sludge floc

From September 2023 until March 2024, the active biomass in the WWTP of Tarragona remained stable, which is an indicator of the stability of the plant. In the following figure (Figure 10), regular and compact flocs can be observed and there is an equilibrium between the microstructure and macrostructure of the flocs.

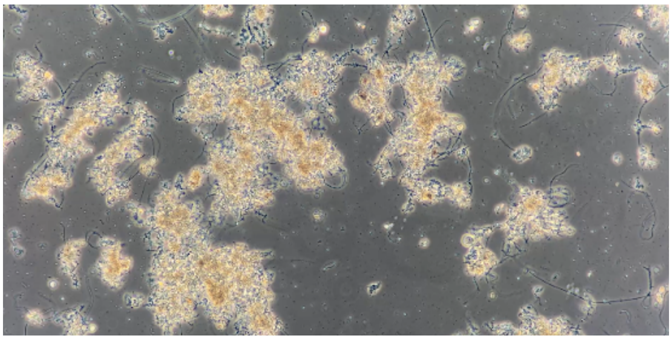


Figure 10. State of the activate sludge from September 2023 until March 2024.

In April 2024 an increase in Type 021N filamentous bacteria occurred as it is shown in Figure 11, where the increase of these type bacteria is evident, forming interflocular bridges, which cause sedimentation problems.

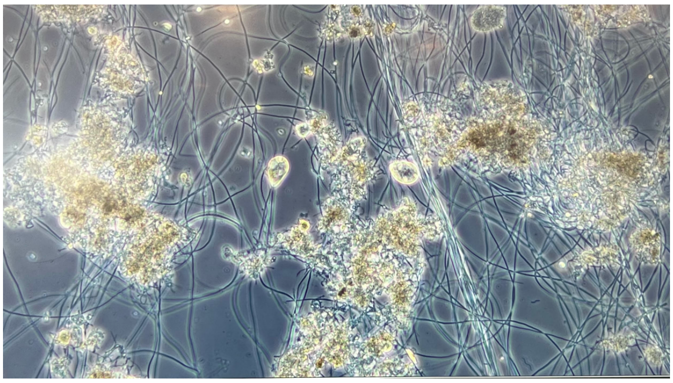


Figure 11. Punctual state of the activated sludge in April 2024.

This change was promptly detected and corrected by the process department, increasing the excess purge flow rate. This corrective action reduced the biomass in the aeration tank and effectively removed the filamentous bacteria excess. Consequently, the biomass levels gradually returned to normal values. The following figure (Figure 12) shows the state of the activated sludge after the corrective measure implemented at the beginning of May 2024.

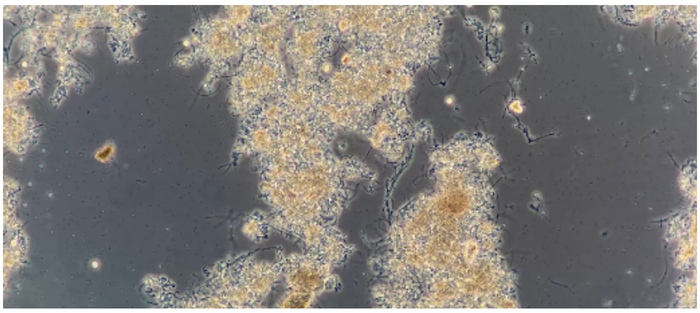


Figure 12. State of the activated sludge in the beginning of May 2024.

5.4. Biochemical Oxygen Demand in Five Days (BOD5)

The main objective of this assay is to determine the mass load into the aeration tank and to ensure compliance with BOD_5 effluent requirements determined in the discharge permit ($BOD_5 \leq 25$ ppm).

BOD_5 measures the amount of dissolved oxygen required by microorganisms for the aerobic oxidation of biodegradable organic matter present in water, during a 5-day incubation period. The determination of the mass load (post-decantation water BOD_5) into the aeration tank is useful to obtain the potential food available for the sludge. This value, expressed in BOD_5 Kg, is used to calculate the CM (food to microorganism ratio) which is obtained dividing the BOD_5 Kg by MLSSV Kg. The CM ratio significantly influences the ability of the sludge to settle and compact, as indicated by the SVI. Either not having enough microorganisms to biodegrade matter or not having enough BOD_5 Kg to feed microorganisms, increases SVI (poorer settleability).[5]

The following table contains the MLSSV, CM and SVI results obtained for each month from all the period in which I have been in Ematsa for my dual internship.

