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TITLE Improvement Strategy for reducing environmental impact of a wastewater treatment plant

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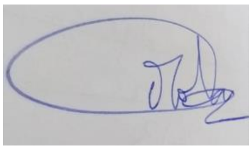
DECLARATION

I**, Hidayat Mohammedi** hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.



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CERTIFICATION

This thesis has been submitted with my approval as the supervisor.

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Abstract:

A wastewater treatment plant (WWTP) must be able to operate satisfactorily during critical situations, service shutdowns and power outages. That makes the management of the wastewater plant difficult because of disturbances that can be produce and which are difficult to characterize and predict. The slightest failure is harmful in an environment where performance is paramount. It is therefore necessary to ensure permanently the proper functioning of the wastewater treatment plant toward the objectives assigned to it. To answer this question, a Design Failure Modes and Effect Analysis (DFMEA), based on the daily physico-chemical parameters of pollution, has been developed for the WWTP of Ain Temouchent (treatment capacity of 10,920 m^3/day) and crucial problems which penalize its operation and limit its reliability has been identified. Preventive and corrective actions are proposed.

Keywords

Security, treatment plant, management, treatment efficiency, failure, operating safety

Résumé:

Une station d'épuration des eaux usées (STEP) doit pouvoir fonctionner de manière satisfaisante lors des situations critiques, d'arrêts de service et de pannes de courant. Cela rend la gestion de la station d'épuration difficile en raison des perturbations qui peuvent être produites et qui sont difficiles à caractériser et à prévoir. La moindre défaillance est néfaste dans un environnement où la performance est primordiale. Il est donc nécessaire d'assurer en permanence le bon fonctionnement de la station d'épuration des eaux usées pour atteindre les objectifs qui lui sont assignés. Pour répondre à cette question, une analyse des modes de défaillance et de leurs effets (DFMEA), basée sur les paramètres physico-chimiques quotidiens de la pollution, a été développée pour la station d'épuration d'Ain Temouchent (capacité de traitement de 10 920 m3/jour) et des problèmes cruciaux qui pénalisent son fonctionnement et limitent sa fiabilité ont été identifiés. Des actions préventives et correctives sont proposées.

Mots-clés

Sécurité, station d'épuration, gestion, efficacité du traitement, défaillance, sûreté de fonctionnement

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Finally, to the bless of my life; my grandmother Sultana; thank you for being the guide, the supportive (emotionally and Financially). Thank you for your unconditional love that you grant me all my life.

Dedicate

This thesis is fully dedicated to the Soul of my grandfather

BOUMEDIENE KASMI (HAJ DIDEN)

To my guide and teacher who taught me everything I know, to the one who taught me how to dream; you have gone before witnessing me achieving my dreams, this work is for you!

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List of Abbreviations

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DMFEA	Design Failure Mode and Effect Analysis
DO	Dissolved Oxygen
FMEA	Failure Mode and Effect Analysis
FTA	Fault Tree Analysis
FAO	Food and Agriculture Organization
IWRM	Integrated Water Resources Management
MENA	Middle East and North Africa
OJ	Official Journal
TSM	Total Suspended Matters
UN	United Nation
WHO	World health Organization
WWTP	Wastewater treatment Plant

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km^3	Cubic kilometer
m^3/cap/yr	Cubic meter per capita per year
m^3/yr	Cubic meter per year
m^3	Cubic meter
ha	Hectare
mm^3/yr	Cubic millimeter per year
km^2	Square kilometer
mm/yr	Millimeter per year
°C	Degree Celsius
°K	Kelvin Degree
Mm	Millimeter
m^3/day	Cubic meter per day
m^3/hr	Cubic meter per hour
(m)	Meter
m^2	Square meter
mg/L	Milligram per liter
mg	Milligram
mL	Milliliter
mm/yr	Millimeter per year

I. INTRODUCTION

I.1 Introduction

The Middle East and North Africa (MENA) region suffers from physical water scarcity it is the driest region of the World. The region population represents 6.3% of the world's population, however, only 1.4% of the world's renewable fresh water is available (Roudi-Fahimi, Creel and De Souza, 2002). A person living in the MENA region has access to only 1,200 m^3/cap/yr against the world average of 7,000 m^3/cap/yr (Philippe Marin, 2014), while the water security threshold is estimated at 1,700 m^3/cap/yr of renewable water (Brown, Matlock and Ph, 2011). We note that MENA region has the highest per capita rates of freshwater withdrawal in the world (804 m^3/yr) and currently over 75% of its renewable water resources are exploited. Because of expanding population and rapid economic growth, the per capita water availability is expected to reduce in the coming decades. By the year 2050, two-thirds of MENA countries could have less than 200 m^3 of renewable water resources per capita per year (EcoMENA, 2018). Water shortage in the MENA region will be significant in the next decades, for instance about 20% is attributed to climate change and 80% is due to increase in demand, population growth and fast economic development (Immerzeel et al., 2011). Agriculture plays a significant role in the economies of the majority of the countries in the MENA region. However, agricultural potential will be limited due to the decrease in water availability that leading to a competition between different water uses.

In Algeria, the vulnerability of available water resources is affected by several problems such as climate change, increasing population growth, surface and groundwater pollution, and the over exploitation of fresh water resource. These make the country exposed to water scarcity at the local and regional level. Algeria is among the most populous country in the Maghreb. Algerian population was estimated at 42.23million in 2018 (World Data Info, 2020). Face to this considerable population; water resources in Algeria are polluted. Uncontrolled and untreated municipal wastewater, discharge of untreated effluents from industries pollutes underground and surface water resources while about 75% of the urban population is connected to a sewage network. Agricultural sector is considered the major polluter of surface water due to the uncontrolled discharges of nitrates and phosphates (Wang, Lee and Melching, 2015). Moreover, the drought that Algeria witnessed for several decades affected negatively water resources. During the last 25 years, the country has experienced a severe drought, which has affected the country's rainfall by causing important deficit evaluated to nearly 30% (Messahel and Council, 2007). The drought had also a negative impact on the modes of flow of the surface water, the level of filling the reserves and the underground waters (Messahel and Council, 2007). From 2000 to 2002, the pluviometric deficits have reached around 50 to 60% in the Centre and Eastern areas of the country (Messahel and Council, 2007). Moreover, also socio-economic activities of the country have been affected by the drought. Renewable water resources (surface water and groundwater) were estimated at around 16.5 billion m^3 for an average year on the basis of climatic series from before the 1980s (Hamiche, Stambouli and Flazi, 2015). This estimate was revised down to around 12.2 billion m^3 taking into account the droughts experienced by Algeria since the 1980's, with a decrease in water resources of around 25% (Hamiche, Stambouli and Flazi, 2015). Therefore, water availability dropped to under 447 m^3/cap/yr in 2012, which is significantly below the "scarcity threshold" of 1,000 m^3 per year set by the UNDP (Hamiche, Stambouli and Flazi, 2015). These problems, if not properly managed are likely to decelerate the country's economic growth.

Non-conventional water resources such as treated wastewater can constitute a solution to reduce the intensive exploitation of water resources. Water reuse can be considered as an adaptation measure to preserve water resources through the reuse by man for uses not intended for consumption, such as irrigation, industry. The use of treated wastewater in agriculture has become a necessity. Reuse of treated wastewater in agriculture has become an important focus of the new water policy of the country. Indeed, rainwater, water from dams and groundwater will not be enough for the needs of the country, which explains the ambition of Algeria to treat a billion m^3 of wastewater for the irrigation of 100,000 ha (Gharzouli R., 2014). According to the National Sanitation Office (2013), the quantities of water treated and reused in agricultural irrigation, reached in 2013 a volume of 19 million m^3 for the irrigation of 12,000 ha. The Algerian current policy aims to increase the wastewater treatment capacity from 550 million m^3/yr secured by 146 WWTP to 1200 million m^3/yr (216 WWTPs) by 2020. In order to irrigate 100,000 ha (Karef, 2017b).

I.2 problem statement

Wastewater treatment technology is a very complex succession of unit processes, each of them designed to remove a specific pollutant from wastewater (Robescu, 2011). Wastewater systems should insure good quality effluents with low costs, under a very restrictive legislation. Problems facing WWTP operators are various, such as covering energy costs, finding financing solutions for rehabilitation and modernization or expansion. Accidents occurred in these plants highly affect system efficiency and effectiveness as well as employee health. The quality of treated water has direct relationship with the crops quality which in result affects the human health and the environment. If the WWTP is not functioning in the way it is supposed to do, it will affect the treated water quality (Mulutu, 2016). Therefore, risk analysis in WWTPs is quite important to detect and prevent possible accidents in the manufacturing process. This is why a performance study is necessary to ensure well-functioning of the plant and predict the main failures that harm the good functioning of this system. Along years scientist have tried to assess the functioning of WWTPs based on different methodologies; the continuous improvement strategy (CIS) based on the principles of Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control), Lean Six Sigma approach, failure modes and effects analysis and Design Failure Modes and Effect Analysis (DFMEA) are all approaches that demonstrated their efficiency in detecting the failure in WWTPs around the world.

In this work the performance of Ain Temouchent waste water treatment plant is put under question, the failure will be detected by following the Design Failure Modes and Effect Analysis (DFMEA) where the suitable solutions to the problem will be communicated. Previous studies demonstrated that some quality indices of effluent water of the WWTP under study does not meet the Algerian government for irrigation water standards, World Health Organization (WHO) and Food and Agriculture Organization (FAO), while phosphorus concentration is superior to standards. In addition, the huge amount of thrown sludge after treatment were recorded (Haidara, 2018). These observations indicate the presence of problem during the treatment process. The roots of these problems will be investigated and determined in this work in order to solve problems and insure the well performance of the WWTP.

I.3 Study Area

I.3.1 Study area geographical situation

The area in interest is the Wilaya of Ain Temouchent. It is located in the North Western part of Algeria, a hundred kilometers far from the Moroccan border. The Wilaya is surrounded by the Mediterranean Sea to the North; the city of Sidi Bel Abbes to the South; The city of Oran to the West and the city of Tlemcen to the Southeast. The region is extended over an area of 2,376.89 km^2 (Ministry of Finances, 2016). In 2018, the population of Ain Temouchent region is estimated to 83.894 in 2018 inhabitants (ministry of industry, 2018).The region is divided into 28 municipalities (Ministry of industry, 2020)

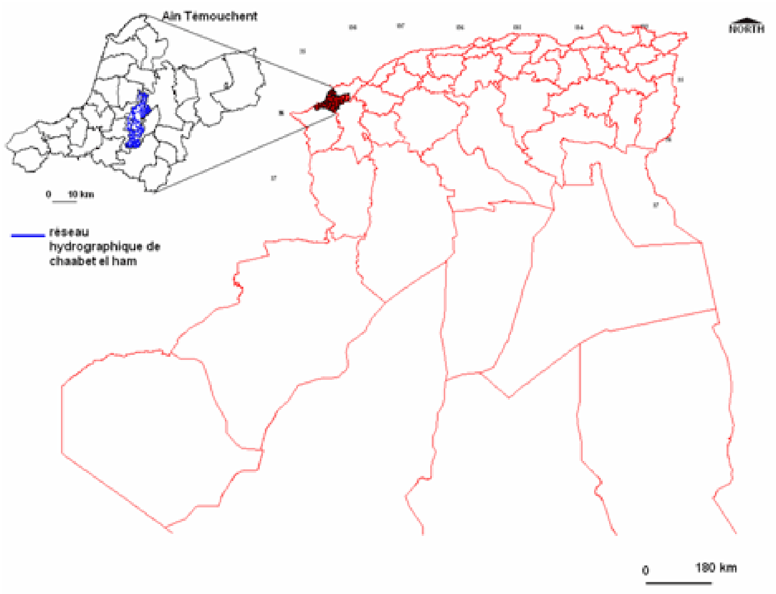


Figure I.1: Ain Temouchent Geographical Location

I.3.2 The waste water treatment plant under study

Ain Temouchent wastewater treatment plant is found in the northern side of the city of Ain Temouchent, meters away from the national road of Terga. In the East we find the police station of the city, it is limited in the South by the national road towards Oran, wadi Sarrane is limiting the plant from North, and some resident buildings are found in the west. The area of the wastewater treatment plant is estimated at six ha. It treats the domestic wastewater from the city of Ain Temouchent and the rainwater. The sewage water is transported to the plant by unitary sewerage system. The plant became operational in January 2014. The domestic wastewater from 72,800 inhabitants is treated by the plant. The plant treats 10,920 m^3/day of waste water, this means 455m^3/hr. This amount rises to 1,365 m^3/hr when it rains. The plant uses activated sludge technique. In 2017 the plant treated 3.5 million m^3 in.

Figure 2: Geographical location of the WWTP

I.4 Objectives:

I.4.1. General Objective

The main objective of this work is to investigate the failure in the functioning system of the waste water treatment plant (domestic wastewater) of Ain Temouchent, a semi-arid region located in the North Western part of Algeria and propose approaches to solve the problem.

I.4.2 Specific objectives

As a result to our optimal objective, the specific objectives would be

1. Assessment for the effluent water quality discharged from water treatment plant
2. Follow statistical analysis to detect the problems related to the treatment process in water treatment plant
3. Select the most crucial problem according to the criticality index
4. Propose the suitable solution for the problem following the principles of Failure Modes and Effect Analysis (DFMEA) methodology

1.5 Research questions

In order to fulfill our objectives, the following questions must be answered:

1. What is the physico-chemical and biological parameters of the effluent water from the treatment plant?

First of all, by answering this question we will assess the quality of the water resulting from the treatment plant.

2. Where is the problem in the treatment process?

In here we intend to compare the treated water characteristics with the WHO standards, and detect where the failure is.

3. What is the most critical problem that should have the priority to be treated?

This question will reveal the most important malfunctioning that should be treated in the first place in order to insure the continuity of the water treatment plant function.

4. How can we treat this problem so the plant functions properly?

The result of this question will be the proposition of legitimate solution that will insure the treatment plant well-functioning.

II. LITERATURE REVIEW

II.1 Introduction

As mentioned before Algeria new policy dedicated the treated water to the irrigation. WWTPs play an important role here, since they are the furniture of the water in question. The World Health Organization (WHO) in 2006 declared that nutrients and fertilizers found in treated water can reduce the input of artificial fertilizers, plus the reduction of the environmental pollution because of the production and the use of artificial fertilizers. It has also positive impacts on incomes of farmers, free fertilizers and good quality of product (WHO, 2006).

While any failure in the treatment process (primary, secondary or biological) can lead to serious problem if directly using the water for irrigating the crops. The presence of germs in the WWTPs resultant water endangers the health of farmers and consumers. The high salinity harms the soil and plants because of the accumulation of salt and leads to reduction of crops production. The increase of nitrogen and phosphorus concentration reduces the agricultural production yield and pollutes the groundwater (WHO, 2006).

Aissa (2013) has declared that the treated waste water of the plant of Chlef is used only to irrigate arboriculture because of problem in chlorine disinfection step. The family of crops can be extended if this problem is fixed (Aissa, 2013). From here we conclude that if WWTPs does not perform satisfactorily, serious consequences can be conducted.

Wastewater treatment plants, in particular those using the activated sludge process, may be subject to failures that limit the reliability of treatment performance. These problems appeared very early with the development of activated sludge, but their frequency increased with the introduction of processes designed for the removal of nitrogen and phosphorus.

II.2 Background

A modern and efficient wastewater treatment plant (WWTP) is obtained by improving not only the equipment and technology but also the management. We define a system that has an operating safety as system able to achieve what it was designed for, without incident calling into question its profitability and without an accident putting safety at stake (Megdiche, 2004).

Robescu (2016) has followed the continuous improvement strategy (CIS) based on the principles of Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) to select the bio-augmentation as solution for improving the biological wastewater treatment process, reducing operational costs and reducing sludge production. The operational reduction of 16.74% has been observed in 2015 compared with the same period of 2014.

According to Meisel et al. (2007) and UN Water (2015), Lean Six Sigma approach leads to improve the wastewater treatment performance and reduces the cost. Reducing phenol concentration in the treated effluent has been reached by following the Six Sigma methodology (DMAIC) (Boruath and Nath, 2015).

Among many techniques developed in system reliability analysis, fault tree analysis (FTA) is one of the popular and efficient methods. FTA is a top down, deductive failure analysis in which an undesired state of a system is analyzed. In this study, the problem of reliability was studied on Tehran West Town waste- water treatment plant. This plant is a conventional acti- vated sludge process, and the effluent is reused in land- scape irrigation. The fault tree diagram was established with the violation of allowable effluent BOD as the top event in the diagram, and the deficiencies of the system were identified based on the developed model. Some basic events are operator's mistake, physical damage, and design problems. The analytical method is minimal cut sets (based on numerical probability) and Monte Carlo simulation. Basic event probabilities were calculated according to available data and experts' opinions. The results showed that human factors, especially human error had a great effect on top event occurrence. The mechanical, climate, and sewer system factors were in subsequent tier. Literature shows applying FTA has been seldom used in the past waste water treatment plant (WWTP) risk analysis studies. Thus, the developed FTA model in this study considerably improves the insight into causal failure analysis of a WWTP. It provides an efficient tool for WWTP operators and decision makers to achieve the standard limits in wastewater reuse and discharge to the environment. (Taheryaum, M, 2015)

Failure mode and effect analysis (FMEA) is a widely used risk assessment tool to identify the potential failure modes of a product or a process. By ranking the priorities for corrective action according to the respective effects of the failures, the chance of the failures can be reduced or eliminated. However, there could be several difficulties during conducting con- ventional FMEA such as the subjective and qualitative description in natural language, the relative importance among the risk ratings, the difference of risk representation among the same ratings; and the knowledge shared among FMEA team members. Thus, a new risk as- sessment system based on fuzzy theory is proposed in this paper to deal with these difficul- ties. Furthermore, an FMEA is conducted for a sewage plant to demonstrate the proposed fuzzy assessment of FMEA. (Ruey H, Y, Mei-Huan H, 2007)

The results of study conducted by Mutlu et al., in 2106 showed that the potential accidents can be decreased by the successful application of FMEA in the co-generation system in a waste water treatment plant. In this study, a real life case study was conducted to show the application of the FMEA method to the cogeneration unit in the wastewater treatment plant (WWTP) in Istanbul, Turkey. Two important systems, namely the thermal oil heating system and turbine system were analyzed extensively to go into the details of the cogeneration unit in the WWTP. The failures were sorted in descending order according to the risk priority number (RPN) through the use of the FMEA method for the thermal oil heating system and turbine system. The results of this study showed that the decision makers or engineers can use the FMEA method to utilize occupational health and safety practices in the manufacturing system. This will lead to more efficient and effective process in the cogeneration unit in the WWTP.

The goal of the analysis established by Tanaka and Rosseljong (2009) was to provide a technical understanding of the cause(s) of failure, its consequences, and a mean to correct any problem with the gearbox of waste water treatment facility in USA. This FMEA tells the gearbox supplier that they have to be careful not only for manufacture and assembly, but also for application effects.