Table 11. MLSSV, CM and SVI results obtained between September 2023 and April 2024.

	MLSSV (ppm)	CM	SVI (mL/g)
September-23	2666	0,32	169
October-23	2260	0,40	204
November-23	2460	0,37	198
December-23	2573	0,35	173
January-24	2263	0,39	237
February-24	2761	0,34	257
March-24	2479	0,40	269
April-24	1567	0,71	473

In the table, the data for MLSSV clearly shows a significant decrease in April 2024. This indicates a reduction in the active microorganisms' population in the aeration tanks, nearly doubling the food to microorganism ratio (CM) from 0.40 to 0.71. This increase in the ratio corresponds to a substantial rise in the SVI, which resulted in a poorer settleability of the sludge (larger SVI). The drop of MLSSV in the aeration tanks was due to an intentional removal of biomass. As mentioned before, there had been a sudden increase in Type 021N filamentous bacteria, which can cause bad compaction of the sludge (bulking). The solution was is to increase the excess sludge flow rates, to remove more biomass and therefore reduce the filamentous bacteria. The biomass levels then increased progressively without the anomalous quantity of filamentous bacteria. The increase of filamentous bacteria can be caused by illegal discharges in the sewer system, which alter the activated sludge.

The determination of BOD_5 in the effluent waters ensures compliance with discharge permit requirements ($BOD_5 \leq 25$ ppm). The table below presents the BOD_5 results of Tarragona WWTP for influent and effluent waters, along with the treated water per day and the yields, which indicate the efficiency of the treatment process in removing Biochemical Oxygen Demand in Five Days.

Table 12. BOD_5 results for the influent and effluent waters and yields between September 2023 and April 2024..

	BOD_5			
	Influent (ppm)	Effluent (ppm)	Yield (%)	Treated water (m^3/day)
September-23	363	12	97	22,691
October-23	368	12	97	24,029
November-23	396	11	97	22,584
December-23	469	10	98	20,343
January-24	483	12	97	22,850
February-24	478	12	97	23,488
March-24	418	18	96	24,217
April-24	453	16	96	22,821

As it can be observed through the reported data, the BOD_5 yield at Tarragona WWTP ranges from 96% to 98%, consistently accomplishing the discharge permit requirements. This demonstrates effective degradation of the organic matter. The BOD_5 values of influent water vary between 363 and 483 ppm, whereas effluent water ranges from 10 to 18 ppm.

For further comparison, Table 13 presents BOD_5 data compiled by the "Institut Català d'Estadística" up to 2022.[6]

Table 13. Average treated water per day and BOD_5 yields of catalan WWTPs.

	Average treated water (m^3/day)	Average BOD_5 Yield (%)
2022	1,673	97,1
2021	1,715	96,9
2020	1,935	96,3
2019	1,785	96,3

In the Tarragona WWTP, the requirements of the discharge permit for BOD_5 have been successfully fulfilled with yields of 96% or higher. This demonstrates the efficiency of the plant, because as it was discussed in the 4.1. subsection, Tarragona WWTP treats a significantly higher amount of water compared to the average catalan WWTP.

5.5. Chemical Oxygen Demand (COD)

This assay is performed to quantify the oxygen required to completely oxidize the organic and inorganic matter present in a known volume of sample.

To protect the receiving waters, the effluent COD is required to be ≤ 125 ppm. The COD yield is calculated by comparing the influent and effluent COD levels. The following table presents the COD values for both the influent and effluent waters, as well as the yields for each month since the beginning of the dual mention internship.

Table 14. COD results for the influent and effluent waters and yields between September 2023 and April 2024..

	COD		
	Influent (ppm)	Effluent (ppm)	Yield (%)
September-23	625	74	88
October-23	855	74	90
November-23	897	81	90
December-23	832	62	92
January-24	830	54	93
February-24	846	48	94
March-24	746	57	92
April-24	800	69	91

As it can be observed in the table through the reported data, the COD yield at Tarragona WWTP ranges from 88% to 94%, consistently accomplishing the discharge permit requirements. This demonstrates effective oxidation of the organic and inorganic matter.