II.2 Factors likely to affect the operation of an activated sludge waste water treatment plant

II.2.1 The nature of the wastewater and the network:

The discharges, include greases, brine, heavy metals, toxic (phenols, cyanides, must be controlled. Water septicity is common on long, gently sloping networks. To avoid fermentation, a speed greater than 1m / s must be ensured. The sulphide concentration of the input effluent must be less than 1-2 mg / L. Regular cleaning of the network is a guarantee of proper functioning. (Degremont Suez, 2005)

II.2.2. The design of the station:

Storm and buffer tanks provide rapid restitution and stirring to avoid deposits. For the pre-treatment a moderated speed in the sand separator, a steady zone at the outlet of the degreaser in order to favorate the concentration and the recovery of grease. (Degremont Suez, 2005)

II.1.2.1 Primary decantation:

Oversizing is to be avoided in order to limit the residence time to 2 hours. The sludge must be extracted as regularly as possible and at concentrations below 10g/L. Avoid thickening the primary sludge in the primary settling tank. (Degremont Suez, 2005)

II.1.2.2 Biological basins:

- Contact area: to be provided if only one biological basin (channel)
- Anoxia, anaerobic: Avoid the design favoring the accumulation of floats (outlet by spill), ensure good homogenization as well as good mixing.
- Aeration tank: Favorate outlets by spillway to avoid the storage of floats. The ventilation station must be properly sized (compressor and distribution of aerators) so that the power is sufficient to avoid deposits and dead zones.
- Degassing: Provide a degassing tank before clarification, especially when the liquid height of the aeration tank is greater than that of the clarifier in order to eliminate dissolved gases (nitrogen and air) and if the height of fall is greater than 50 cm.
- Clarifier: It must be sized according to the flow rate, the sludge concentration and the settling capacity of the sludge. The recovery of the sludge (scraped or recovery by suction tubes) must be uniform throughout the slab. A recycling rate of 150% should be provided in order to avoid too long a storage period of the sludge, in particular during peak flows. (Degremont Suez, 2005)

II.2.3. Operation of the station:

Regardless of the nature of the water and the design of the facility, good station management is imperative for functioning correctly. To insure the well-functioning it is necessary to follow the operating instructions (Degremont Suez, 2005) for:

- ✓ the biological input charge
- ✓ the characteristics of the input water
- ✓ the temperature (minimum sludge age for nitrification)
- ✓ supply properly oxygen
- ✓ regularly extract excess sludge (maintain an aerated sludge age close to the minimum age)
- ✓ avoid storing floats, mainly in unventilated areas
- ✓ limit the sludge residence time to 2 h

II.2.4 Malfunctions

The main dysfunctions linked to filamentous organisms on a station manifest themselves in two forms:

- the filamentous expansion

- the foaming

The causes are often multiple and the choice of solutions requires a global analysis

A. the filamentous proliferation:

Bulking sludge means the presence in a flock (or between) of filamentous organisms which disturb the settling properties of the sludge (high sludge index and greater than (200ml/g) and therefore compromise the quality of the purified water. The disturbance caused by the filaments is proportional to their density and especially to their length. Taking into consideration the diversity of filaments and the conditions which can favor this problem, the practical approach in the event of the appearance of filamentous proliferation consists in:

- ✓ Evaluating the extent of colonization by filamentous microorganisms.
- ✓ Identify the filamentous species involved (microscopic examination).
- ✓ Determine appropriate remedies

At short term, treat the symptoms: modify the rate of recirculation of the mud, add decantation aids, perform a chlorination of the mud (for more details on the methods allowing the actions to be implemented, (see purifying biomass waste water).

At long term, treat the origines: check the septicity of the influent, the supply of nutrients, the absence of deposits, modify the mass load, the aeration rate, etc.

A frequently used control method is the chlorination of activated sludge, the principle of which consists in destroying the filaments on the surface of the flock without affecting the flocculating bacteria.

B. Foaming

The foaming of activated sludge is a phenomenon which results in the formation of a layer of a foam on the surface of the aeration tank, either whitish in color or brown in color (chocolate mousse).

C. Organic mosses

These mosses form clusters of stable light brown to dark brown floats which gradually cover the surface of the biological tanks and can be transferred to the clarifier and then evacuated with the effluent. The two main filamentous organisms responsible for this foaming and are

Nocardia spp and Microthrix parvicella. These slow-growing organisms are commonly associated with the presence of septicity, deposit, heterogeneity, grease at a relatively high temperature (above 18°C) and with significant mud ages (above 5 days).

Due to its stability, this foam is very difficult to be removed by chemical means, although the spraying of the mud with chlorinated water can, in the short term, constitute an interesting method.(Actes du colloque Lyon, 1994)

The most effective means of control must be directed towards eliminating the conditions which promote the growth of these filaments, namely:

- removal of the septic acid Volatile Gases (VFA), deposits, heterogeneity, grease, etc.
- minimize the age of the sludge
- construction of a pool without the possibility of accumulating floats: avoid submerged walls which trap scum, build degassing wells which make it possible to eliminate the floats.
- evacuation of floats from biological reactors to avoid recycling and permanent reseeding.

D. Sludge lift

A problem sometimes encountered with sludge with good settlability is the rise or flotation of flocs on the surface of the clarifier. The two most common causes are degassing and denitrification. The problems are accentuated by the presence of filament. In both cases the production of nitrogen (degassing of the supersaturation liquor and / or transformation of nitrates into gaseous nitrogen) results in the formation of micro bubbles which are fixed on the flocs and can cause flotation.

To fix these problems following steps should be taken:

- Systematically provide a degasser before the clarifier and limit the fall to 50 cm (degasser – clarifier)
- Design the clarification with the possibility of recycling at a rate of 150%
- At high temperatures, avoid operating with excessively high sludge ages and / or high sludge concentrations.
- Plan to optimize denitrification (Actes du colloque Lyon, 1994)

II.3 Design Failure Modes and Effect Analysis (DFMEA)

Design Failure Modes and Effect Analysis (DFMEA) is an inductive analysis of the effects of component failures on subsystems and the system. It is a systematic process to identify potential modes of failure before they occur, with the intention of eliminating them or minimizing the associated risks (Buzzatto, 1999, Faucher, 2004, Landy, 2007 and Faucher, 2009). The US Army was the first one developing the (DFMEA) in 1949 in the aeronautical sector. Then it was used for the first time in the 1960s for aircraft safety analysis, next in the 1970s it has been adopted in the automotive, chemical and nuclear sectors in Europe. At the beginning it started as FMEA (Analysis of Failure Modes and their Effects) then it has been developed by adding the criticality estimate risks to become Design Failure Modes and Effect Analysis (DFMEA) (Megdich, 2004).

II.3.1 DFMEA and risk analysis

1. Risk definition

Risk can be defined as the occurrence of an unexpected event, more or less harmful, faulty or not, which may cause damage. The damage may be repaird, in the form of compensation. It is characterized by its nature, its probability of occurrence and its severity. Managing risk is to control it in the view of eliminating it if possible, or even reducing it and transfer the imponderable (the unavoidable statistical risk). (Hergon, 2006).

DFMEA has developed a risk analysis method for facilities. This process allows us classify all elements of the facility according to their level of criticality. Based on this classification, modifications are occurred to the project starting from the design (Pirrolet, 1999). The method is called inductive because it starts by defining elementary causes to deduce the final consequences. In contrast, deductive methods consist on analyzing the final consequence in order to seek its elementary causes (Ridoux, 1994).

The process of DFMEA is represented in the following tables:

Table1: DFMEA risk analysis process (Preliminary Risk Assessment PRA)

1	2	3	4	5	6

System or sub-system	phase	Dangerous elemants	Causes of dangerous situation	Dangerous situation	Event causing potential accident

7	8	9	10	11
Potential accident	Consequence	Classification according to criticality	Preventive measures	Measures application

Table2: DFMEA risk analysis process Preliminary Risk Assessment PRA (Faucher, 2007)

1	2	3	4	5
System or sub-system	Dangerous element	Why the situation is dangerous?	Dangerous situation	The reason of accident

6	7	8	9
Accident	Accident effect	Accident probability	Prevention measures

The terms used in tables can be explained as following:

- System or subsystem: identification of the set studied
- Phase: phase or mode of use during which certain elements can generate a risk
- Dangerous element: element of the subsystem or system with an intrinsic danger
- Causes of dangerous situation: events, malfunctions, errors, etc., which can transform a dangerous element into a dangerous situation.
- Dangerous situation: situation resulting from the interaction of the dangerous element and the system set, according to the previous column
- Event causing a potential accident: events, malfunctions, errors ..., likely to transform a dangerous situation into an accident

- Potential accident: accident resulting from dangerous situations, following an event in the previous column
- Consequences: consequences of potential accidents when they occur
- Classification according to citicality: qualitative expression of the severity of the consequences of the accident (for example: minor, significant, critical, catastrophic).
- Preventive measures: measures considered to eliminate or control the risks identified
- Measures application: remarks and information relating to the previous measures

The aim of the RPA is to : 1) identify risks and their causes, 2) to study the consequences that may arise from the existence of dangerous elements, 3) to define design rules and procedures and 4) to eliminate or control dangerous situations and potential accidents. RPA is an inductive, but also deductive approach, which makes it possible to search for combinations of events (Faucher, 2009). Deductive: the approach is of course reversed, since we start from the undesirable event and then look for all possible causes using a top-down approach (Alani, 2006). For complex systems, it is carried out at the beginning of the design phase, to be considered as a first approach to the risks presented by a system (preliminary risk analysis), then the DFMEA will be used for analysing the reliability and safety of the system, as the project progresses (Faucher, 2009).

2. History and application areas of DEMEA

The DFMEA method was developed in the United States and has been used since the 1940s in space and aeronautics. Since its first implementation, adaptations have been made and concern the DFMEA: product, process, machines, means of production and organisation. A large number of international, national and sectoral standards have been developed over several decades (Zwingelstein, 2014). It has been used in the United States by the company Mc Donnell Douglas since the 1960s. It consisted in listing the components of a product and accumulating information on failure modes, their frequency and consequences. The method was developed by NASA and the arms industry under the name FMEA to evaluate the effectiveness of a system (Kelada, 1994). In the late 1970s, the method was widely adopted by Toyota, Nissan, Ford, BMW, Peugeot, Volvo, Chrysler and other major car manufacturers. The method has proved its worth in the following industries: space, armaments, mechanical, electronic, electrical, automotive, nuclear, aeronautics, chemical, computer and more recently, it is beginning to be used in services (Kelada, 1994). During the 1980s, French car manufacturers introduced reliability clauses in contracts with their suppliers of components for automobiles on the one hand and with their suppliers of production machinery and equipment on the other. In the latter case, the clauses generally provided for a DFMEA to be carried out. The DFMEA tables and the criticality assessment method which had then been developed for the supply of production equipment in the automotive sector were subsequently frequently used in other sectors. This appropriation may not always have been carried out wisely (the references, the way in which the method is implemented in a precise framework, with specific concerns as well as the results achieved, are not necessarily transposable to other fields), but it probably contributed a great deal to propagate the DFMEA method in France (Faucher, 2009).

Currently:

- ✓ Among the methods of reliability analysis, DFMEA is in a good position
- ✓ Some procedures defined within the framework of a quality approach (application of ISO 9000 standards, for example) include the use of DFMEA at different stages of product or process development
- ✓ In its principles, DFMEA has been a stabilized method for many years: the standard NF X 60-510 "Techniques for analysing the reliability of systems
- ✓ Procedure for failure mode and effects analysis (FMEA)" was published in December 1986 (Faucher, 2009).

II.3.2. FMEA

The notion of criticality is added to the FMEA to give the DFMEA. The relationships between failures and the resulting effects constitute the FMEA part, and it is fundamental to understand how to describe these relationships (Faucher, 2009).

II.3.2.1 FMEA Operations

FMEA has been defined as a means of identifying potential failure modes, with a view to eliminating them or minimizing their consequences. Priority will be given to those failure modes whose effects are "most damaging" or "most severe" or "most critical", in a particular field (quality, production, safety...). We will then seek, in this order, to eliminate these failure modes (by acting on their causes) and to minimize their consequences. On the other hand, some failure modes can be accepted as having "acceptable" effects, and for these, the design will be considered suitable (Faucher, 2009).

A. The main features of the FMEA

The FMEA is a method for analyzing the reliability of systems, it proceeds from an inductive, qualitative, exhaustive approach (Faucher, 2009).

A.1. Method for analyzing system reliability

The NF X 60-510 standard is entitled "System reliability analysis technique - Procedure for failure mode and effects analysis (FMEA)". The FMEA is an analytical method that allows the reliability (or its corollary, failure) of the studied system from the study of the failures of its components (Faucher, 2009).

A.2 An inductive approach

Is an a priori approach, practised with the aim of preventing failures (Hergon, 2006). It has a bottom-up approach in which all possible combinations of elementary events are identified that lead to the occurrence of a single undesirable event (Alani, 2006).

A.3 A qualitative method

FMEA is one of the methods for assessing system reliability. Reliability and other concerns such as maintenance, maintainability, availability, safety are complementary and often associated. Unlike other methods or tools for operational safety, the FMEA is a qualitative method only (Faucher, 2009).

B. Simple failures, multiple failures, duplicated systems

B.1.The FMEA, a method for analysing simple failures

The FMEA has one limitation that it only deals with single (simple) failure. Sometimes referred to address only one failure mode at a time, with the assumption that everything else in the system is functioning properly (Faucher, 2009).

B.2. Simple systems, redundant systems

The notion of a simple or redundant system is not only related to the physical architecture of the system, but also to the definition of the expected mission or function of the system (Faucher, 2009).

B.3.An exhaustive analysis

Whatever the level of decomposition of the system into components, and the nature of these components (material, function...), the quality of the results obtained from the FMEA will be directly related to the care to identify all the components to detect all the failure modes (Faucher, 2009).

B.3.1. Failure combination method (or failures)

There is always an inductive approach, starting from failures and moving towards effects. When we talk about combinations of failures, we can therefore only refer to combinations of failures belonging to this list. The principle will thus consist in considering these failures two by two (or three by three) and in identifying the effects or consequences of their combination (Faucher, 2009).

B.3.2. Fault tree analysis method

The fault tree method is a deductive method, going from effects to causes. This method is in line with this logic by making it possible to search not only for simple or unique failures, but also for combinations of failures that may be at the origin of the observed effects or identified a priori (Faucher, 2009). For a system, there is the FMEA record, but there is a failure tree associated with each adverse event.

The FMEA identifies the consequences of unique failures. It will be the first step to ensure that the system design meets the single failure criterion and provides a list of unique failures that can be addressed by other methods (Faucher, 2009).

II.3.3 From FMEA to DFMEA

We will now complete the Failure Mode and Effects Analysis (FMEA) for Design Failure Mode and Effects Analysis (DFMEA). The DFMEA adds to the FMEA the new concept of "criticality" whose main objective is to prioritize or identify the most important risks (always in order to address them preventively) (Faucher, 2009).

II.3.3. DFMEA

a) What is the purpose of using the DFMEA?

A DFMEA is used wisely, when the investment (objective, expected results, mobilization of people costs) justifies it (Faucher, 2009).

b) What is the DFMEA study for?

The DFMEA study is used to assess in a systematic way the defects that could appear in the use of a means, a product or the application of a process. It is possible to draw a parallel with risk analysis, as the tools are complementary. The DFMEA study is not a fixed element. It is advisable to review it after a period of activity on a product, process or means of manufacture, and to re-assess its rating. It is advisable to re-evaluate the study (Berson, 2014).

c) Why set up the DFMEA?

The DFMEA 's structured approach aims above all to :

- Identify and evaluate the failure modes and their possible effects

-Identify and rank the actions to be taken in priority to reduce the risk associated with these failure modes

- Minimize corrective actions

- Put it in writing (Siris et. All)

II.3.3.4 The operation of the DFMEA

The DFMEA method includes:

1. **The booklet of critical points**

The objective of the DFMEA was to identify the failures and/or critical components. When a complex system with hundreds of failure modes has been analysed, it may be necessary to gather in a reduced document the only points that appeared critical. This document is frequently referred to as the "critical point booklet". In practice, it may be a simple compilation of DFMEA headings relating to the points designated as critical (Faucher, 2009).

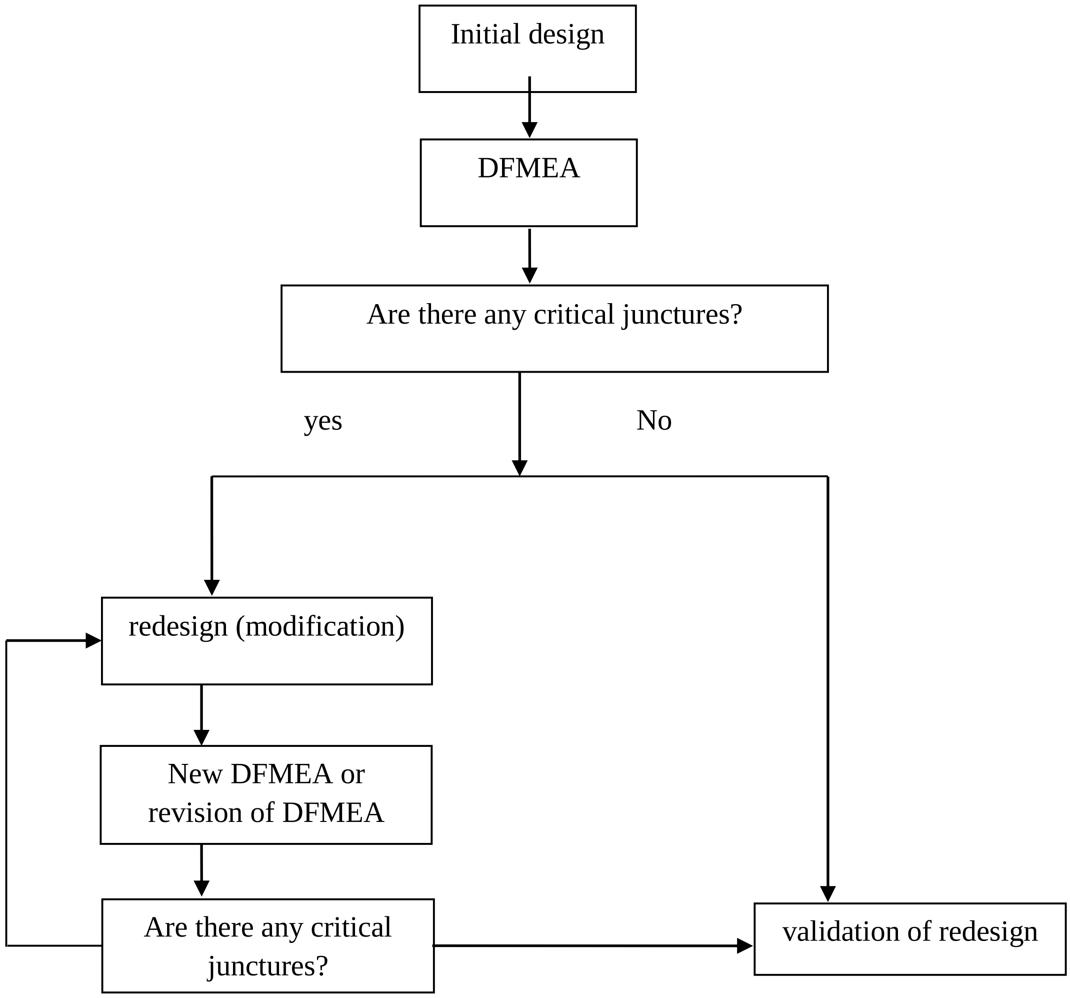
2. **The columns "modification" on the DFMEA table**

This is to indicate directly the modifications planned for the critical points, then to carry out a new criticality evaluation, by integrating these modifications. This way of proceeding may lead to consider that DFMEA goes as far as the search for solutions (or even to redesign), but there is a boundary between the DFMEA and this later phase (Faucher, 2009).

3. **DFMEA and (re)design**

Some modifications can likely be proposed by those who have carried out the FMEA(C)(criticality), but it seems logical to consider that the search for solutions will often seems like a re-design phase. Even if the persons who carry out the DFMEA can also be the designers, it is essential to situate the DFMEA and the design (or re-design), one in relation to the other, by considering the DFMEA as a method to validate the design or to identify the unsatisfactory design points, according to the iterative process described in the following scheme (Faucher, 2009).