Table 15 contains the COD data of catalan WWTPs compiled by the "Institut Català d'Estadística" up to 2022.[6]

Table 15. Average treated water per day and yields of catalan WWTPs.

	Average treated water (m^3/day)	Average COD Yield (%)
2022	1,673	93,4
2021	1,715	92,9
2020	1,935	91,7
2019	1,785	93,2

While the COD yield obtained in the Tarragona WWTP is slightly below the catalan average, the substantial volume of water treated daily underscores its effective processing capabilities.

5.6. Conductivity and pH

The aim of these assays is to diagnose possible saline intrusions or illegal discharges.

Conductivity measures water salinity, an important parameter in the purification process because it can destabilize the biotic composition of the aeration tank. A sudden increase in conductivity can indicate the municipal sewage system is in poor conditions. In areas close to the coastline, ruptures in the sewage system allow salty water entrance. In addition, an increase in salinity can also be due to illegal discharges. The following table shows the average conductivity values in the influent water.

Table 16. Conductivity results for the influent water between September 2023 and April 2024..

	Conductivity (µS/cm)
September-23	3.456
October-23	3.129
November-23	3.198
December-23	2.927
January-24	2.471
February-24	2.430
March-24	2.529
April-24	2.609

The expected conductivity value for influent water is 2500-2800 µS/cm based on historical records. In September 2023, the average value was 3456 µS/cm, which is considered high, and this is attributed to the particular value obtained on September 5th which was 10235 µS/cm. This value indicates a possible saline intrusion or illegal discharge. After that incident, influent water's conductivity was checked every day, but conductivity returned to normal values immediately, meaning that this was a punctual event. If the conductivity value had not returned to normal, the entrance to the aeration tank would have been closed to prevent the destabilization and loss of the activated sludge.

pH is determined in different units of the WWTP to ensure no damage is produced in the microorganisms' population of the activated sludge and digester, which are highly pH dependent.

To know the pH in the anaerobic digester, pH is determined in the IDR and IDD samples (internal recirculated digester and internal digested digester) and the pH is determined in the IRB samples to know the pH in the aeration tank.

The following table contains the average pH values obtained from September 2023 to April 2024.

Table 17. pH in the IDR, IDD and IRB samples between September 2023 and April 2024..

	IDR pH (pH units)	IDD pH (pH units)	IRB pH (pH units)
September-23	7.10	7.10	7.17
October-23	7.10	7.10	7.31
November-23	7.10	7.10	7.33
December-23	7.10	7.10	7.36
January-24	7.10	7.10	7.39
February-24	7.10	7.10	7.35
March-24	7.10	7.10	7.34
April-24	7.10	7.10	7.35

Numerous studies indicate that the optimal pH range in the anaerobic digester, is close to neutrality, where the highest methane production and organic matter reduction occur.[8] The Tarragona WWTP maintains a stable pH of 7.1 units in the digester, very close to the optimal value, ensuring in this way efficient biodegradation and methane generation.

As for the anaerobic digestion, many studies have also been done in the activated sludge optimal pH, which ranges from 6.8 to 7.4. This pH range supports optimal microbial activity, effective nitrification, proper floc formation, and overall system stability.[13] Tarragona WWTP's activated sludge is within the optimal values. In Table 17 it can be seen that the pH has only varied from 7.17 units to 7.39 units.

5.7. Digester Ratio, Dry Matter (DM) and Volatile Dry Matter (%VDM)

Anaerobic digestion, a critical process for wastewater treatment, operates under two primary temperature regimes: mesophilic (35-37 °C) and thermophilic (50-55 °C). Despite the mesophilic digestion regime is slower and yields lower biogas it has been chosen due to its lower energy costs.[9]

The anaerobic digestion is a 4-step process. The following figure is a scheme of the pathway that takes place.