Scheme 1 : main component of DFMEA design



II.3.3.4 Definition of DFMEA

The DFMEA, Design Failure Mode and Effects Analysis, is an efficient analysis tool that allows an in-depth identification of risks of a process, a product or a means of production drift. It is part of the logic of risk control; its purpose is to set up preventive action plans aiming at eliminating or reducing the risks related to user safety, non-quality, loss of productivity, customer dissatisfaction (Practical sheet, 2014). DFMEA is defined as an "inductive method of system analysis used for the systematic analysis of the causes and effects of failures that may affect the components of the system". This method is systematic, participatory and preventive (Hergon, 2016).

a. Objective of the DFMEA

The DFMEA is a technique that leads to the critical review of the design in order to evaluate and ensure the operational safety (safety, reliability, maintainability, and availability) of a production facility (Ridoux, 1994). It aims, in a rigorous inductive approach, to identify failures whose consequences may affect the operation of a system and to prioritize them according to their level of criticality in order to control them. The output is the set of potential malfunctions associated with their criticality (frequency of occurrence, severity of effects and probability of failure detection) as well as the action plans to be implemented in order to reduce criticality by varying one of the three factors (bigret, 2011). Moreover, it enables the weak points of a system to be identified and remedied, the means of protecting against certain failures to be specified, the people concerned by a project to engage in dialogue, better knowledge of the system and, above all, to study the consequences of failure (Martin et.all, 1999).

b. DFMEA Principle

Identify potential error risks (or failure modes) and assess their effects and causes (Morcrette, 2000).

DFMEA is to identify and prioritise the potential failure modes that may occur on equipment, to investigate the effects on the main functions of the equipment and to identify the causes. For the determination of the criticality of failure modes, DFMEA requires for each failure mode the investigation of the severity of its effects, the frequency of its occurrence and the probability of its detectability. When all this information is available, different methods exist to deduce a value for the criticality of the failure mode. If the criticality is judged to be unacceptable, then it is imperative to define corrective actions to correct the new severity of the failure mode (if indeed possible), change its frequency of occurrence, and possibly improve its detectability (Zwingelstein, 2014).

c. DFMEA types

There are several areas where DFMEA can be applied:

- ❖ **DFMEA organization**

DFMEA is applied to the different levels of the business process, from the first level which includes the management system, the information system, the production system, the personal system, the marketing system and the financial system, to the last level such as the organization of a work task (Kelada, 1994).

- ❖ **DFMEA-Product**

It is used to assist in the validation of studies to define a new product manufactured by the company. It is implemented to evaluate the potential defects of the new product and their causes. This evaluation of all possible defects will make it possible to rectify them, after prioritization, by implementing corrective actions on design and preventive actions on industrialization (Ridoux, 1994).

- **DFMEA -Process**

It is used to study the potential defects of a new product, generated by the manufacturing process. In the case of a new process, the DFMEA-Process will allow its optimisation, aiming at the elimination of the causes of defect that may have a negative effect on the product. If it is an existing process, it will allow its improvement (Ridoux, 1994).

- **DFMEA device**

Allows the anticipation of risks linked to the non-functioning or abnormal operation of a piece of equipment or a machine (Practical sheet, 2014).

- **DFMEA service**

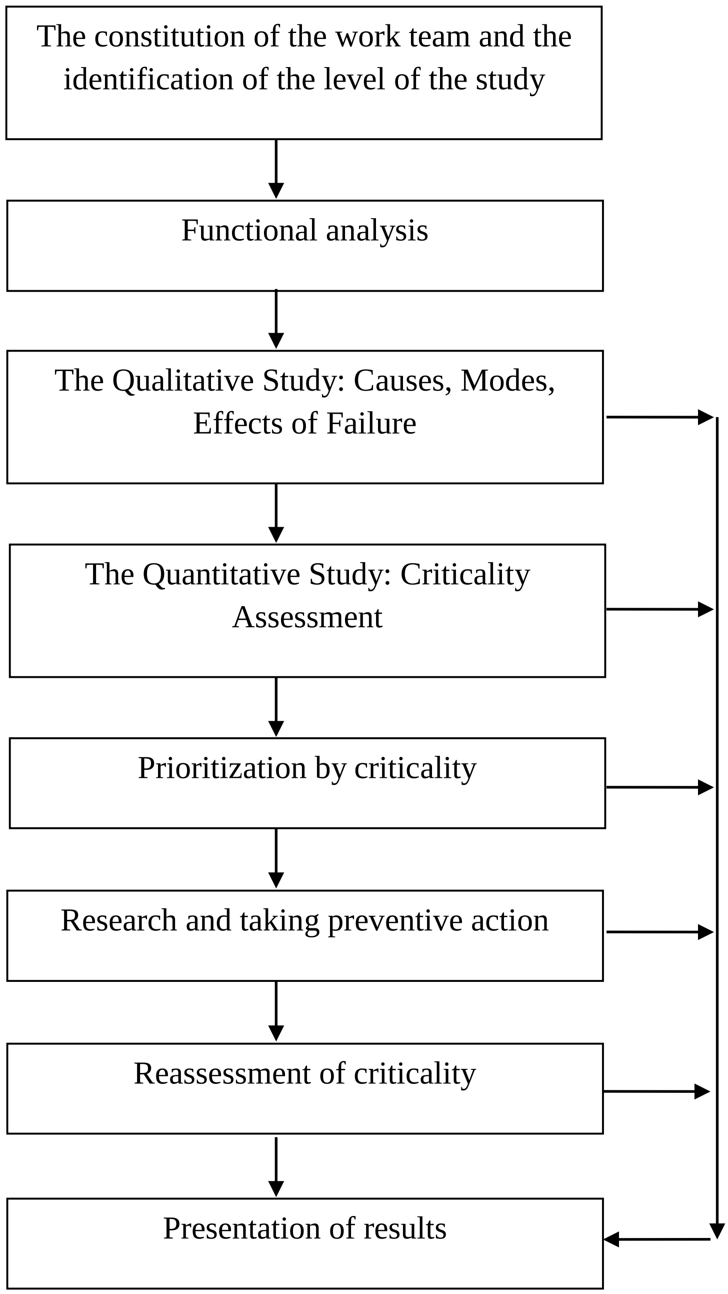
Applicable to verify that the added value achieved in the service meets customer expectations and that the service delivery process does not lead to failure (Faucher, 3013).

- **FMECA security**

It is used to ensure the safety of operators in processes where there is a risk to operators (Kelada, 1994).

d. Steps of the DFMEA Analysis

The method is structured in an eight-step process (figure)


The constitution of the work team and the identification of the level of the study
Functional analysis
The Qualitative Study: Causes, Modes, Effects of Failure
The Quantitative Study: Criticality Assessment
Prioritization by criticality
Research and taking preventive action
Reassessment of criticality
Presentation of results

d.1 Building the team of work

DFMEA relies on group work, collective reflection and the experience of the participants. It is therefore necessary to set up a working group whose choice of participants depends on their:

- ✓ experience
- ✓ knowledge of the issue
- ✓ level of technicality
- ✓ ability to work in a team

The working group must be led by a moderator responsible for monitoring the results. Once the working group has been set up, present the methodology followed for the analysis (Practical sheet, 2014).

d.2 Functional analysis

The purpose of the functional analysis is to determine in a rather complete way the main functions of a product, the constraint functions and the elementary functions.

- ❖ The main functions: are the functions for which the system has been designed, therefore to satisfy the user's needs.
- ❖ Constraint functions: respond to the interrelations with the external environment.
- ❖ Elementary functions: provide the main functions, which are the functions of the different elementary components of the system.

In order to carry out the functional analysis correctly, three main steps must be carried out:

- Define the need to be satisfied. The principle is to describe the need and how it is being met and how it is likely to be unmet.
- Define the functions that correspond to the need.
- Establish the functional tree in order to visualize the functional analysis. Very often the main functions include sub-functions or result from a set of elementary functions. Hence the need for the functional tree (Kelada, 1994).

d.3 Qualitative study of failures

It consists in identifying failure modes, their effects and the causes leading to the malfunction of a system element. These three notions are linked by the following relationship: Cause → Mode → Effect (Noureddine, USTO)

d.4 Quantitative study

- ❖ **Acceptability, criticality, judgement criteria**

A "critical" failure if judged through one or more criteria, is unacceptable to us. The notion of acceptability is a relative notion; it only makes sense in a given context (Faucher, 2009).

The judgment we can make about a failure can be:

- ➢ mono-criteria: in this case, the criterion is generally the severity of the effects of the failure
- ➢ bi-criteria: in this case, the two criteria are generally the severity of the effects of the failure and the probability of its occurrence; and
- ➢ multi-criteria: in this case, the criteria are, for example, the severity of the effects of the failure, the probability of occurrence of the failure, the possibility of detection of the failure, etc. (Faucher, 2009).

- ❖ **Scales of judgment**

Criticality, or criticality rate, is the combination of the severity of an effect and the frequency of its occurrence, or other attributes of a failure, as a measure of the need for treatment or mitigation (Humber, 2012). Failure criticality analysis was performed using the grids proposed by the DFMEA tool (Marry et.all, 2010). The criticality C, deduced by the product of the three nominal indices F, G, and D

C: Criticality (the product of occurrence, severity and detection, allowing decisions to be made on corrective actions to be taken).

F: Frequency (probability that a defect occurs for a given cause)

G: Gravity

D: Detection (Francois, 2002)

d.5 Prioritization

Prioritization according to the criticality scale makes it possible to decide on priority actions. It makes it possible to classify the failure modes and to organize their treatment by order of importance (Kelada, 1994).

d.6.Research

preventive/corrective actions After the classification of the different potential failure modes according to criticality indices, the group designates those responsible for the search for preventive or corrective actions (Kelada, 1994).

d.7. Follow-up of actions taken and criticality reassessment

A new criticality index is calculated in the same way as in the first evaluation, taking into account the actions taken. This value of the new criticality index is sometimes referred to as the residual risk and may be illustrated in the form of a Pareto chart. The objective of this reassessment is to determine the impact and effectiveness of the actions taken. Therefore, the new criticality index must be below the criticality threshold (Kelada, 1994).

d.8. Presentation of results

To be able to carry out and apply the DFMEA, it is necessary to have tables specially designed for the system under study and prepared according to the objectives sought. These tables are usually arranged in columns and generally contain the information necessary to carry out the study (Kelada, 1994).

II.4 Conclusion

From here we conclude that the DFMEA can be applied to any system or process with a significant number of potential failures and whose improved operation provides a significant gain. It is totally appropriate for the industrial sector, but can also be transposed to service companies.

III. MATERIAL AND METHODS

The daily physio-chemical parameters of the WWTP of Ain Temouchent of 2014, 2015, 2017, 2018 and the first semester of 2020 were collected from the laboratory of the WWTP. With the aim of gaining some experience I carried out practical work in sampling in the laboratory of the plant where; under the supervision of the chemical specialists of the laboratory, I participated in the weekly water analysis. Sampling of the treated wastewater has been done using automatic samplers. The physio-chemical parameters that are usually analyzed in the laboratory are: Temperature, pH, Electrical conductivity, Total suspended matter (TSM), Dissolved oxygen (DO), Biological oxygen demand (BOD5), Chemical oxygen demand (COD), Ortho Phosphates ($PO4^{3-}$), Total Phosphorus (TP), Nitrate- nitrogen (NO_3-N), Ammonium nitrogen ($N\text{-}NH_4^+$), Nitrite-Nitrogen (NO_2^-) and total Nitrogen (TN).

1. Temperature

In the WWTP of Ain Temouchent, the temperature measurement is done by an electronic thermometric, which is soaked carefully in the water sample. Then, the reading of the value is done after the stabilization of the thermometer.

Figure III.1. Temperature measurement with electronic thermometer

2. **pH**

The Potential of Hydrogen in the WWTP of Ain Temouchent is measured with a CRISON brand pH meter.

3. **Electrical Conductivity**

Conductivity expresses the capacity of water to conduct an electric current. Expressed in micro Siemens per second, temperature, the concentration of total dissolved salts, salinity and total dissolved solids (TDS) are used to calculate the electrical conductivity of water, where the value of the conductivity varies with these factors. It helps to indicate the water's purity. In the WWTP of Ain Temouchent, the conductivity is measured using a CRISON brand conductivity meter. The figure below shows the measurement of PH and conductivity.

Figure III.2: pH and conductivity measurement

4. **Total Suspended Matters (TSM)**

Organic and mineral fine particles compose the suspended matters which are insoluble in water and the responsible on the turbidity of water. The materials and experimental procedure used to determine the total suspended matters in the laboratory are explained below:

- ✓ Vacuum pumps
- ✓ Filtration unit
- ✓ Micro fiberglass filters

- ✓ Stove
- ✓ Desiccator
- ✓ Analytical balance
- ✓ Pliers

Procedure

a. The first thing to do is to wash the filter paper by distilled water in the vacuum filtration unit, then drie it in the stove at a temperature of 103 to 105 °C, for 2 hours. Then it is kept in a desiccator in order to ensure that every trace of water is eliminated than it is ready to be weighed. This weight represents M_1.

b. Secondly, the dry filter is placed in the funnel of the filtration device, and connected to a vacuum suction device which will accelerate the filtration process.

c. A very specific volume of the treated wastewater is filtered in a few seconds.

d. We carefully remove the filter that has in it our suspended matters, from the funnel using flat-ended pliers. It is then weighed using the analytical balance.

e. In order to remove all the water from the filter we dry it at about 105 °C, then cool it, and finally weight it to get the suspended matter results represented as M_2.

We can get the suspended matter value by using the following formula:

$$TSM\ (mg/l) = (M2-M1)*1000/V$$

Where:

TSM: Total suspended matters (mg/l)

M2: Mass of the filter after drying (mg)

M1: Mass of the empty filter, before filtration (mg)

V: Volume of the water sample filtered (ml)

Figure III. 3: Total suspended matters measurement

5. **Dissolved Oxygen (DO)**

The amount of oxygen gas dissolved in water (DO) is critical to the vitality of most aquatic organisms because it provides them with oxygen needed for cellular respiration. At the WWTP of Ain Temouchent level, dissolved oxygen is obtained by using a HACH brand oximeter. The oximeter probes are placed in the water sample. The reading of the value is done after the stabilization of the oximeter.

Figure III.4: Dissolved oxygen measurement

6. Biological Oxygen Demand (BOD5)

The biological oxygen demand (BOD) value refers to the concentration of organic matter in wastewater. BOD expresses the amount of dissolved oxygen the aerobic microorganisms require to oxidase or decompose the organic matter present in sample wastewater. BOD is often expressed by the milligrams of oxygen consumed per litter of sample, over incubation for 5 days at 20 °C in the darkness.

In a closed system microorganism consume oxygen in the water sample generating carbon dioxide (CO_2). The carbon dioxide CO_2 reacts with sodium hydroxide (NaOH) creating negative pressure in the medium, this pressure is measured by the transmitter. The transmitter transforms the pressure value directly to the BOD_5 (mg /l). With sample volumes, we regulate the amount of available oxygen which can make a complete determination of BOD at different concentrations and with different volumes.

For the BOD system, we have:

- ✓ Measuring heads (BOD sensors)
- ✓ Measuring bulbs brown
- ✓ Magnetic stirrers
- ✓ Pliers
- ✓ Rubber carcass for the necks of the bulbs
- ✓ Sodium hydroxide (NaOH) lenses
- ✓ Thermostatic incubator with constant temperature at 20 degree Celsius
- ✓ Inhibitor of nitrification.
- ✓ Containers and pipettes of several sizes
- ✓ Distilled water
- ✓ Calibration tablet for system controls OXITOP: D (+) glucose $C_6H_{12}O_6$ and L- glutamic acid $C_5H_9NO_4$.

Procedure

a. We select a sample of volume corresponding to the desired BOD to be obtained.

b. Than the bulbs are cleaned with distilled water so they are lightened, then with the sample of the treated water.

c. After that our bulbs are clean, we add a quantity of the homogenized sample.

d. We agitate each bulb with a magnetic stirrer.

e. Surround the neck of the bulb with a rubber carcass. Inside, add with the pliers the lenses of NaOH. Then fill with the treated water up to the limit without exceeding.

f. Finally, we place the bulbs in an incubator for the measurement of BOD5.The incubator is set to zero value and launched working at 20°C. The result of the value will be displayed directly on the device after five days.

Figure III.5: Biological oxygen demand measurement

7. Chemical Oxygen Demand (COD)

Chemical oxygen demand represents the amount of oxygen needed to chemically stabilize the carbonaceous organic matter by strong oxidant agents in an acidic medium. Below is the description of method used in the laboratory of the plant to determine the COD.

The test is an oxidation of the organic matter by a strong oxidant represented by the potassium dichromate ($K_2Cr_2O_7$) at high temperature and in an acidic medium carried out by adding the sulfuric acid (H_2SO_4) solution. Oxidizable substances reaction with potassium dichromates is accelerated by adding silver sulphates (Ag_2SO_4) as a catalyst. The presence of chloride is masked with mercury sulfate ($HgSO_4$). The presence of Cr^{6+} is indicated by a yellow coloring of it. This color transition is captured by a Spectrophotometer and expressed in mg O_2 /l (milliliter ppm O2).

The following material are used:

- ✓ COD measurement kits (Example: LCK 314 15-150 ppm / LCK 114 150-1000 ppm)
- ✓ Distilled water (dissolution cleaning).

- ✓ DRB-200 Digester
- ✓ Spectrophotometer DR 5000
- ✓ Gradette support
- ✓ Graduated pipette 2 ml
- ✓ Pipette aspirator 2 ml

Procedure

a. We select the suitable COD program: the program heats the vat for a period of 2 hours at 150 °C, then it will be cooled to 120 °C.

b. Into the vats, we add the solution of the kits after being mixed to have a homogeneous solution and 2 ml of water sample are pipetted carefully.

c. The thermostat is heated to a specific temperature, then we put the vats in a heating block DRB -200, and close the cover of protection. We lace the vats in the conventional COD digester for two hours at 150 °C.

d. We remove the hot vat and invert carefully twice.

e. The vat is cooled at room temperature in the vat support.

f. Finally, we clean the outside part of the vat and measure it with a HACH brand spectrophotometer.

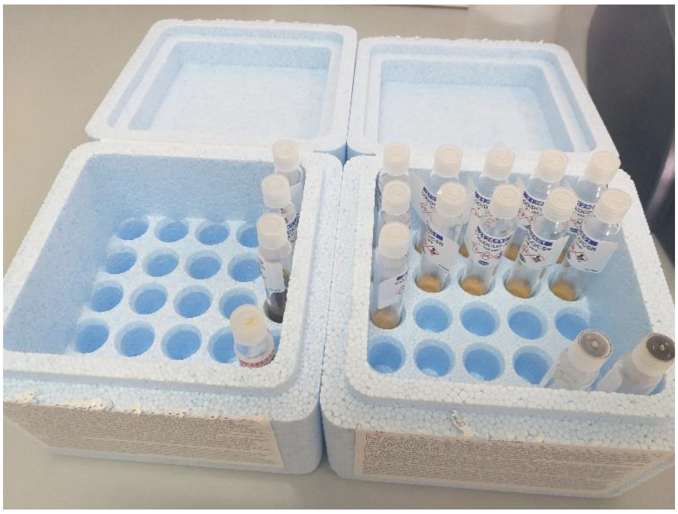


Figure III.6: COD measurement

8. **Ortho Phosphates ($PO4^{3-}$)**

Phosphorous is a mineral nutrient fundamental to all plants and microorganisms growth. Phosphorous concentration is a direct sign of the level of eutrophication phenomena. Phosphorous is present in the environment combined with organic matter and inorganic as orthophosphates and polyphosphates forms.

Ammonium molybdate and antimony potassium tartrate react in an acid medium with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex. This complex is reduced to an intensely blue-colored complex by ascorbic acid. The color is proportional to the phosphorus concentration. Only orthophosphate forms a blue color in this test.

The following materials are used:

- ✓ LCK 348 reagent.
- ✓ Distilled water.
- ✓ DR 5000 colorimeter.
- ✓ Graduated pipette 2 ml.
- ✓ Aspirators pipette 2 ml.

procedure

a. First step is to take off the sheet of protection from the detachable DosiCap Zip
b. Unscrew the DosiCap Zip.
c. Then, take 0.5 ml of sample with the pipette.
d. Screw the DosiCap Zip.
e. Agitate, then with a pipette of 0.2 ml we take that volume from reagent B (LCK 348 B) and add it into the vat once cooled.
f. Screw a gray DosiCap C (LCK 348 ^{o}C) onto the vat, and then mix very well the contents of the vat.
g. Let it rest for 15 minutes, then we mix again, be sure that the outside part of the vat is clean and measure.

The procedure described above is for the output water sample, same thing is done for the input we change only LCK 348 with LCK 350.

9. Total Phosphorus

The determination of total phosphorus (TP) in an aqueous sample is based on digestion of the sample to convert phosphorus compounds into orthophosphate, which can then be determined based on spectrophotometry according to the method described above for determination of orthophosphate.

Figure III.7: Phosphates and total Phosphorous measurement

10. Nitrates Nitrogen (NO3-N)

Nitrogen is a mineral nutrient fundamental to all plants and microorganisms' growth. Nitrate-nitrogen is the last product in the oxidation process of ammonia resulted from the first stage of the degradation of nitrogen.

In a solution of sulfuric acid and phosphoric, nitrates react with the dimethylphenol to give nitrodimethyl phenol.

The following items are used in the measurement process:

- ✓ Nitrate measuring kit (LCK 339)
- ✓ Distilled water
- ✓ Espectro DR 5000
- ✓ Graduated pipette 2 ml
- ✓ Aspirators pipette 2 ml

Procedure

a. 1 ml of water sample is pipped

b. 0.2 ml of the LCK 339 A solution is also pipped

c. Close the vat and ensure a homogenized mixture to the contents.

d. After fifteen minutes, thoroughly clean the outside part of the vat and measure.

Same procedure is followed for N-NO_3 of input measurement.

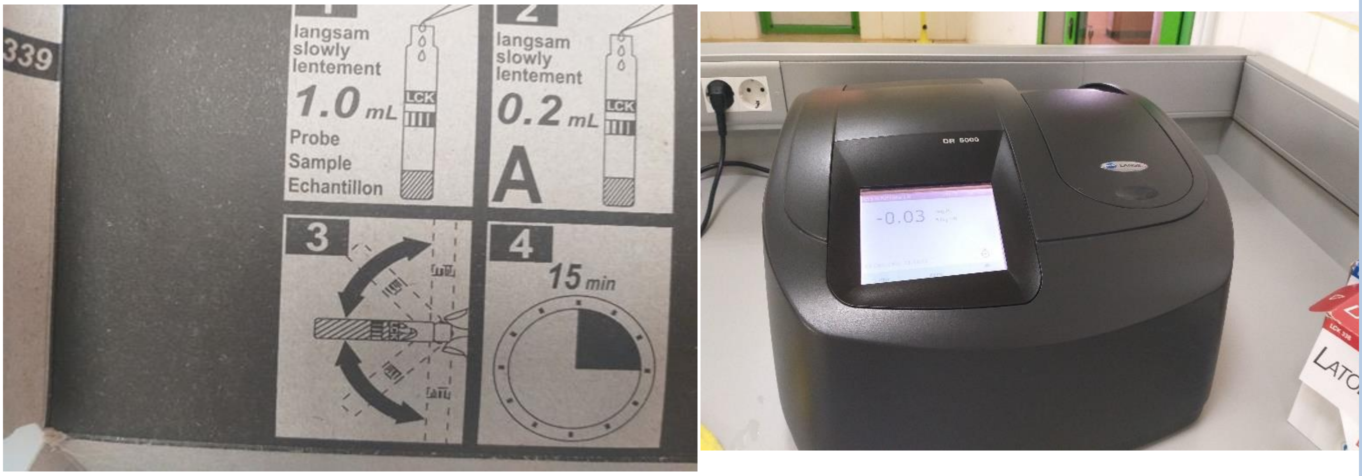


Figure III.8: Nitrates nitrogen measurement

11. Ammonium Nitrogen N-NH4$^+$

We can find nitrogen of wastewater in organic and inorganic forms. Inorganic forms are soluble in water and immediately available to the plant, while microorganisms must mineralize organic forms. The mineral forms of nitrogen are ammonium and nitrate.

In the presence of sodium as a catalyst and at a basic pH with a value of about 12.6, the ammonium ions give a blue color after reacting with hypochlorous and salicylic ions.

The following materials are used:

- ✓ Ammonium measurement kit (LCK 302/303).
- ✓ Distilled water.
- ✓ Espectro DR 5000.
- ✓ Graduated pipette 2ml.
- ✓ Aspirator pipette 2ml.

Procedure

a. First step is to take off the sheet of protection from the detachable DosiCap Zip.

b. Then we unscrew the DosiCap Zip.
c. Add 9 drops of Nessler reagent and 6 drops of polyvinyl alcohol dispersing agent to the water sample
d. 0.2 ml of sample is then pipetted.
e. Then we screw the DosiCap Zip.
f. Agitate until the total dissolution of the formed product.
g. After 15 minutes, we mix again, and then thoroughly clean the outside part of the tub and measure the number we read is for NH_3 in order to get the one of NH_4^+ we multiply by 1.29.

Figure III.9: Ammonium nitrogen measurement

12. Nitrite

Since nitrite is the intermediate of nitrification reaction in waste water treatment process it is only present in very low concentrations under normal nitrification conditions (about 0.1 mg/L), it is usually regarded as a minor measurement parameter in wastewater treatment plants. In the nitrification phase ammonium is oxidized using oxygen to form nitrite than nitrate.

By diazotising the nitrites with sulphanilic acid at pH 2.5 and subsequently coupling the compound formed with α-Naphthylamine (Griess reagent), a red azo dye which is stable for at least 12 hours is obtained, the intensity of which is measured at 520 nm.

The following items are used in the measurement process:

- ✓ Nitrite measuring kit (LCK 341)
- ✓ Distilled water
- ✓ Espectro DR 5000
- ✓ Graduated pipette 2 ml
- ✓ Aspirators pipette 2 ml

Procedure

a. Remove the Dosi Cap Zip cover that initially contains the LCK 341 solution

b. Add 2 mL of the water sample to the Dosi Cap Zip tube

c. Return the cover of the tube and agitate well the solution

d. Wait for 10 minutes than put the tube in the spectrometer and read.

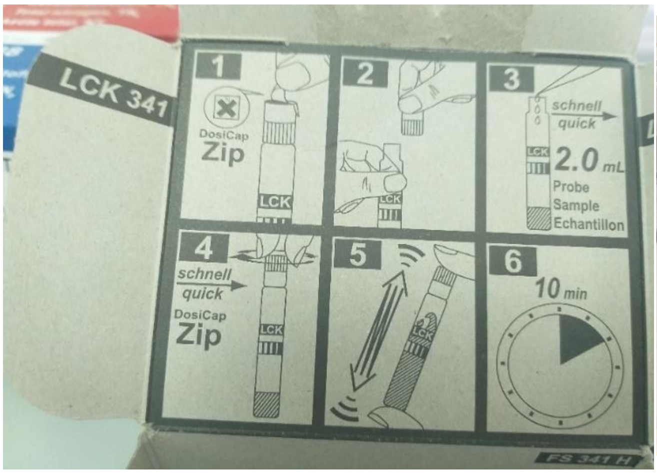


Figure III.10: Ammonium nitrogen measurement

13. Total Nitrogen

Total Nitrogen (TN) is the sum of nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N) and organically bonded nitrogen. At the entrance total Nitrogen is equal at ammonia-nitrogen only, however; at the output it is present as N-NO3 and N-$NH4^+$ the sample is heated at 360–410°C with concentrated sulfuric acid (H_2SO_4), which decomposes ("digests") the organic sample by oxidation to liberate the reduced nitrogen as ammonium sulfate. Catalysts like selenium, Hg_2SO_4 or $CuSO_4$ are often added to make the digestion go faster. Na_2SO_4 is also added to increase the boiling point of H_2SO_4. Digestion is complete when the liquor clarifies with the release of fumes.

The following items are used in the measurement process:

- ✓ LCK 238 reagent
- ✓ Distilled water
- ✓ Espectro DR 5000
- ✓ Graduated pipette 2 ml
- ✓ Aspirators pipette 2 ml

Procedure

a. Remove the cover Dosi Cap Zip cover

b. Take 0.2 mL from reagent A

c. Then add one pastille from reagent B

d. Put it in LT200 for 30 minutes at 120 ^{o}C

e. Cool it for 15 minutes, then agitate it to be mixed very well

f. Take 0.5 mL and put it in the Dosi Cap Zip tube

g. Now we add 0.2 mL from reagent D and we ensure that the solution is mixed well

h. Let it again rest for 15 minutes

i. We clean the vat and put in the spectrometer and we note the given value

Figure IV.11: Total nitrogen measurement

III.2 Statistical Analysis

Daily water analysis data obtained from the WWTP of Ain Temouchent are classified in excel, then compared to the norms of World Health Organization (WHO) and transformed to graphs in order to have a meaningful understanding.

III.3 Dysfunctioning analysis

From the graphs and the results of calculating the difference between the values of the plant and the WHO standards we can define the problem in the plant performance and preventive or corrective solutions are proposed by following the steps of DFMEA.

DFMEA is to identify and prioritize the potential failure modes that may occur on equipment, to investigate the effects on the main functions of the equipment and to identify the causes. For the determination of the criticality of failure modes, DFMEA requires for each failure mode the investigation of the severity of its effects, the frequency of its occurrence and the probability of its detectability.

IV. WASTEWATER TREATMENT PLANT OF AIN TEMOUCHENT

IV.1. Geographical Location

The wastewater treatment plant of Ain Temouchent is located on the northern side of the city of Ain Temouchent, near the national road towards Terga. It is limited to the East by the police station of the city, to the South by the national road towards Oran, to the North by the wadi Sarrane, to the West by some living residences. The wastewater treatment plant is implemented on an area of six ha. It treats all domestic wastewater and rainwater from the city of Ain Temouchent. A unitary sewerage system transports the wastewater to the plant. The operation of the plant has started in January 2014. The plant treats the domestic wastewater from 72,800 inhabitants. The average daily treated wastewater is estimated to 10,920 m3/day, namely (455m3/hr). During the rainy period, the average treated is estimated to 1,365 m3/hr. The plant use activated sludge technique. The Total annual volume of treated wastewater is estimated to 3.5 million m3 in 2017.

Figure IV.1: Geographical location of the WWTP (Source: Google Earth Pro, 2020)

IV.2. Description of the Operating Process of the Treatment Plant

At WWTP, both the wastewater and the sludge are treated for that there is two departments, one for treating the wastewater and the other is for treating the sludge.

III.2.1 Description of the Treatment Processes of the Wastewater

The storm water is collected by the storm weir which is located outside the plant.

The storm weir

The domestic wastewater from the city of Ain Temouchent from is transported gravitationally by a storm weir towards the treatment plant by a pipe made of concrete, with a diameter of 800 mm and a length of 250 m. During the rainy period, the exceeded wastewater to the inflow rate to be treated is deviated laterally through a channel towards the wadi Sarrane.

Figure IV.2: The Storm weir (Source: WWTP of Ain Temouchent, 2020)

Once the water is inside the plant it will go through several treatment processes:

Figure IV.3: wastewater inlet in the WWTP (Source: WWTP of Ain Temouchent, 2020)

a. Pre-Treatment

At this level the wastewater go through mechanical and physical treatment processes, the WWTP of Ain Temouchent, carry out:

a.1. SCREENING

Large solid waste such as dishcloths, plastics, wood, tires, cans, etc. are disposed of. The equipment required at this level are:

- ✓ **mobile vertical emergency bar screen**:

Before the coarse mechanical bar screen, there is a vertical travel barrier to be used only during the maintenance period of the coarse mechanical bar screen. The mobile vertical bar screen is made of galvanized steel, 850 mm wide and 1000 mm high. The thickness of the bars is 15 mm and the spacing between the bars is 50 mm.

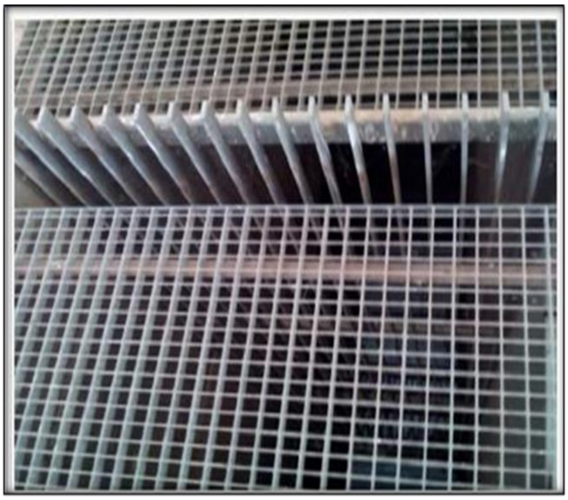


Figure IV.4: The mobile vertical bar screen (Source: WWTP of Ain Temouchent, 2020)

- ✓ **Coarse Mechanical Bar Screen**

A vertical screen with coarse mechanical bars used for pre-treatment. It operates automatically following the rise in the upstream wastewater level and has the following characteristics: width 1000 mm, bar spacing 35 mm, bar thickness 30 x12 mm. It is designed to remove all solid pollutants of considerable size to prevent clogging of the sand trap and fine bar screen cells. At this level, solid waste with a size greater than or equal to 35 mm is eliminated. The collected solid waste is then taken over by a steel screw conveyor and discharged to prevent the diffusion of bad odours.

Figure IV.5: The coarse mechanical bar screen (Source: WWTP of Ain Temouchent, 2020)

A.2 THE SAND TRAP

The sand trap removes at first time sand elements contained in the wastewater that move to the bottom of the channel. By gravity, the collected elements are retrieved in a hopper located under the canal and conveyed by a pump towards the sand washer. The volume of the sand pit is 7.86 m3, with seven rectangular holes. Each hole is 8 mm wide and 900 mm long. They are installed orthogonally to the wastewater flow. The sand pit is also provided with two pumps for sand extraction and a sensor to detect the level of settled sand.

Figure IV.6: The sand trap (Source: WWTP of Ain Temouchent, 2020)

A.3. FINE MECHANICAL BAR SCREENS

Two sub-vertical fine bar grids are placed, with a slope of 85°. The width of each bar screen is 1000 mm, the distance between the bars is 3 m, the discharge height from the bottom of the channel is 4.5 mm. Both units are designed to remove all solids with dimensions greater than or equal to 3 mm.

Figure IV.7: Fine Mechanical bar screens (Source: WWTP of Ain Temouchent, 2020)

a.4. CONTROL OF THE PRE-TREATED WASTEWATER FLOWRATE

A venturi meter mounted at the bottom of a channel measures the flow of pre-treated wastewater from the previous units. An ultrasonic flowmeter is fitted, by means of which the different flow values in cubic metres per hour can be read. It displays the instantaneous flow rate as well as the accumulation for the whole day. It is placed in a compartment adjacent to the installation block.

Figure IV.8: Pre-treated wastewater (Source: WWTP of Ain Temouchent, 2020)

a.5. THE LIFTING STATION

The lifting station is composed of four submersible pumps, i.e. three pumps in service and one pump in stock. Their performance is capable of satisfying the maximum peak flow rate in rainy seasons, each pump having a flow rate of 500 m^3/h. From there, the pre-treated wastewater is directed to the following units where the remaining polluting greases, oils and sands are removed.

Figure IV.9: The lifting station (Source: WWTP of Ain Temouchent, 2020)

A.6. Sand, Grease and Oil Removal

This is the process of physical treatment of wastewater. Pre-treated wastewater has a significant amount of sand, grease and oil, which can impede or slow down the performance of downstream structures. At this stage of pre-treatment, we find two pieces of equipment (grit remover and degreaser) for the removal of sand, grease and oil. These two pieces of equipment have a volume of 120 m^3 each, a width of 5.7 m, a height of 5 m, a surface area of 10 m^2 and a length of 12 m. To ensure the removal of inert elements of small granulometry, a mechanized sand trap is utilized in which air is blown through a compressor to prevent the fermentation of the effluent to be treated.

Lubricants and floating bodies are transferred to the surface in the area of the lateral stilling zone. Grease and sand oils are recuperated by means of a motorized mobile bridge with a bottom scraper for sands. The floats and oils are discharged by a scraper into two storage basins with a capacity of 20 m3 each embedded in the downstream side of the sand pit. The sand decanted at the bottom of the basin is scraped off in the pit at the entrance of the sand pit. A pump collects the sand in an intermittent manner by pushing it back into a washing device. The retention time for an intermediate flow rate is 25 minutes, resulting in a separation efficiency of 98.5% for particle sizes between 0.12 and 0.16 mm.

Figure IV.10: Sands, grease and oil removal units (Source: WWTP of Ain Temouchent, 2020)

At this point the primary treatment ends and the water is transferred to the secondary treatment units.

b. Secondary Treatment: Biological Treatment

The pre-treated water drains into a section where a volume of recycled sludge from the second clarifier is added. In this compartment, the recycled sludge from the clarifier is pumped in liquid form and mixed with the pretreated water. Then the water that has been mixed with the recirculated sludge circulates in the distribution channel with the aerated liquor before entering the denitrification tank.

B.1. AERATION BASINS

- **Denitrification**

Biodenitrification can be described as a process by which microorganisms convert nitrate ions and nitrogen gas (N_2), nitrous oxide ions (N_2O) into nitric oxide (NO). Biological denitrification is the most widely used system for nitrogen removal in urban water treatment plants.

Bacterial strains that can develop biological denitrification are termed heterotrophs because they can metabolize the complex organic substrate by oxidizing its various compounds using molecular oxygen (when available) or the oxygen present in the nitrate. Under conditions of anoxia, specific bacteria reduce nitrate by a mechanism in which nitrate and nitrite dissolved in water replace oxygen for cellular respiration.

The nitrate dissimilation process is carried out by a series of complex two-step enzymatic catalysis reactions: In the first stage, nitrates are reduced to nitrites, in the second stage, nitrites are reduced to nitrogen gas (N2). At Ain Temouchent wastewater treatment plant level, there are two denitrification basins with the following features: height 4.77 m, width 20 m and length 21.7 m. The wastewater is subjected to a strong agitation during this process by means of a series of mixers acting in counter-current. This type of device has optimum mixing characteristics.

Figure IV.11: Aeration basins for denitrification (Source: WWTP of Ain Temouchent, 2018)

B.2. NITRIFICATION

The nitrate dissimilation process is carried out by a series of complex two-step enzymatic catalysis reactions: In the first stage, nitrates are reduced to nitrites, in the second stage, nitrites are reduced to nitrogen gas (N2). At Ain Temouchent wastewater treatment plant level, there are two denitrification basins with the following features: height 4.77 m, width 20 m and length 21.7 m. The wastewater is subjected to a strong agitation during this process by means of a series of mixers acting in counter-current. This type of device has optimum mixing characteristics.

Figure III.12: Aeration basins for nitrification (Source: WWTP of Ain Temouchent, 2020)

The water after passing through all these steps then flows to the secondary clarifiers.

B.3. SECONDARY CLARIFIER

The treatment plant of Ain Temouchent is endowed with two circular secondary peripheral clarifiers with bottom scraper, a central deflector for radial distribution, a surface blade for the evacuation of the scum towards the scum box linked to a well, a mobile pump ensures the evacuation of these scums with the oils and greases. The tractors have a diameter of 25 m and a total height of 4.4 m.

Figure IV.13: A secondary clarifier (Source: WWTP of Ain Temouchent, 2020)

According to the staff of the plant's laboratory, previous studies carried out before the construction of the treatment plant have shown that the wastewater from the Ain Temouchent is charged with a high concentration of phosphorus (more than 40 mg/l), compared to European wastewater (maximum 20 mg/l). However, some analyses conducted by the plant's laboratory have shown that the treated wastewater from the clarifiers contain a high amount of phosphorus remains. For this purpose, the water exiting the clarifiers must be treated in a tertiary way.