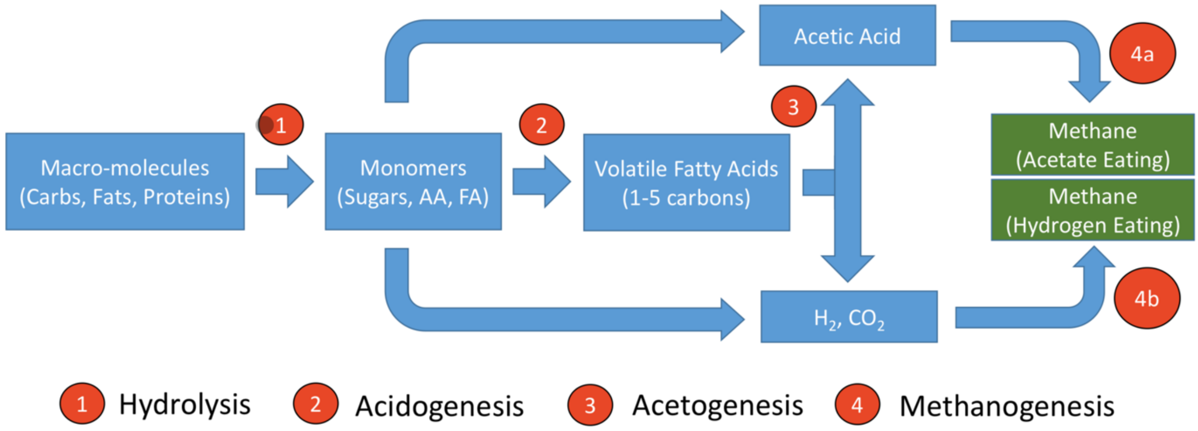


Figure 13. Anaerobic digestion pathway.[15]

Firstly, saprophytic bacteria break down complex organic matter into simpler soluble molecules (hydrolysis) and then convert the simple molecules into volatile fatty acids, alcohols, hydrogen, and carbon dioxide (acidogenesis). Then, acetogenic bacteria convert volatile fatty acids and alcohols into acetic acid, hydrogen and carbon dioxide, substrates necessary for methanogenesis (acetogenesis). Finally, methane-formers bacteria use acetic acid and hydrogen to produce methane (methanogenesis).[9]

The alkalinity of the system is the ability of the solution to resist changes in pH. As volatile acids are formed, these dissociate, and hydrogen ions are released. The free hydrogen ions would gradually force the pH of the digester downward, but the alkalinity of the system will absorb these ions and allow the methane-formers to "catch up". If the system becomes unbalanced, the alkalinity will gradually exhaust causing the pH in the digester to fall, inhibiting the bacteria. Controlling the digester by monitoring the pH is not sufficient, because when there is a shift in pH means that the system has lost the alkalinity, and at that point, it is too late to go back. For this reason, the acids/alkalinity ratio is also determined. If a progressive increase of the ratio is noticed, there is enough time to diagnose the problem and apply corrective measures.[10]

VDM is a measurement of organic matter in the sludge, and it is used as a basis for determining the organic load into the digester. VDM reduction is an indicator of digester efficiency.[9]

In the following table the volatile fatty acids/alkalinity ratio and the organic matter reduction obtained since September 2023 until April 2024 are shown.

Table 18. Volatile fatty acids/alkalinity ratio and organic matter reduction.

	VFA/TA	VDM reduciton (%)
September-23	0,11	50
October-23	0,12	46
November-23	0,12	45
December-23	0,11	46
January-24	0,10	47
February-24	0,09	55
March-24	0,10	51
April-24	0,08	51

The acids/alkalinity ratio is the correct method to monitor a digester health, because a shift in this parameter occurs days before a pH shift. In a well-functioning digester, the ratio should be between 0.05 and 0.15, with values over 0.15 indicating potential issues.[15] The ratios obtained in the Tarragona WWTP's digester vary from 0.08 to 0.12. These results are within the ratio of a healthy digester with sufficient alkalinity is present to counteract acidity.

The organic matter reduction is influenced by several factors:

- Temperature: in Tarragona WWTP, which is a mesophilic digester, is between 35-37ºC.
- Sludge composition, proportion of primary sludge (rich in readily degradable organic matter) to secondary sludge (contains more microbial biomass): in Tarragona, the daily amount loaded consists of 2/3 of primary sludge and 1/3 of secondary sludge.
- Hydraulic retention time: which in Tarragona is 21 days.
- pH and alkalinity: which as mentioned in the 4.6 subsection the pH is 7.1 and the VFA/TA ratio varies between 0.08 and 0.12.