Figure IV.13: Treated wastewater flowing from the clarifiers (Source: WWTP of Ain Temouchent, 2020)

c. Tertiary Treatment

The water coming out of the clarifiers is directed to a distributor well to be subjected to phosphorus precipitation treatment by a dosage of the ferric chloride, mixed at the well through a quick stirrer, separated into three lines and each directed to the clarifloculator for the precipitation of phosphorus in the form of chemical sludge. The chemical sludge is evacuated to the thickener by submerged pumps installed at the chemical sludge well.

C.1. THE CLARIFLOCCULATORS

A couple of circular clarifiers with peripheral traction and a slow type agitator, each with a diameter of 22 m and a total height of 4 m, are mounted for the complexation of phosphorus with ferric chloride. Afterwards, the concentration of phosphorus decreases while a chemical mud is formed. This sludge will be evacuated to the sludge thickener by submerged pumps installed inside the clarifiers.

Figure IV.15: A clariflocculator (Source: WWTP of Ain Temouchent, 2020)

After all these treatment processes, the water will undergo a disinfection treatment for the elimination of pathogenic microorganisms.

C.2. THE DISINFECTION BASIN

Ain Temouchen waste water treatment plantt is equipped with a disinfection basin with the following characteristics: a water height of 2.75 m, a width of 5 m and a length of 23 m. The estimated total volume is 326.6 m3. The reagent for disinfection is sodium hypochlorite (NaClO). The predicted contact time is 43 minutes for the average daily input flow and 14 minutes for the maximum input flow during rainy periods. However, the chlorine disinfection treatment is suspended in the treatment plant due to the absence of sodium hypochlorite in the plant.

Figure IV.15: The disinfection basin (Source: WWTP of Ain Temouchent, 2018)

Finally, the purified wastewater will flow through a canal to be discharged in the wadi Sarrane.

III.2.2 Description of the Treatment Processes of the Sludge

The treatment processes of the sludge are comprised of the following steps:

a. Recycling and Disposal of the Exceeded Sludge

During this step, the activated sludge is withdrawn from the bottom of the clarifier and sent back to the top of the biological treatment, in view of regenerating it and maintaining a substantially constant concentration of purifying microorganisms. A submerged pump and a reserve pump, placed in a well, ensure this recycling operation. Each pump has the following characteristics: The unit flow rate is equal to 455 m3/h and the head is equal to 5.0 m. In the same well, there are two other pumps, one of which is in storage, for the discharge of excess sludge to the thickener. The characteristics of these pumps are as follows: The flow rate is equal to 30 m3/h, the total head is equal to 5.0 m. The maximum concentration of sludge extracted from the clarifier is approximately 0.8%. In each recycling line, a flowmeter is inserted in order to adjust the recycling flow rate according to the flow of wastewater entering the treatment plant.

b. Thickening of Biological and Chemical Sludge

This treatment is the initial step in significantly reducing the volume of sludge from both biological and chemical wastewater treatment. The excess sludge is directed to a circular thickener with a diameter of 16 m and a total height of 4.5 m. Mechanization is applied in a slow scraping and stirring system to facilitate the sliding of the sludge towards the central pit from which it is extracted and to allow the release of pore water and gases contained in the sludge.

Figure IV.16: Sludge thickener (Source: WWTP of Ain Temouchent, 2020)

c. Sludge Dewatering

Dehydration is the second step in reducing the volume of the sludge in order to bring them to the solid state. In the wastewater treatment plant of Ain Temouchent, the dehydration is done through drying beds and by pressing band.

C.1. Drying Beds

We can find six drying beds at the plant, with the following characteristics for each beds: a length of 20 m, and a width of 5 m. The drying time in the plant is normally about 4-6 weeks, however, it can reach 3 to 4 months during hard weather conditions.

Figure IV.18: Drying beds (Source: WWTP of Ain Temouchent, 2020)

C.2. Belt Press

Sludge dewatering is also effected by a conventional belt filter press. The plant is composed of two belt presses located in a suitable dewatering building. Each belt press is 2500 mm wide. Their operating time is approximately eight hours per day, and they operate five days a week.

Figure III.19: Sludge dewatering belt press (Source: WWTP of Ain Temouchent, 2020)

V. RESULTS AND DISCUSSION

V. I. Performance Analysis

In order to evaluate the quality of the treated water and monitor its efficiency, a series of physicochemical analyses were carried out at the outlet of the WWTP for the years of 2014, 2015, 2017, 2018 and the first semester of 2020. All the analyses that we have carried out represent all those made for the diagnosis of a treatment plant. They are carried out on: BOD_5, COD, Temperature, pH, conductivity, N-NO_3^-, NO_2^-, N-NH_4^+, Total Nitrogen, PO_4^{3-}, Total Phosphorus, Dissolved Oxygen and Total suspended matters. The parameters are compared to the WHO, FAO and the Algerian government standards.

TableV.1: FAO standards for physico-chemical of water used for irrigation (Source: (Ayers & Westcot, 1985)

Potential Irrigation Problems				**Units**	**Degree of Restriction on Use**		
Salinity					**None**	**Slight to Moderate**	**Severe**
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 - 2000	> 2000
Infiltration							
SAR	= 0 - 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	=3 - 6		=		> 1.2	1.2 – 0.3	< 0.3
	=6 - 12		=		> 1.9	1.9 – 0.5	< 0.5
	=12 - 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20- 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity							
	Sodium (Na)						
	Surface irrigation			SAR	< 3	3 - 9	> 9
	Sprinkler irrigation			meq/l	< 3	> 3	
	Chloride (Cl)						
	Surface irrigation			meq/l	< 4	4 - 10	> 10
	Sprinkler irrigation			meq/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous Effects							
	Nitrogen (NO_3 - N)			mg/l	<5	5 - 30	> 30
	Bicarbonate (HCO_3)			meq/	< 1.5	1.5 – 8.5	> 8.5
pH				**Normal Range 6.5 – 8.4**			

Table V.2: FAO Laboratory standards needed to evaluate common irrigation water quality problems Source: (Ayers & Westcot, 1985)

Water parameter	**Symbol**	**Unit**	**Usual range in irrigation water**	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	dS/m

(or)				
Total Dissolved Salts	TDS	mg/l	0 – 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	meq/l	0 – 20	meq/l
Magnesium	Mg^{++}	meq/l	0 – 5	meq/l
Sodium	Na^{+}	meq/l	0 – 40	meq/l
Carbonate	CO^{--}_3	meq/l	0 – .1	meq/l
Bicarbonate	HCO_3^-	meq/l	0 – 10	meq/l
Chloride	Cl^-	meq/l	0 – 30	meq/l
Sulphate	SO_4^{--}	meq/l	0 – 20	meq/l
NUTRIENTS				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	pH	1–14	6.0 – 8.5	
Sodium Adsorption Ratio	SAR	(meq/l)	0 – 15	

Algerian standards for the Physico-chemical parameters

Table V.3: Algerian standards for physico-chemical of water used for irrigation (Official Journal of the Algerian Republic, 2006).

PARAMETRES VALEURS	**LIMITES**	**UNITES**
Temperature	30	C°
pH	6.5 – 8.5	
TSM	35	mg/1
BOD_5	35	mg/1
COD	120	mg/1
Total Nitrogen	30	mg/1
Phosphates (PO_4^{-3})	02	mg/1
Total Phosphorous	10	mg/1

❖ **Physico-chemical parameters**

1. **Temperature**

The temperature of treated water for the years, 2014, 2015, 2017, 2018 and 2020 is drawn in the following graph and compared to the FAO guidelines.

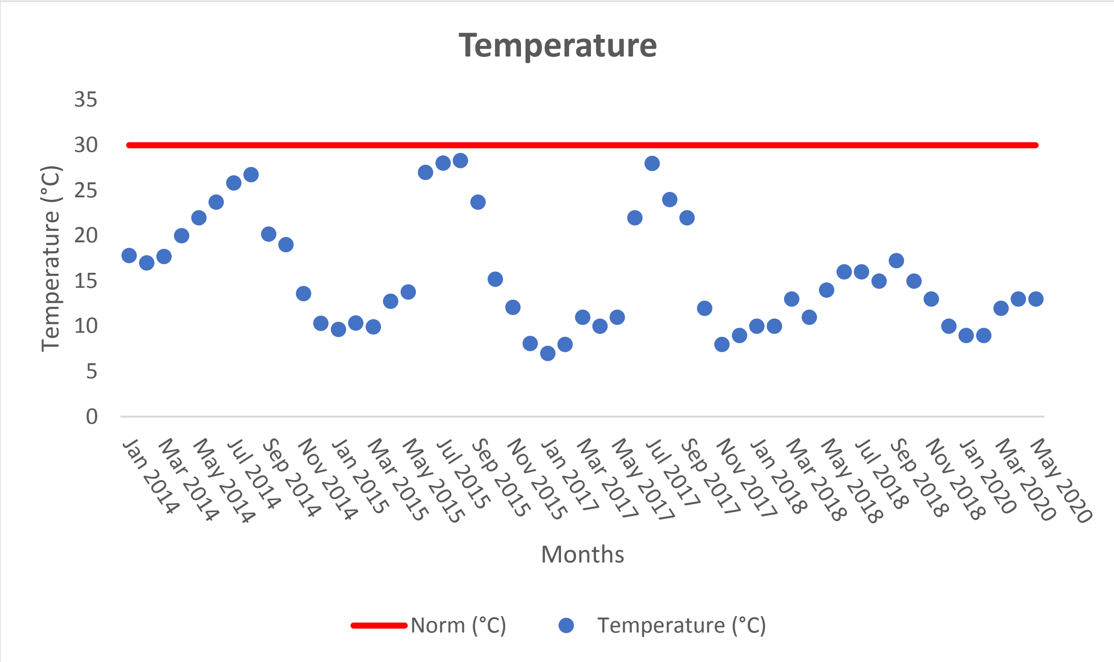


Figure V.1: Seasonal variations of Temperature values for waste water after treatments (2014-2020)

Temperature is an important ecological factor. The analysis of this parameter is very important, as it conditions many parameters, such as electrical conductivity, dissolved oxygen and pH, as well as the degradation and mineralization reactions of organic matter [30]. Also, it plays an important role in biological nitrification and denitrification.

According to graph V.1, the temperature values analyzed during the study period vary from 7 ºC in January 2017 to 28.32 ºC in June 2017. Temperature variation over time is influenced by seasonal change and atmospheric temperature, as Algeria is known to have the four seasons from cold in winter and hot in summer.

We can observe that the temperature is at the norms and did not exceed the norms set by the FAO.

2. pH

The average change in the pH of the water at the inlet of the WWTP is shown in Figure V.2

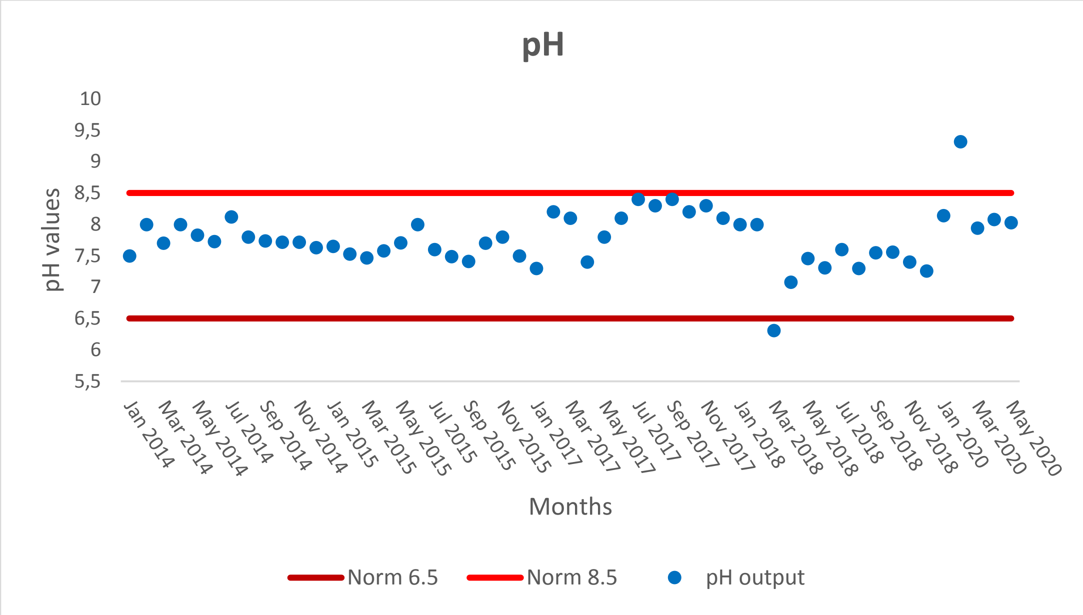


Figure V.2: Seasonal variations of pH values for waste water after treatments (2014-2020)

The pH plays an important role in many processes of aquatic life. It reflects many biological and chemical processes that occur in the aquatic environment. The main ones are the photosynthetic activities of aquatic plants, respiration of aquatic organisms, decomposition of organic matter, precipitation, dissolution, and redox reactions that occur in the aquatic environment. Living organisms are both pH-dependent and pH-sensitive. It is not only a measure of the potential pollutant, but is also initially related to the concentration of many other substances, especially weakly dissociated acids and bases.

The pH values vary from 6.31 in March 2018 to 9.32 in February 2020 with an average of 7.77. These minimum and maximum values are the only values out of norms as shown in the figure V.2. It was noticed that the highest values of pH are in the last spring/summer period in Algeria ranging from March to September. This can be attributed to the elevation in temperature which generate a loss of CO_2 because of evaporation and precipitation of monocarbonates. (Hutchinson & Stokes, 1975). We notice also, that the two values out of norms are noted in 2018 and 2020 which indicates that the plant is not functioning well.

3. Conductivity

The seasonal variations of the conductivity of the water at the outlet of the WWTP (2018 and 2020) is shown in Figure V.3,

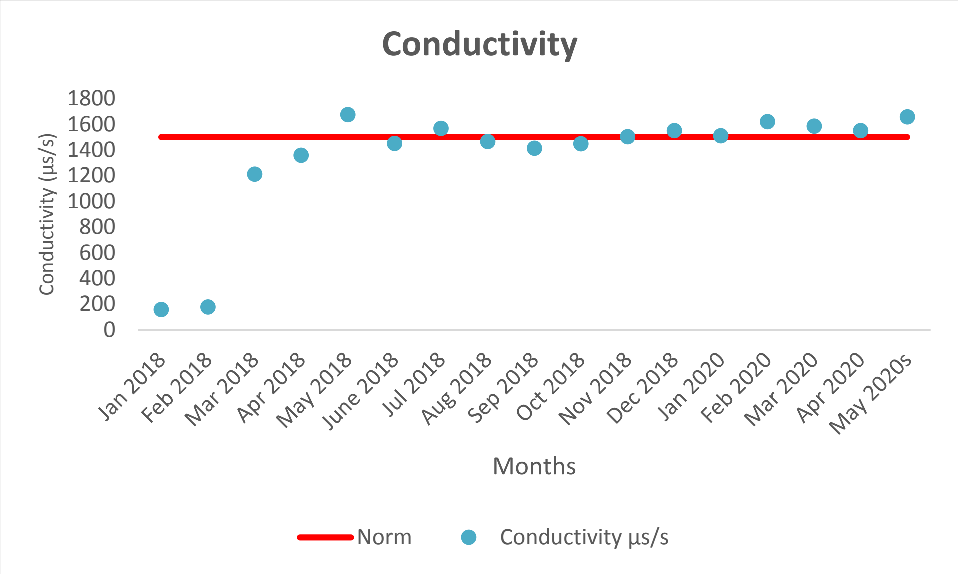


Figure V.3: Monthly variations of conductivity values for waste water after treatments (2018, 2020)

As shown in figure V.3, the water conductivity is around the norms, where the minimum value of 159.25 µS/s was recorded in January 2018 and the highest value of 1677,75 µS/s in May 2018 &2020. The highest value is greater than the norm by 11,85%. This indicates that there is a considerable number of ions in the discharged water that consider a sign for a problem in the functioning.

4. Total Suspended Matters

The seasonal changes in the TSM concentrations of the water at the outlet of the WWTP (2014 2020) is shown in Figure V.3,

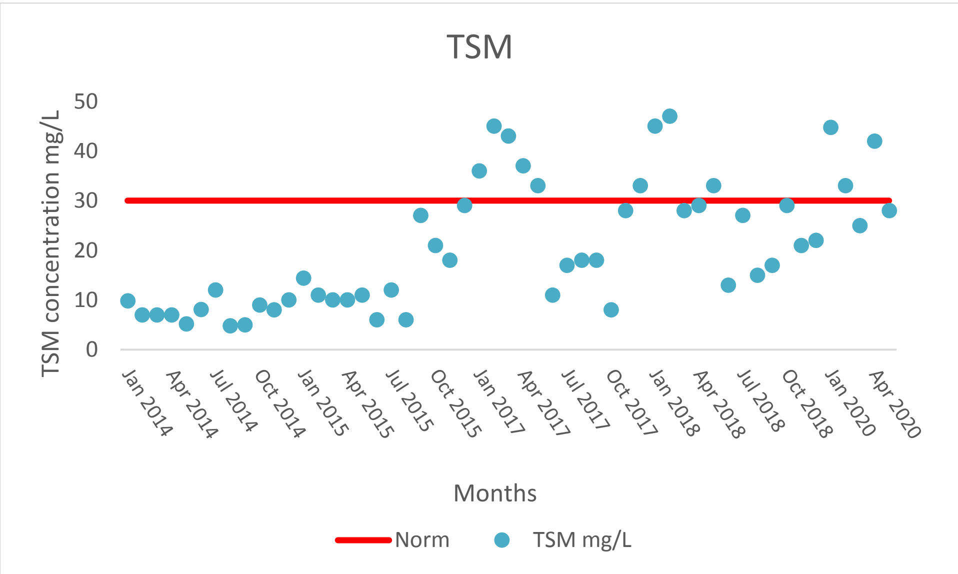


Figure V.4: Seasonal variations of TSM values for waste water after treatments (2014-2020)

TSM represent materials that are neither in a dissolved nor colloidal state, and therefore filterable. They are organic and/or mineral and allow a good evaluation of the degree of pollution of a water [26]. According to figure V.4, we distinguish that TSM concentrations are unstable during the study period. From January 2014 to December 2015, the amount of TSM in the treated water is under the norms. However, in 2017, 2018 and 2020 an increase in the TSM concentrations were detected and exceeds the norms with the highest values in the cold seasons. The highest concentration is recorded in February 2018 at a value of 47 mg/L, while the lowest concentration of 4.8 mg/L was registered in August 2014. This can be explained by "solid transport, which is very high in the wetter months and low in the warmer months, despite evaporation and algal production". For this reason, the outflow concentrations are variable that means bad decantation.

5 Dissolved Oxygen DO

Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms and is used as an indicator of the health of surface-water bodies (Lewis, 2006). Oxygen content of water depends on a number of physical, chemical, biological and microbiological processes. The content of oxygen is an important indicator of pollution of a water body, indicating its biological state, the predominant processes occurring in it, the destruction of organic substances and the intensity of self-purification.

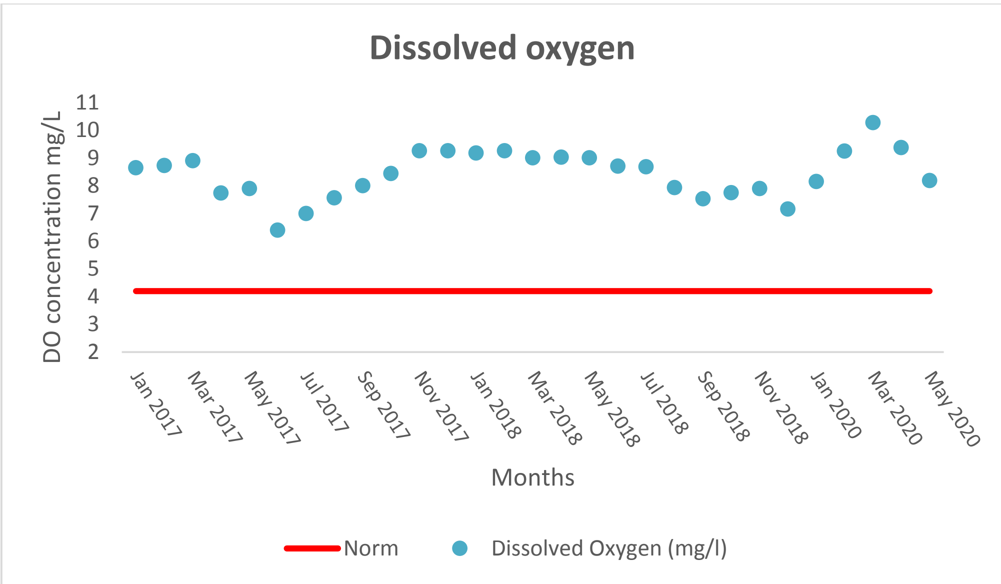


Figure V.5: Monthly variations of DO values for waste water after treatments (2017, 2018, 2020)

In the present study, an assessment of the dissolved oxygen status for the treated wastewater from the WWTP of Ain Temouchent has been carried out throughout the years of 2017, 2018 and 2020. The maximum concentration of dissolved oxygen in the treated water with a value of 10,27 mg/L was recorded in March 2020. However, a minimum value of 6.39 mg/l was detected in June. Increased aeration derived from the blooming of active winds play an important role in increasing dissolved oxygen in the surface water especially in winter season. However, a minimum value of DO in summer may be due to higher temperature that increases evaporation process and the high load of agricultural and sewage wastes, contain high load of organic matter that consume large amount of DO mostly in the surface layer.

6 .Biological Oxygen Demand BOD_5

BOD_5 or biological oxygen demand is the amount of oxygen needed by aerobic micro-organisms to oxidize biodegradable organic matter in water. It is therefore a potential consumption of oxygen by biological means. This parameter is a good indicator of the biodegradable organic matter content of polluted natural water or waste water.

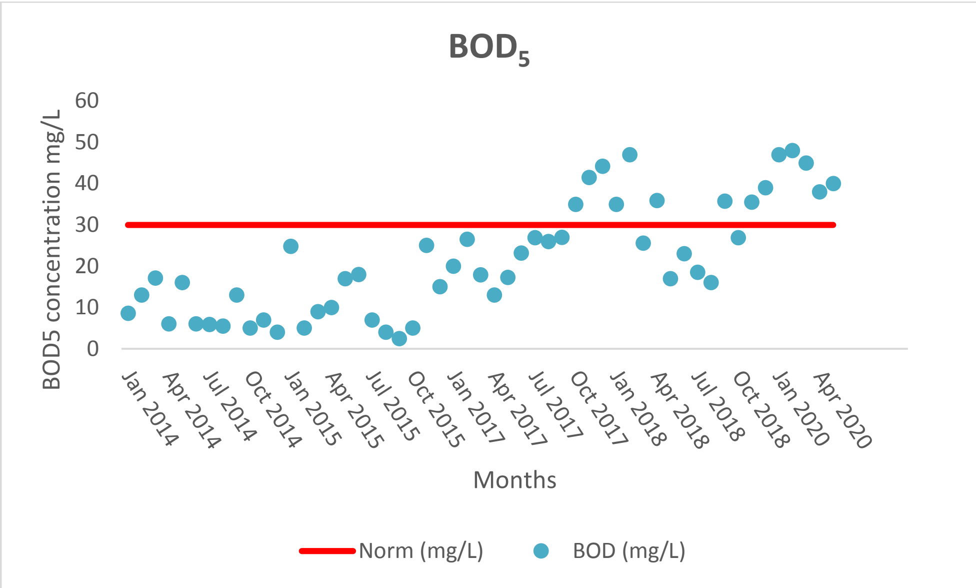


Figure V.6: Seasonal variations of BOD_5 values for waste water after treatments (2014-2020)

As shown from Figure V.6, the highest concentration of 48 mg/L was recorded in February 2020 and the lowest concentration of 2.5 mg/L in September 2015. Based on results obtained, the amount of BOD_5 in the discharged water is higher than the norms in several months especially in winter and autumn, also, we should specify that this elevation is marked in the autumn of 2017 and the winter of 2018 and 2020. These results lead us to think in the bad functioning of the treatment process at the plant level which lead to bad quality of water for irrigation.

7 Chemical Oxygen Demand COD

COD is defined as the amount of dissolved oxygen used to oxidize and stabilize a sample when organic or inorganic matter of sample solution is responsive by a strong chemical oxidant. The higher COD values, the higher the amount of pollution in the water sample. Generally, COD is considered one of the important quality control parameter of an effluent in wastewater treatment facility (Wu et al., 2011)

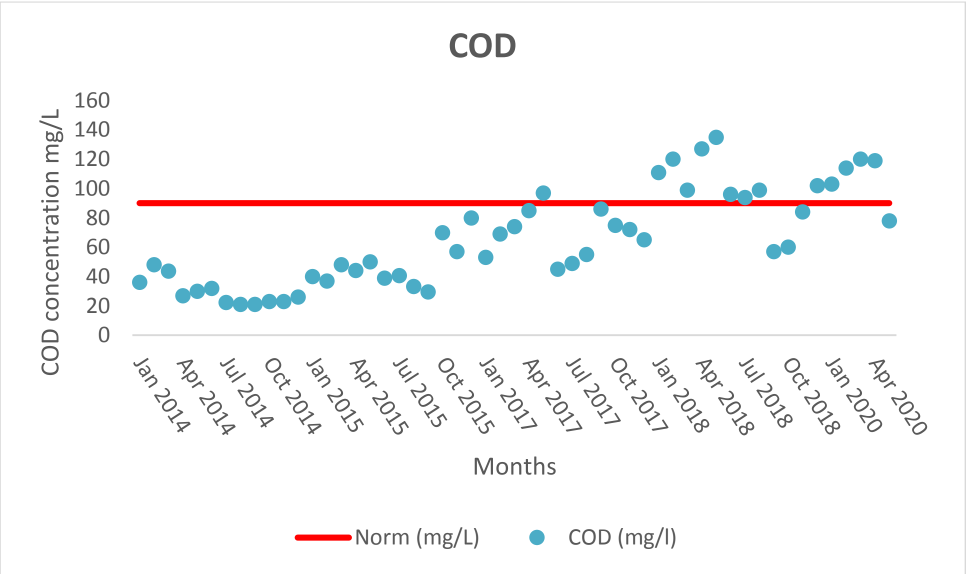


Figure V.7: Seasonal variations of COD values for waste water after treatments (2014-2020)

The absolute values of chemical oxygen demand (COD) for the waste water after the treatment varies between a minimum of 21 mg/L in September 2017 and a maximum of 135 mg/L in May (Figure V.7). The overtaking of values over the norm is observed in the autumn of 2017 and winter of 2018 and 2020. This means the chemical compounds are not oxidized and the process of treatment represent a problem.

8 Nitrate N-NO_3

Nitrogen is one of the biologically important elements in the aquatic environments where Nitrate is the final oxidation product of nitrogen compound in natural waters (Riley and Chester, 1971). For plants, however, nitrates are an essential source of nitrogen and in many cases appears to be the major limiting nutrient for phytoplankton growth. Usually, the nitrate ion exists at higher concentrations than ammonium in irrigation water. Natural soil nitrogen or added fertilizers are the usual sources, but nitrogen in the irrigation water has much the same effect as soil applied fertilizer nitrogen and an excess will cause eutrophication problems, (Tak et al., 2010).

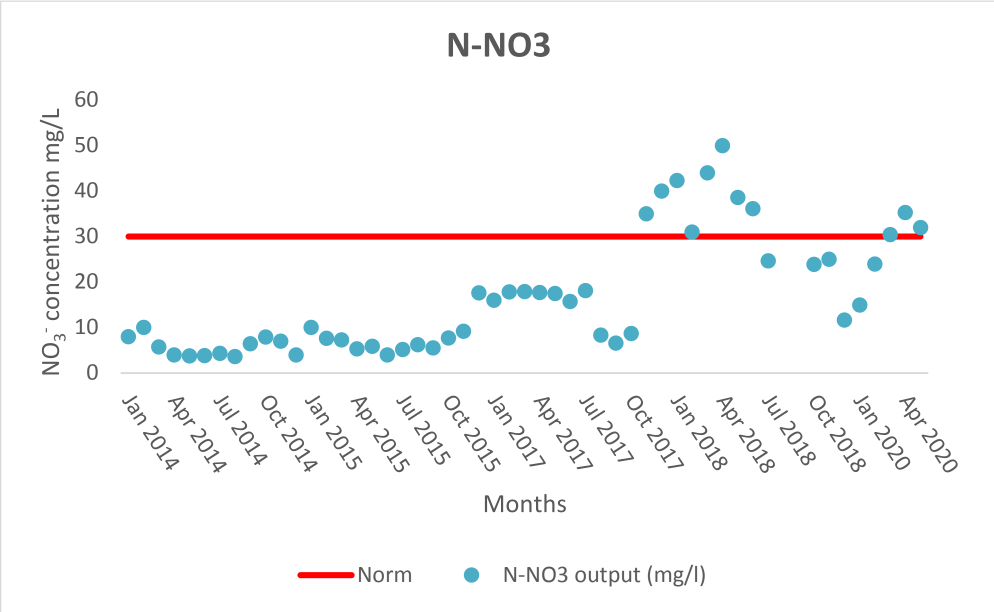


Figure V.8: Seasonal variations of NO_3^- values for waste water after treatments (2014-2020)

From Figure V.8, it was evident that in the period from 2014 to 2017 seasonal maximum nitrate values occurred during the winter season but still under the norm line. This can be attributed to the high precipitation associated with high freshwater discharges and high concentrations of washed nutrient salts from agricultural areas. In addition, lower winter temperatures may contribute to increased solubility of dissolved oxygen in water. On the other hand, the low value in summer may be due to increased nitrate uptake by phytoplankton blooms developed during warmer seasons, resulting in increased denitrification (EPA, 2001). Fortunately, in the period (2014-2017), the variation in nitrates in the water recorded during this period is below the limited value set by the Algerian government for irrigation water (30 mg/l). This result can be attributed to the performance of nitrification-denitrification bacteria during biological treatment. However, in the years of 2018 and 2020 we see an instability in the concentration of Nitrate while it exceeds the standard value, a hypothesis can rise here stating that the denitrification of NO_3^- to NO_2^- than N_2 has failed, which lead us to suspect the existence of problem in the biologic treatment.

9 Nitrite – N (NO_2^-)

Nitrite ions (NO_2^-) are the product of either the oxidation of ammonium ion ($NH4^+$) under aerobic conditions by nitrosomonas bacteria or the reduction of nitrate ions (NO_3^-) in anoxia by heterotrophic bacteria.

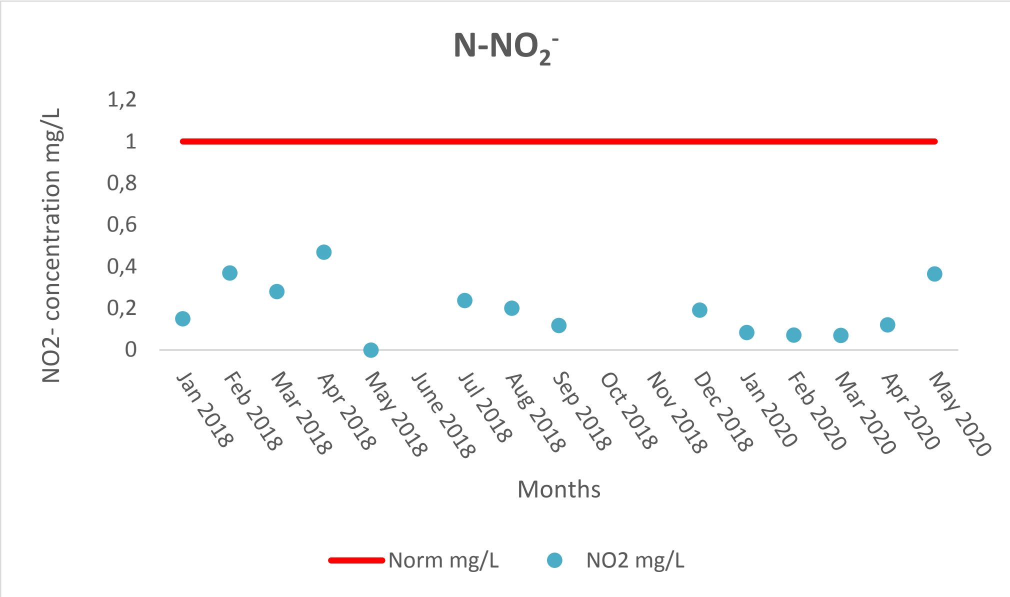


Figure V.9: Monthly variations of NO_2^- values for waste water after treatments (2018, 2020)

From the figure V.9, it was noticed that the amount of NO_2^- in water is under the norm value set by the Algerian government for irrigation water (1 mg/l), with a maximum value of 0.47 mg/l in April 2018 and minimum value of 0.001 mg/l in the in May 2018.

10 Ammonium -N (NH_4^+)

Ammonia is being produced for commercial fertilizers and other industrial applications. Naturally occurring sources of ammonia include the decomposition or degradation of organic wastes, gas exchange with the atmosphere, forest fires, animal and human wastes, and nitrogen fixation processes. Ammonia enters the aquatic environment through both direct ways, such as municipal sewage discharges and animal excretion of nitrogenous wastes, and indirect ways, such as nitrogen fixation, atmospheric deposition and agricultural runoff. (EPA, 2019). Ammonium ion NH_4^+ is frequently found at low levels in water compared to nitrate and organic nitrogen. It is the predominant form in the pH range of most natural waters and less toxic to fish and aquatic life as compared to NH_3. As the pH increases above 8, the ammonia fraction begins to increase rapidly. In the rare situation that a natural water pH exceeds reaches 9, ammonia and ammonium ion would be nearly equal (Wall, 2013).

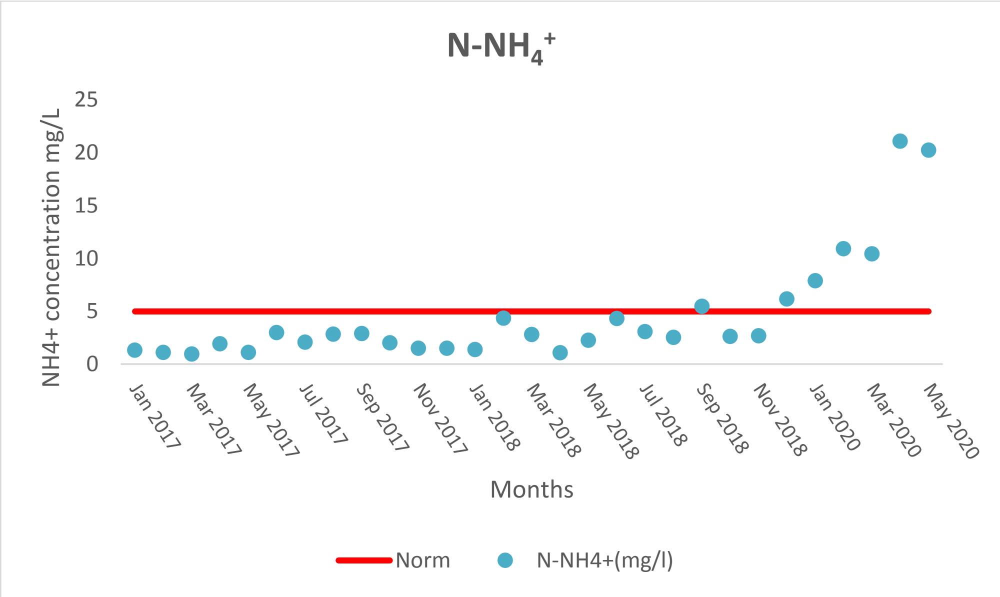


Figure V.10: Monthly variations of NH_4^+values for waste water after treatments (2017, 2018, 2020)

In the period between 2017 and 2018 ammonium was present in the treated water of Ain Temouchent at a very low concentration, with the lowest concentration of 0.97 mg/L in March 2017. However, an elevation in its concentration was recorded in May 2020 with a value of 21.1 mg/L. In this period the concentration of NO_3^- ions was quiet low, that may explain the fact that NH_4^+ was not oxidized to give NO_3^-.

11 Orthophosphates PO_4^{3-}

Phosphorus can hasten eutrophication (a decrease in dissolved oxygen concentration in water bodies because it increases mineral and organic nutrients) in rivers and lakes. Phosphorus high concentration was the Ain Temouchent WWTP major problem since it has started working.

From Figure V.11, it was observed that the variation of the phosphates throughout the years under investigation is not uniform. The minimum value was detected in November 2018 since the irrigation is not high in this periode time comparing to the spring and summer seasons. Generally, as seen from Figure V.11, the PO_4^{-3} concentrations are high than the limited phosphate standard set by FAO and the limited value set by the Algerian government for irrigation water (2 mg/l). Unfortunatly, the effectiveness of phosphorus removal during wastewater treatment can vary, depending on the available equipment and the treatment methods used. Only wastewater treatment plants that employ specialised phosphorus removal techniques will normally be able to remove phosphorus to the desired levels. (Andrew Miley, 2018)

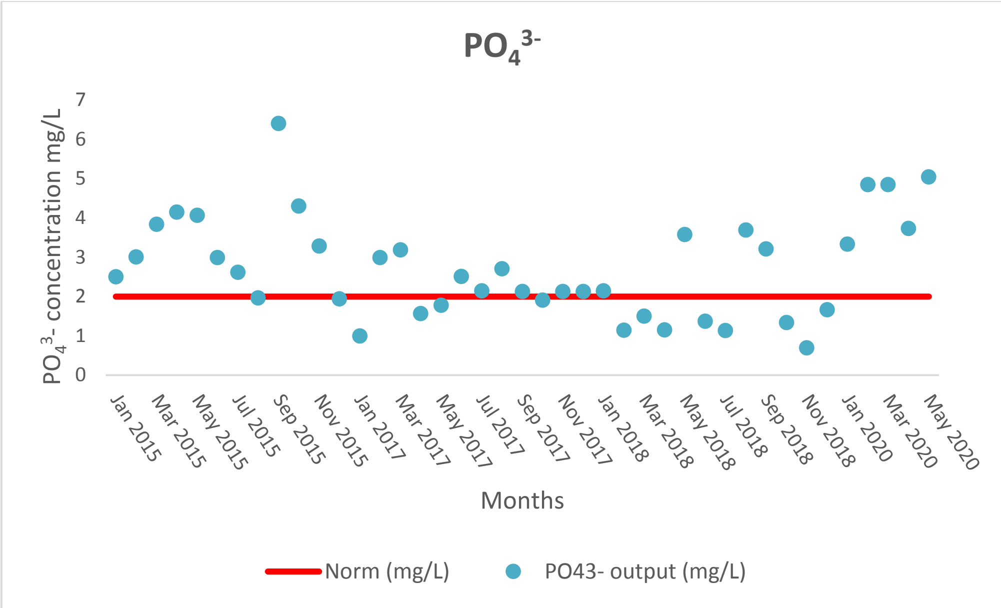


Figure V.11: Monthly variations of PO_4^{3-} values for waste water after treatments (2015, 2017, 2018, 2020)

12. Total Phosphorus TP

Total Phosphorus concentrations in mg/L of treated waste water are shown in the following graph

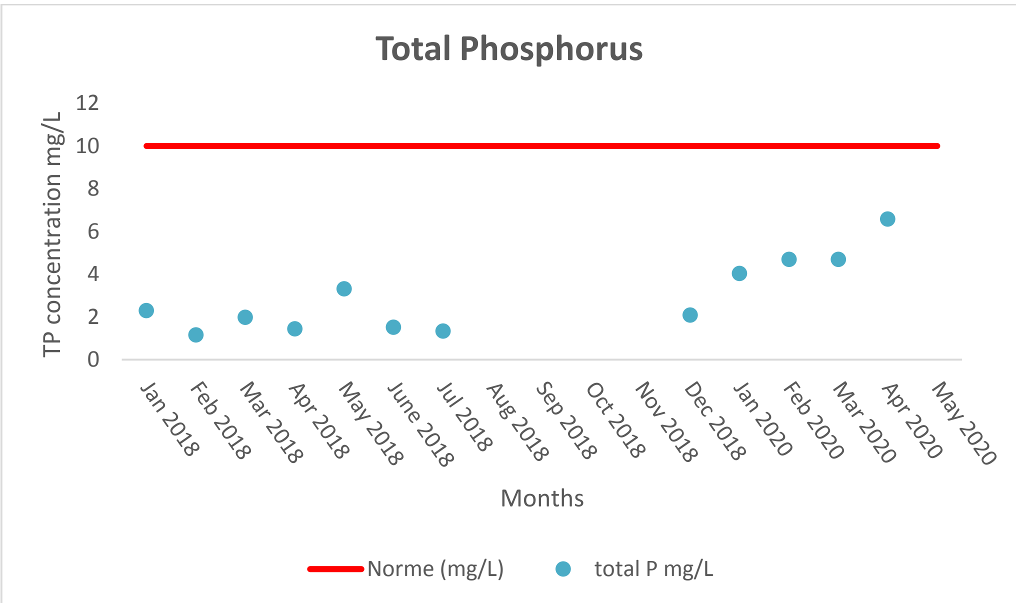


Figure V.12: Monthly variations of TP (mg/L) values for waste water after treatments (2018, 2020)

Total phosphorus has been measured starting from 2018, we have the result of 2018 and the first five months of 2020. In this period the maximum recorded value is 6.57 mg/L in April 2020 and the minimum is recorded in February 2018 with a value 1. 16 mg/L. These values are under the norm value of 10 mg/L.