In Tarragona WWTP the organic matter reduction ranges between 45% and 51%, which is an intermediate digester efficiency considering the data detailed in studies indicates the typical range of organic matter reduction is between 40% and 60% in mesophilic anaerobic digesters used in urban wastewater treatment plants.[11,12]

5.8. Ammonium probe data compilation

An ammonium probe has been installed in the aeration tank to compile data on the ammonia concentration, which helps in the evaluation of the nitrification and denitrification processes. The following discussion highlights the relevance of these processes, the role of the ammonium probe and the preliminary data collected in April 2024.

In the nitrification phase, ammonia is oxidized to nitrite and then to nitrate by nitrifying bacteria in the presence of oxygen as showed in Reactions 1,2 and 3 in subsection 2.3.

In the denitrification phase, nitrate is subsequently reduced to molecular nitrogen (N_2) by the denitrifying bacteria as showed in Reactions 4 and 5 in subsection 2.3. Organic matter is oxidized by oxygen or nitrate, acting as electron acceptors. If nitrate is used as a terminal electron acceptor instead of oxygen during denitrification, the aeration requirement for biochemical oxygen demand (BOD) is reduced. [5]

Ematsa wants to take advantage of this reduction of aeration requirement and stop the air blowers at certain times. These stops would reduce the electrical cost of the plant and avoid an uncontrolled denitrification in the clarifier, which would suspend the sedimented biomass due to N_2 bubbles.

The efficiency of nitrogen removal is correlated with the degree of nitrification achieved. The organisms responsible for nitrification (*Nitrosomas* and *Nitrobacter*) have low yields and growth rates compared to others in the activated sludge and are also very sensitive to pH and temperature.

An extensive and systematic research by Shammas involved 45 separate experimental studies under various controlled environments to determine the optimal conditions for the nitrification process. In that study several experiments with different pH, temperature and MLVSS concentrations were performed and from the obtained results it was concluded that MLVSS concentration influences the extent of temperature and pH effects and high nitrification efficiencies can only be obtained with extremely long retention times or a combination of high MLVSS and elevated temperature.[14]

In Ematsa, the ammonium probe was installed on April 17th, before the summer season. With this probe ammonium concentrations will be compiled and compared with the pH, temperature and MLVSS. The following table contains the data compiled during April 2024.

Table 19. Average MLVSS, T, pH and ammonia concentration in the aeration tank.

	MLVSS (ppm)	T (°C)	IRB pH (pH units)	Ammonia concentration (ppm)
April-24	1567	20.6	7.35	52,1

Given the recent installation of the probe, it has not compiled sufficient data to extract conclusions. In addition, in summer when the temperature rises and high nitrification efficiencies are reached, the air blower stops will be performed, and more information related to the change in ammonia concentration will be obtained.

Due to the reasons mentioned above, up to the extent of this bachelor's thesis (September 2023 - April 2024), results can not be discussed.

6. Conclusions

In this Bachelor's Thesis, the operation of the Tarragona WWTP was examined through the results of the required control analyses, and the conclusions are as follows:

- To ensure the correct functioning of the Tarragona WWTP assays cannot be discussed individually, most analyses have to be interpreted altogether.
- To ensure the correct state of the activated sludge, microscopic and macroscopic assays are fundamental. It can be clearly stated considering the April 2024 situation, in which a sudden increase of Type 021N filamentous bacteria took place. If the activated sludge had not been observed under the microscope weekly, the bacteria would have kept increasing and as a consequence, there would have been sedimentation problems. At that point, the state would have been much harder to revert. In other situations, the column settling assay helps to detect flocculation and sedimentation problems taking place in the clarifier.
- Sudden changes in the usual results of the analyses are often indicators of a problem in the plant. It is essential to detect them, as they mean that the plant is in a transient state. A diagnosis must be obtained before it starts to affect the quality of the effluent. At that point, the consequences are more serious, and the situation is more difficult to reverse.
- To be able to discuss results and extract conclusions from the newly installed ammonium probe, more data has to be compiled. The extent of this bachelor thesis is from September 2023 up to April 2024 and the probe was installed mid-April. For this reason, the research on this topic will be continued in the summer, when the temperature rises and the nitrogen removal efficiency increases.

7. Bibliography

(1) Real Decreto 849/1986, de 11 de abril, por el que se aprueba el Reglamento del Dominio Público Hidráulico, que desarrolla los títulos preliminar I, IV, V, VI y VII de la Ley 29/1985, de 2 de agosto, de Aguas, Real Decreto n.º 849/1986 (April 30, 1986) (España). *Boletín Oficial del Estado*, (103). https://www.boe.es/buscar/act.php?id=BOE-A-1986-10638 (accessed 2024-04-23).