13. Total Nitrogen TN

Total Nitrogen concentrations in mg/L of treated waste water are shown in the following graph

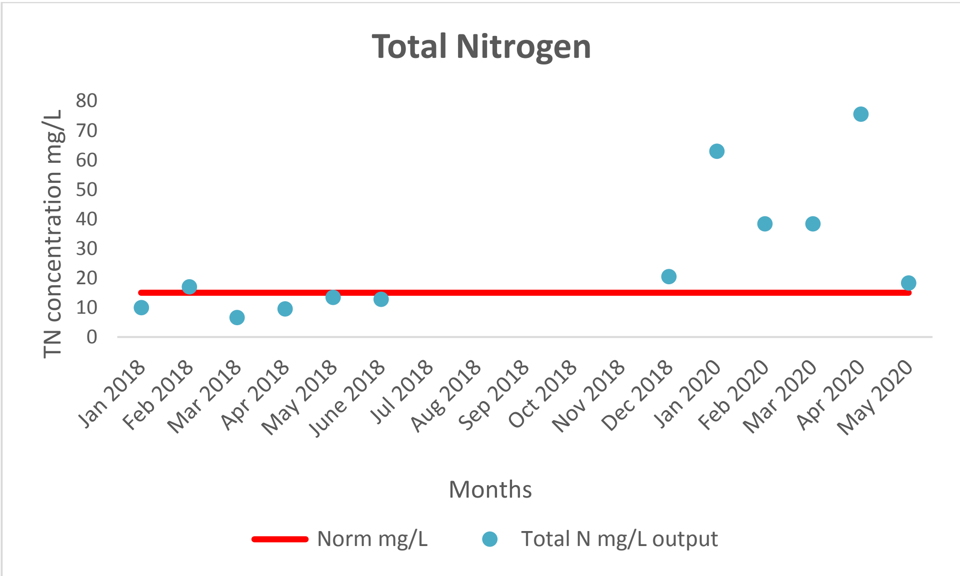


Figure V.12: Monthly variations of TN (mg/L) values for waste water after treatments (2018, 2020)

The results from figure V.13 confirm what we have found in the NO_3^- and NH_4^+ that total nitrogen concentration is high in 2020 and it is overpasses the norm of 15 mg/L. in April 2020 the concentration has reached 75.6 mg/L while the minimum value of 6.6 mg/L was recorded in March 2018.

Process operating parameters

The operation of a WWTP is based on several essential parameters, namely: mass load, volume load, sludge concentration in the aeration tank, sludge age and residence time. The latter gives some characteristics on the operating parameters of activated sludge systems.

Due to lack of data of daily load and dry matter concentration we could not calculate the majority of process operating parameters. But, we can calculate the factor of biodegradability K and use it in our discussion in the case of COD and BOD.

❖ **Biodegradability Factor K**

K is the ratio between the concentration of COD over the concentration of BOD, its value gives us an idea about how biologically degradable our water is. Our decision is made according to the following intervals:

1<K<1,5 the effluent is biodegradable

1,5<K<2,5 the effluent is moderately biodegradable

K>2,5 the effluent is not biodegradable

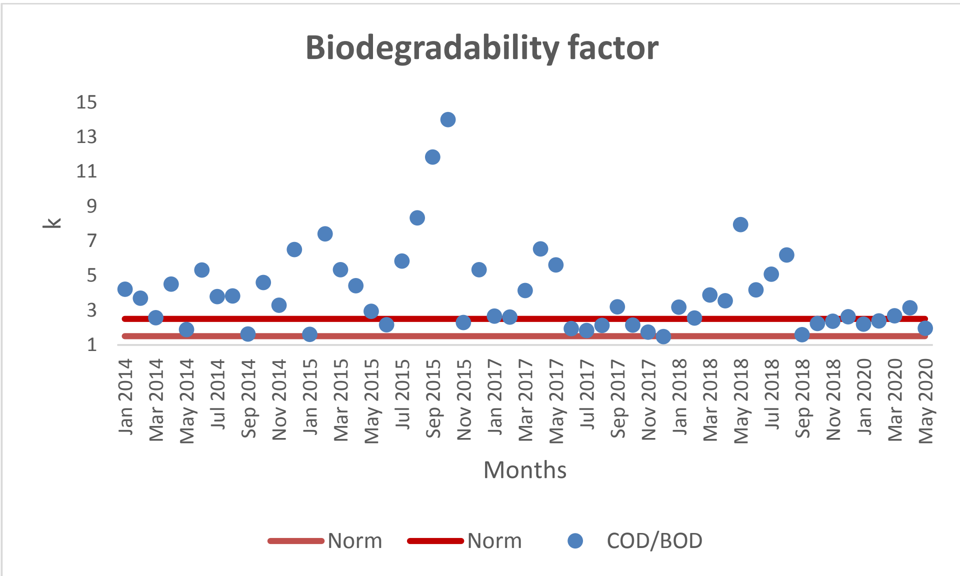


Figure V.14: biodegradability factor (2014,2015,2017,2018,2020)

General discussion and conclusion

From the analysis of the performance of the station of Ain Temouchent based on the physico-chemical parameters and the parameters of system operation, we noticed that total suspended matters TSM, chemical oxygen demand COD, biological oxygen demand BOD, orthophosphate PO_4^{3-} and nitrate NO_3^- are present in the outlet water with high concentration especially in the period from 2017 to 2020. We can say that the WWTP has functioned very well in the first years after its launch in 2013. However, in last three years, some critical parameters do not meet the standards which indicates the presence of problems in the treatment process.

The plant was designed to treat 10,920 m^3/day coming from sewage of 72.800 in 2013 habitant. However, the habitant of Ain Temouchent has increased to 83.894 in 2018 (ministry of industry,

2018) with a daily flow ranging from 8.200 m^3/day to 16.000 m^3/day. This non uniformity in treated water leads to problems in treatment process that in consequence affects negatively the quality of the effluent water. Also, the majority of parameters out of norm are treated in the aeration basin that lead us to think in the possibility of the shortage in the bacteria in the basin. This can be justified by the high values of V_{30} which are always higher than 900 mL, while they are supposed to be less than 400 ml. This problem appeared in 2018, hence before this date the values of V_{30} were in the range of 200-300 ml.

Deeper analysis will be held in the coming part where we will study the causes of the dysfunction of the station of treatment based on DFMEA analysis.

V.II. Failure Analysis of the WWTP of Ain Temouchent

The control of WWTPs and their operation is often tiring because of the upheavals that can occur and which are difficult to define and predict. A simple failure detected is detrimental in an environment where performance is necessary. It is therefore mandatory to ensure that the WWTP is always in good working order (Faucher, J, 2009; Curely, V, 2014). Once the standards are exceeded and related to the non-compliance with discharge standards, the malfunctions will then be analyzed based on the DFMEA which analyzes the failure modes, in order to find the causes, their effects and try to find solutions to solve the problems and ensure the continuity of correct system operation (Faucher, J, 2009).

V.II.1. Main dysfunctions observed in the wastewater treatment plant

In this study we will mainly focus on the parameters that showed an overtaking to the norms, these parameters are: Biological Oxygen demand BOD, Chemical Oxygen Demand COD, Total Suspended Matters TSM, Orthophosphates PO_4^{3-} and Nitrogenous compounds (Nitrates NO_3^- and Ammonium NH_4^+). Temperature, pH, Conductivity, Dissolved Oxygen, Nitrite NO2-, Total Nitrogen, Total Phosphorus have been interpreted in the section of performance.

a. *Total suspended matters*

The previous analysis of total suspended matters (figure V.4) showed that the TSM concentration has exceeded the norm with 56,66% in 2018.

The malfunctions concerning the TSM are given in Table IV.3, where each failure is given its causes and the main possible corrections.

Also, for each failure, a degree of criticality is assigned to demonstrate the importance of the failure in the operation of the treatment plant.

The degrees of criticality given in the DFMEA table are:

(1) : Minor failure

(2) : Major failure

(3) : Critical failure

(4) : Catastrophic failure

Where:

Minor Failure: It is a failure, which does not reduce the organization of a device and allows it to perform its required function". It causes negligible damage to either the system or the environment.

Major failure: It is a failure, which may reduce the ability of a more complex device to perform its required function. It is also referred to as a significant failure. It does not cause significant damage to the system, the environment or humans.

Critical failure: "Failure that could cause injury to persons or serious damage to equipment. This failure results in the loss of an essential function(s) of the device with an impact on the environment, systems and people.

Catastrophic failure: "Failure that results in the loss of an essential function(s) of a device by causing significant damage to the system, the environment and may even result in death.

Table V.4: Analysis of the dysfunctions observed with their causes and some specific solutions proposed for TSM in the framework of the DFMEA

Dysfunction	**Causes**	**Solutions**	**Criticality degree**
- Sealing between the bars - Presence of a large quantity of accumulated deposits and filaments	- Water too heavily laden -Waste nature mixed with raw water - Waste size	- Cleaning and maintaining them in good working conditions, especially in the winter period when it freezes. - Continuous cleaning.	**3**

	- Very slow effluent flow rate - Improper cleaning of grilles	- Put on a signal device in case of clogging. - Measuring the flow speed	
Corrosion	Presence of corrosive products in the water -Iron presence -Nature of materials used in the manufacture of the pieces of the station	Use corrosion protective products such as paint...	**2**
Breakdown of the comb	-Broken pieces on the inside -Presence of a blocked element -Plugging -Malfunctioning	Quick and automatic adjustment	**3**
Grid breaking	Very high effluent flow speed	Install sensors to control and measure the flow rate and speed of passage at the entrance	**4**
Problem with air blower pumps	-Plugging -Sand leakage indoors	-Periodic cleaning of the pumps. -Availability of spare parts for each type of pump in case of failure.	**2**
Sand deposits on the bottom and	-Prolonged period of effluent in the basin	- Good sand recovery -Continuous cleaning -The equipment in place must allow daily evacuation of the deposits.	

accumulation of sandy material	-Problem with the bottom scraper	- Design an efficient and easy refusal recovery system (channels remaining dry in the absence of effluent passage). -Daily extraction (if manual operation) of sands and deposits from the bottom of the structure. - Drain the work when not in use.	**2**
Presence of sand particles at the outlet	-Insufficient time for sedimentation -Failure to respect the time required for the effluent to clear the sands -Overloaded water	-Respect the particle velocity and limit the settling time.	**2**
Flow overload at the facility	Lack of monitoring and continuous control and measurement	locating the sensors and flow devices at the entrance to the structure and taking time measurements.	**3**
Total stop of process function	-Poor management -Sampling errors that require water testing in the laboratory	-Good management and organization -Develop an automation and remote management model to solve problems in a very fast and measurable way of the breakdown degree.	**4**

	-lack of continuous monitoring and control	-Monitoring and Maintenance of components	
Effectiveness of the degreaser in the capture of colloidal greases is limited	Elevated water effluent temperature Presence of tensioactive products such as detergents	-Enrich the effluent with products that can lower the temperature. -Create an internal circulation of the effluent using turbines to regulate the water temperature and facilitate the removal of grease. Systematic elimination of floaters.	**3**
-Problem with the surface scraper -High quantity of fats and oils and poor recovery	- Raw water quality -Incorrect dimensioning -Time is not controlled	- Continuous control of the floating load - Presence of the automatic detectors signalled in case of leaks or failure of the deep pumps or at the scraper level	**3**
Sludge leaks	Hydraulic overload	Reduce the treated volume	**2**
- Low agglomerated sludge	- Scattered growth of bacteria	-Identify the source of the overload - Increase ventilation in case of temporary overloads (seasonal variations). Provide for an increase in aeration capacity	**2**

- Abnormally high TSM content at the output	- Very high organic overload: high mass load treatment	- Adding, as a last resort, a flocculating agent to improve sedimentation - Increase the frequency of sludge extraction to reduce the age of the sludge	
- Increase in the Mohlmann Index (sludge volume index) - Sludge departure (with unchanged sludge appearance)	Increase in sludge concentration in the aeration basin: reaction to a hydraulic surge or temporary overload.	-Extraction of sludge to obtain fresher, more settleable sludge	**3**
Highly colloidal water	-Ventilation breakdown - Risks of bad aeration -Excessive increase in sludge that may contribute to a new upsurge in nutrient deficiencies.	- Increase the number of bacteria - Construct recovery chutes to evacuate surplus in case of high organic matter load - Minimizing the flow at the entrance of the aeration basin	**2**
-Poor oxygenation at the aeration basin. level -Incorrect adjustment of the aerators	- Over-consumption of electricity -Failure of every second turbine in a row	-Check all electrical installations -Set up automated sensor boxes in case of problems.	**3**
- Sludge lifts to the clarifier top surface	-Anoxic period too short in the aeration basin. - Denitrification at the bottom of the clarifier: release of nitrogen	Decrease aeration in the aeration tank (longer anoxia time and partial inhibition of nitrification)	**3**

	microbubbles and entrainment of sludge to the surface		
- Increase in the Mohlmann Index. - Difficulty in settling. - Flaky aspect of the sludge (lightness and large friction surface) and filamentous overgrowth (explosion of sulfur-assimilating bacterial growth). - Odour of rotten eggs possible (bulking)	-Septic effluent: presence of sulfureted hydrogen. - Explosion of sulfur-assimilating bacterial growth leading to filamentous overgrowth -Development of flaky sludge that prevents settling (lightness and large friction surface) -Aeration basin mixing fault	- Investigate the reason for effluent septicity (return to the top of the sludge storage silo drips, aeration basin mixing and deposit build-up, excessive residence time in the clarifier or in the networks, settling in the networks). - Separate the functions of thickening and sludge storage - Prohibit the return to the water treatment chain of drippings from the sludge storage silo. - Check the condition of the clarifier bottom scraper. - Ensure proper mixing of the aeration tank. - Controlling hydrogen sulphide emissions into the sewer system (installation of oxidation pots, air or water injection, submerged iron sulphate lift station, oxidation towers)	**3**

- Good purification. With bad decantation and a clear outlet. - Presence of filaments. - No notable presence of hydrogen sulphide	Organic overload with lack of aeration (network flushing) - Connection of industrialists or craftsmen. - Effluent with abnormally low pH (<0.6) - Development of mycelium (fungi and molds)	- Significantly increase aeration and more even sludge extraction - If necessary, use bleach at a rate of a few grams per cubic meter. The lethal dose of filamentous cultures is lower than the bacteria useful for purification. This application entails a risk of total destruction of the microflora and production of toxic compounds (chloramines). - Search for the acid source - Neutralize effluents - Increase ventilation - Increase the frequency of sludge extraction	**3** **3**
-Presence of sludge in the chloration tank	-Leakage at the decanter -Hydraulic limit situations of the	-Check sludge recovery lines	**3**

	clarifier and clogging of the clarifier	-Continuous water analysis at the outlet	
-Accumulation of sludge in the decanter -Loss of decanter efficiency	-Loss of a valve-pump assembly -Check the bottom scraper	-Check the bottom scraper -Control the quality of the sludge water at the outlet of the decanter	**4**

b. Biological oxygen demand COD

From our previous analysis to the performance of the station we noticed that the concentration of BOD_5 in the treated water overpasses the norm in autumn and winter time, while the overtaking ranges from 16% in October 2017 and 60% in February 2020. It is to highlight that this dysfunctioning is observed starting from autumn 2017, while the BOD_5 concentration is under the norm from 2014 to summer 2017.

c. Chemical Oxygen Demand COD

Figure V.5 shows that the COD amount in effluent is upper than the norm in the period from November 2017 to May 2020, with a minimum surpassing of 58% in January 2020 and a maximum with 322% in May of the same year. However, in the period from 2014 to 2017 no overtaking was marked and the quality of the treated water met the standards.

d. Biodegradability factor K

It is clear from figure V.14 that the majority of K value are superior of 2,5 with some ranging from 1,5 to 2,5. We noted a minimum value of 1,47 in October 2015 and a maximum at 14 in December 2017. We can say that the treated water is either moderately biodegradable or in the most months not biodegradable and the water entering the station is mixed with industrial descharges.

in the table V.5 we will discuss in detail the main failures in relationship with Biological Oxygen Demand and Chemical Oxygen Demand.