(2) RESOLUCIÓ MAH/285/2007, de 7 de febrer, per la qual es dóna publicitat a l'Acord del Consell d'Administració de l'Agència Catalana de l'Aigua d'1 d'abril de 2004, de fixació de criteris en relació amb la vigilància i el control de la qualitat de les aigües marines litorals i els paràmetres i límits dels abocaments de terra a mar. (February 7, 2007) (Catalunya). *Diari Oficial de la Generalitat de Catalunya,* (4818). https://dogc.gencat.cat/ca/document-del-dogc/?documentId=433406 (accessed 2024-04-23).

(3) Ematsa | Empresa Municipal Mixta d'Aigües de Tarragona, s. f. https://www.ematsa.cat/wp-content/uploads/2023/07/2023_MEMORIA_EMATSA.pdf (accessed 2023-11-29).

(4) Orden de 13 de julio de 1993 por la que se aprueba la instrucción para el proyecto de conducciones de vertidos desde tierra al mar, Orden, July 13, 1993 (España). *Boletín Oficial del Estado*, July 27, 1993. https://www.boe.es/buscar/act.php?id=BOE-A-1993-19593 (accessed 2024-05-26).

(5) *Advanced Biological Treatment Processes*; Wang, L. K., Shammas, N. K., Hung, Y.-T., Eds.; Humana Press: Totowa, NJ, 2009. DOI: 10.1007/978-1-60327-170-7

(6) *Aigua*. Medi Ambient i Sostenibilitat, n.d. https://mediambient.gencat.cat/ca/dades-documentacio/estadistica/indicadors-i-estadistiques/aigua/ (accessed 2024-06-01).

(7) Eikelboom, D. H. *Process control of activated sludge plants by microscopic investigation*; IWA Pub.: London, 2000.

(8) Parra Orobio, B. A., Torres Lozada, P., Marmolejo Rebellón, L. F., Cárdenas Cleves, L. M., Vásquez Franco, C., Torres López, W. A., & Ordóñez Andrade, J. A. (2014). Influencia del pH sobre la digestión anaerobia de bio-residuos de origen municipal. *Revista U.D.C.A Actualidad & Divulgación Científica, 17*(2). https://doi.org/10.31910/rudca.v17.n2.2014.421

(9) Meegoda, J., Li, B., Patel, K., & Wang, L. (2018). A Review of the Processes, Parameters, and Optimization of Anaerobic Digestion. *International Journal of Environmental Research and Public Health*, *15*(10), 2224. https://doi.org/10.3390/ijerph15102224

(10) *The Watewater Management Program*. (1996). Vermont Agency of Natural Resources. https://dec.vermont.gov/sites/dec/files/wsm/wastewater/docs/Combined%20Lab%20Manual.pdf (accessed 2024-06-02).

(11) *Biosolids Technology Fact Sheet Multi-Stage Anaerobic Digestion* . (2006). https://www.epa.gov/sites/default/files/2018-11/documents/multistage-anaerobic-digestion-factsheet.pdf

(12) Shrestha, B., Hernandez, R., Fortela, D. L. B., Sharp, W., Chistoserdov, A., Gang, D., Revellame, E., Holmes, W., & Zappi, M. E. (2020). A Review of Pretreatment Methods to Enhance Solids Reduction during Anaerobic Digestion of Municipal Wastewater Sludges and the Resulting Digester Performance:

Implications to Future Urban Biorefineries. *Applied Sciences*, *10*(24), 9141. https://doi.org/10.3390/app10249141

(13) Tchobanoglous, G. (2014). *Wastewater engineering : treatment and resource recovery* (5th ed.). McGraw-Hill.

(14) Shammas, N. Kh. (1986). Interactions of Temperature, pH, and Biomass on the Nitrification Process. *Journal (Water Pollution Control Federation)*, *58*(1), 52–59. http://www.jstor.org.sabidi.urv.cat/stable/25042841

(15) Sheff, B. (2019, February 26). *Chemistry for digesters*. American Biogas Council. https://americanbiogascouncil.org/wp-content/uploads/2019/03/Chemistry-for-Digesters-New.pdf