Table V.5 Main dysfunctions observed with their causes and some specific solutions proposed

Dysfunction	Cause	Solution	Criticality

Poor purification	-Purification cycles too short -Insufficient sludge -Organic overload -Insufficient aeration cycle	- Decrease the number of daily cycles - Increase sludge content -Increase the ventilation time	**3**
- Development of viscous foams on the surface of basins - Bad decantation. -Restoring BOD5/N/P balance by adding urea	Significant nitrogen deficiency. -Effluent not strictly urban: connection of industrialists or craftsmen.	- Uncovering the source of imbalance -Restoring BOD5/N/P balance by adding urea	**3**
Presence of light protein foams on the surface of basins	-Presence of surfactants in the effluent received (detergents) or protein effluent. - Likely connection of industrialists (dairy) or craftsmen - Sludge too young - Extraction too large and too brutal	- Investigate and treat the source of surfactant or protein effluent input - Reduce sludge extraction volumes	**3**
- Sludge removal without change of aspect - Increase in the Mohlmann Index	- Increase in sludge concentration in the aeration tank: reaction to a hydraulic surge or temporary overload	- Increasing sludge recirculation to stop the evolution of sludge haze in the clarifier - Extracting sludge to obtain younger, more settleable sludge	**3**

- Sludge leaks	- Hydraulic overload	- Decrease the volume processed	**2**
-Low Nitrification	- Sludge age too short: extraction too high - Correct sludge age: limited aeration	- Decrease sludge extraction - Increase ventilation - Check effluent for toxicity, pH and temperature	**3**
- Low denitrification	- Too short anoxia time in the pools - Recirculation of the mixed liquor is too low (anoxie line at the head) - BOD5/N ratio too low	- Decrease the oxygenation of the aeration basin - Increase recirculation of mixed liquor - Discover the source of the imbalance. Acting the brownness at the source	**3**
-Volatile fatty acid-generating septicity	-Returns from excess sludge storage silos -Extended residence of mud at the bottom of the thickener (more than two days). -Returns of old floats from the clarifier or degassing station. -Water from oversized or under-loaded or poorly exploited pre-treatment works (e.g. insufficient extraction of pre-treatment by-products)	-Precipitation: only on reduced sulphur which causes a blackish coloration of the effluent (iron sulphide) -Oxidation (aeration, chemical oxidants) -Pressurization of the network in order to limit the residence time of the water.	**2**

-Presence of foams -Poor degradation of the pollutant load	-Unfavourable environment for the development of bacteria -Increase in dry volatile matter -Dissolved oxygen concentration is not sufficient for organic molecules degradation (poor aeration) -Problem with O2 aerators Continuous and non-measurable sludge recirculation to aeration tanks -Very high water temperature -Age of sludge -variation of the mass load -Oxygen sensor is miscalibrated -Change in pH -Presence of inhibitory elements	-Good oxygenation -friendly environment for bacteria -Instal devices and sensors to specify the amount of O2 -Control the flow rate at the inlet of the aeration basin and measure the quantity of organic load. - Carry out regular water and sludge analysis -Carry out periodic Biological Analysis -Injects flocculants to improve biological bacterial purification in water	**3**
-High sludge load in the aeration tank	-Recirculation of sludge from the thickener to the aeration tank -Problem with the sludge recirculation screws to the thickener,	-Measuring the quantity of sludge circulated in the aeration tank	**3**

	forcing the sludge to return to the aeration tank or clarifier. -Pump clogging	-Periodic cleaning of the transport pipes	
Poor cleaning At the aeration basin level	Carbohydrate-rich substrate -Nutritional imbalances (N) -Nutritional deficiencies -Variation of loads -O2 deficiency and easily assimilated substrate -Nutritional Deficit Not very pronounced (*Time of anoxia too long, floating, septic return, deposits *Diluted effluent Low nutrient (N and P) and O2 deficiency *Slight) -Sludge age, persistent floating and rich in fatty acids (floating on structures) -Underload of the installation -The death of bacteria	-Nutrient supplements -Sludge over-oxidation -Extension of the station -Create a contact zone before the aeration basin	**4**
	-The nature of the pollution to be treated (composition of the waste water, evolution		

Expansion(Abundance)	over time, nutritional deficiencies or imbalances). -The septicity of the wastewater. -Aeration conditions. -Mixing conditions. -Prolonged sludge stays at the bottom of the clarifier. -The mode of flow of the water to be treated. -Deterioration in the quality of the discharge in the event of episodic or chronic sludge loss. -a slightly flaky floc with a large settled volume during the settling test, which makes it imperative to dilute the sludge samples	-Identification of the filaments, intensity of the phenomenon: monitoring of the sludge index, ... -Aeration and sludge management, mixing conditions, composition of the water to be treated	**3**

e. Nitrogenous compounds (NH_4^+, NO_3^-)

From figure V.7 we observed a surpass in the concentrations of NO_3^- starting from the November 2017, this surpass ranges from 3,33% in February 2018 to 66,66% in April 2018. In the period from 2014 to October 2017 no surpass has been noticed.

And from figure V.8 we can see that the levels of ammonium increased starting from December 2018, noting a surpass ranging from 58% in January 2020 and 322% in May of the same year.

In the following table we discuss the main dysfunctions and causes that may occur during the Nitrogen treatment process and we suggest some solutions.

Table V.6: Analysis of the malfunctions observed with their causes and some specific solutions proposed for nitrogenous compounds within the framework of the DFMEA.

dysfunctions	**Causes**	**Solutions**	**Criticality**
- Poor oxygenation at the aeration basin. level -Wrong adjustment of the aerators. -Decrease in dissolved oxygen	- Increase in water temperature -High pollution load - High bacterial mass	- Oxygen sensor Installation. - monitoring and have good management for system tuning.	**3**
-Appearance of mosses and black sludge	-Presence of detergents in effluents received - Probable connection of industrialists. -a turbid outlet effluent (dispersed bacterial growth). A light-colored sludge of low concentration in the aeration tank. -A micro-fauna represented by free bacteria and protozoa of the Flagellates type. -the important contribution of colloidal organic matter (blood,) or at the arrival of hydrocarbons. -Arrival of a toxic substance that has caused the destruction of a large part of the	- Search and treat the source of surfactant supply -a limitation of the load to be treated (transient *bypass*) to reduce the mass load and facilitate flocculation. -The supply of good quality outdoor biomass (IB<150 mL.g-1 of TSS*). -The addition of coagulant- flocculent.	**3**

	biomass		
-Low Nitrification -Low denitrification	-an organic underload. - high oxygenation rates - Age of the sludge too low: too much extraction (fasting sludge) - Short anoxia time in the anoxia basin. - recirculation rate	- Decrease sludge extraction. - Increase ventilation - Check the effluent for toxicity, pH and temperature. - Decrease the oxygenation of the aeration basin (anoxic zone). - Increase recirculation.	**4**

f. *Orthophosphate PO_4^{3-}*

The levels of (PO_4^{3-}) that were analyzed over the study period show unstable variation and significant exceedances presented by 6,5% in November and December 2017 and a maximum value (15%) in October 2015. This is mainly due to dephosphatation in the aeration basin and in the clarifier.

Table V.7: Analysis of the dysfunctions observed with their causes and some specific Solutions proposed for PO_4^{3-} in the framework of the DFMEA

Dysfunctions	Causes	solutions	criticality
Fermentation of the sludge.	- Water loaded with phosphate fertilizer (agricultural source). -a defect in scraping the invert (poor adaptation of the scraper to the invert or scraper not in place).	Recycle the water in the aeration basin and redo the treatment	**4**

Sludge deposits at the bottom of the raider and accumulation of black sludge mass	- Appearance of a foam layer on the surface of the clarifier -Problem with the bottom scraper. - clogging of extraction pipe to thickness	-Continuous cleaning - The equipment in place must allow daily evacuation of the deposits.	**4**
Abundance	-Filamentous bacterial type -The death of bacteria. -Very important length of stay. -Poor sludge extraction management. -Mud index greater than or equal to 200 mL.g-1. -Deterioration in the quality of the discharge in the event of episodic or chronic mud loss. -a slightly flaky flock with a large settled volume. -Type of pollution to be treated (Combination of wastewater, evolution over time, defects to nutrient imbalances)	-Respect and limit the residence time of B.A. and clarifier -Identification of the filaments, and the installation of a specific treatment. -Mud index monitoring	**4**
		Homogeneity between extraction and recirculation Organ verification and control. Equipment maintenance	**4**

We give in the following table some instructions to be followed to insure the best operation of the treatment process.

Table V.8: Main recommendations to be applied for all wastewater treatment steps

Processes	**Operations**
Screen	Checking for clogging
Sandblaster	-Checking the absence of deposits --Disposal of sands
Degreaser	-Checking for correct bubbling -Removal of floaters -Daily extraction (if manual operation) of sands and deposits of bottom of work -Drain the work when not in use.
For all basins	-Measuring the sludge index on a weekly basis
Aeration tank	-Adequate adjustment of ventilation according to load and hydraulic mode -Never program a ventilation shutdown time of more than two hours. -check the oxygen concentration in the pond -Take advantage of the channel type arrangements to organise the evacuation of moss (floating barrier). -Manual scraping if necessary to extract the foams -Limit the waterfall to the clarifier
Clarifier	-Do not interrupt recirculation to concentrate the sludge prior to extraction to the thickener or a maximum shutdown of two hours. -Check that the sludge is properly collected along the entire length of the deck.

	-Check that there are no deposits on the harrows. - Evacuating or sealing floats by sprinkling
Thickener	Controlled power supply to avoid hydraulic shocks

V.III. Possible Areas of Improvement Recommended for WWTP of Ain Temouchent

Referring to the results obtained from our analysis based on DFMEA, we could detect several anomalies. In order to minimize the failures and dysfunctions that exist at the level of the WWTP, with a view to improving its efficiency and its purifying performance knowing that its purified water is intended for irrigation, solutions are proposed to guarantee the good functionality and optimization of the plant:

- ✓ A storage block for all specific parts of each process to avoid long delays in delivery in case of failure.
- ✓ Building shelters for the drying beds in case of bad weather and avoiding continuous recirculation of sludge from the thickener to the aeration tank.
- ✓ Carry out periodic analyses (physico-chemical and microbiological) of the sludge since it is going to be reused for agriculture.
- ✓ Include microbiological and heavy metals analyses in the laboratory. Install devices and sensors to measure dissolved oxygen, as well as sludge concentrations in the settling tanks and aeration tank to know the emptying time.
- ✓ Consider primary settling to reduce the TSM content.
- ✓ Think of making a Coagulation-Flocculation followed by a primary settling when the wastewater is non-biodegradable.
- ✓ Carry out treatment optimized for phosphorus removal to meet the standards
- ✓ Extend the WWTP by adding aeration basin, clarifier and decanter to insure better treatment

V.IV Conclusion

The application of the DFMEA technique has allowed us to give a precise and well detailed understanding of the main damages that cause the malfunctions that may have occurred in the WWTP. Also these two techniques allowed us to tackle the problems that hinder the proper functioning and that require quick and tolerable interventions to guarantee correct continuity and to ensure the smooth operation of the unit.

VI. ALGERIAN WASTEWATER MANAGEMENT UNDER THE FRAMEWORK OF SUSTAINABLE WATER MANAGEMENT AND IWRM

VI.1. Introduction

Algeria with an area of 2,381,741 km^2, is divided into 59 Wilayas (departments), In Algeria the population was 23 million in 87; 40 in 2018 and will be 46 in 2020. (Algerian ministry of Health, 2020)

Algeria has three sets from the North to the South that differ by their relief and their morphology:

The Tell range and the coastline, the chain of the Atlas which runs along the High Plains over at South, and the Saharan desert which extends beyond the massive Atlas.

This provision of relief, marked by different climatic conditions, determines regional agriculture and the volume of water resources. Most of the territory Algerian is a desert (87%), where rainfall is almost nil, but which conceals important fossil resources groundwater. The part north, characterized by its Mediterranean climate, and has renewable water resources, for both surface water and groundwater, Table V.1

Table VI.1: climate variety in Algeria

	Share of the international area	**Climate type**
Tell region	4%	Mediterranean
High plains	9%	Semi-arid
Saharan desert	87%	Arid

90% of surface water is located in the Tell region, which covers about 4% of the territory. The country is characterized by a large disparity between East and West. The West region is well endowed in the plain but benefits from low rainfall. Eastern region is a mountainous area where the main rivers of the country flow. (El HANNACHI et.all, 2014)

The climate in Algeria is different from geographical area to another and that affect the annual rainfall. So; two scenarios are to be distinguished:

variability in rainfall between the West (350 mm of rainfall on average), the East (1 000 mm) and the high relief (where some years can reach 2 000 mm), which becomes almost non-existent from Sahara (average less than 100 mm) and a concentration of precipitation over time (from

December to April each year, when the climatic demand, evapotranspiration, is the lowest) (Morgan Mozas & Alexis Ghosn, 2014).

The water potential is estimated at 18 billion m^3/year distributed as follows.

12.5 billion m^3/ year in the regions North of which 10 billion in flows superficial and 2.5 billion in resources underground (renewable).

5.5 billion m^3/year in the regions Saharan countries, including 0.5 billion superficial flows and 5 billion in underground resources (fossils). (Morgan Mozas & Alexis Ghosn, 2014)

The demand for freshwater, grows every year 4-5%, while natural resources remain invariable not to say that they decrease (pollution problem more and more large). This equation shows that the demand will be greater than resources. As the following table shows the quantity of available water will decrease if the government stands with nothing. (HANNACHI et.al, 2014)

Table VI.2: the availability of drinking water in Algeria

year	1962	1990	1995	1998	2000	2020
m^3/habitant	1500	720	680	630	500	430

Faced with the scarcity of conventional water resources, Algeria can no longer afford to turn their backs on the opportunity to reuse huge amounts wastewater discharged into the wild or into the sea. Rainfall, water from dams and boreholes will no longer be sufficient to meet Algerians needs, which explains Algeria's ambition today to treat one billion cubic metres of wastewater for the irrigation of 100,000 hectares. For the time being, Algeria, which has a treated water volume of 560,000 cubic meters, devotes 65% of its water resources to the agriculture sector (MRE, 2012). It is therefore the rooting a new culture of water, which must be tackled in order to hope for the emergence new mentality and behavior (MRE, 2003). Wastewater treatment and its utilization in irrigation is an attractive option, particularly in arid and semi-arid areas, as it represents a reliable and renewable source of additional water and fertilizer (FAO, 2003).

VI.2 Situation of Irrigation in Algeria

Under water deficit conditions, the agriculture sector is the largest water user, reporting that in 2006, 900,000 hectares or 10.5% of the agricultural land area is irrigated, and 78% of this area is irrigated with groundwater and 13% with surface water (Tamrabet, 2011). The management of irrigated perimeters is gradually improving with their management by the ONID (National Office of Irrigation and Drainage). The extension of irrigated areas in small and medium hydraulics, although encouraging for the development of agriculture to induce a considerable increase in individual boreholes and the dangerous overexploitation of certain groundwater tables, the pricing of agricultural water is low (Benblidia, 2011).

There are two types of irrigated farms: large irrigated perimeters (LIP) under the responsibility of the State and managed by ONID. These perimeters are irrigated by dams and boreholes in the north of the country, while in the south irrigation is provided from deep boreholes in the great aquifers of the Albian (Benblidia, 2011). Their surface area is around 200,000 ha, with the crops grown in the LIPs (in 2008) being arboriculture (64.6%), market gardening (28.5%), industrial crops (6.1%) and the rest cereals and fodder (Benblidia, 2011). Small and medium hydraulics (SMH) made up of small irrigation perimeters and areas (private production) (Benblidia, 2011).

VI.3 Status of Wastewater Reuse in Algeria

The reuse of untreated wastewater is strictly prohibited by Law No. 83-03 of February 5, 1983, relating to environmental protection and Law No. 83-17 of 16 July 1983, bearing the water code. Maximum values for liquid effluent discharges by industrial establishments are defined by Decree 93-160 of July 10, 1993, which also instructs the Wilaya Environment Inspectorates (WEI) to carry out the following tasks controls.

The reuse of treated wastewater is a voluntary and planned action that aims to produce additional quantities of water for different uses. Today, the national strategy of sustainable development in Algeria is particularly materialized through a strategic plan that brings together three dimensions, namely: Social, Economic and Environmental (MRE, 2012). The national sanitation network totals 27,000 kilometers. The recovery rate is, excluding scattered population, of 85%. The overall volume of wastewater discharged annually is estimated at nearly 600 million m^3, 550 million m^3 of which are discharged in the northern cities alone. This figure would rise to nearly 1150 million m^3 in 2020.

The strategy of the Ministry of Water Resources in the field of purification is based on:

- ✓ the protection of the water resource,
- ✓ the eradication of septic tanks,
- ✓ the comfort and well-being of citizens,

- ✓ the Coastal Protection in accordance with the Barcelona Convention
- ✓ And the reuse of treated wastewater, particularly for agricultural purposes.

VI.3.1 Agricultural Reuse

The potential for reuse of treated wastewater for agricultural purposes has evolved significantly, in fact about 17 million m^3 were recorded in 2011, about 45 million m3 in 2012 and 300 million m^3 in 2014, from 25 treatment plant (MRE, 2012). There are 12 wastewater treatment plants managed by ONA (National office of Sanitation) concerned by the projects for the reuse of treated wastewater under study or implementation, for the irrigation of more than 8,000 hectares of agricultural land (MRE, 2012)

VI.3.2 Municipal reuse

The reuse of treated water in urban areas is extremely numerous.

In Algeria, purified wastewater is reused mainly by the civil protection, which recovers 18,763 m^3/month of purified wastewater from Tipaza WWTP to fight fires. Local authorities of Bomerdes recovers 12 m3 /month of purified water for cleaning the city. (BOUCHAALA et.all, 2017).

VI.3.3 Industrial reuse

For some countries, recycled water provides 85% of the global water needs for industry (Adjou, 2013). Industrial EUEI can be carried out in the energy sector, in the closed or open cooling circuits. In addition, this reuse is possible in

industrial laundries, car washes, the paper industry, the production steel, textiles, electronics and semiconductor industries, etc. (MRE, 2012). In Algeria, the only example to be mentioned is that of Jijel WWTP, which cedes a volume of 15,000 m^3/month of waste water for Jijel tannery.

VI.4 Legislative Aspect

A project for the development of Algerian standards and a technical guide for good practices in wastewater reuse for agricultural purposes has been approved by the Algerian Institute for Standardization (IANOR) in 2012 stating that Wastewater reuse requires close coordination between the different structures involved in reuse operations at all levels (MRE, 2012).

Executive Decree 07-149 of 20 May 2007, published in the Official Journal of the Algerian Republic nº 35, 23 May 2007, establishes the modalities for the use of treated wastewater for irrigation purposes in the form of a concession and the related standard specifications (OJ, 2007). This decree regulates all the processes for using the wastewater treated by the treatment plants, through a request addressed by a concessionaire to the Wali (first person in charge of the Wilaya or department) of the region, this request includes an agreement with the treatment plant that supplies the treated wastewater. Technical control, the management of irrigated areas and sanitary control as well as the quality of treated water and agricultural products is carried out by the territorial directorates of each Wilaya under the supervision of different ministries: water resources, agriculture, health, environment and commerce.

VI.4.1 Legislation of crops to be treated with the treated water

Another regulation has been implemented, the inter-ministerial decree of 8 Safar 1433 corresponding to 2 January 2012 setting the list of crops that can be irrigated with treated wastewater. This text is promulgated by the ministers in charge of water resources, agriculture and health. The plots to be irrigated with treated wastewater must not have any crops other than those on the list indicated. Table VI.3

Table VI.3: list of crops that can be irrigated with treated water (OJ, 2007)

Group of crops that can be irrigated with treated water	List of crops
Fruit trees	date palm, vine, apple, pear, apricot, clover, cherry, plum nectarine, pomegranate, fig, rhubarb, peanut, walnut, olive
Citrus	Pamplemousse, limon, orange, mandarin, lane Rene, lime, clementine
Forage crops	Bersim, corn, sorghum, forage, vexe, alfalfa
Industrial crops	industrial tomato, rowing beans, reamed peas, sugar beet, cotton, tobacco
Cereals	wheat, barley, triticale, oats
Crops for seed production	acacia and atriplex
Flowering plants for dry or industrial use	pink, iris, jasmine, marjoram, rosemary

VI.4.2 Wastewater reuse standard

It is prohibited to irrigate crops which are eaten raw. Plots intended to be irrigated with treated waste water must not bear any crops other than those on the list indicated. Plots irrigated with treated waste water must be more than 100 metres away from roads, dwellings, surface wells and other works intended for the supply of drinking water. Any connection with a pipe carrying drinking water is prohibited.

VI.4.3 Institutional Aspect

During the implementation of the concession, the necessary measures must be taken by the various parties involved, each for its own part, in order to prevent the risks of contamination of groundwater and to prevent the risks of contamination of agricultural products (OJ, 2007).

VI.4.4 Private Partners

The use of treated wastewater for irrigation purposes is subject to the concession regime. The concession may be granted to any legal or physical person, public or private law, which proposes to distribute treated waste water to users for irrigation purposes. The application for a concession shall be sent by the applicant, in duplicate, to the wali having territorial jurisdiction.

VI.4.5 Public Partners

The hydraulic services of the wilaya are required to set up a system for monitoring and controlling the quality of purified waste water intended for irrigation and the evolution of the quality of groundwater. The health services of the wilaya must ensure a regular control of the health of the personnel assigned to irrigation with purified wastewater. The trade services of the wilaya must ensure a biological and physico-chemical control of the agricultural products irrigated with treated wastewater.

VI.4.6 Financial Provisions

The concessionaire is required to pay the fees fixed by the finance law, due for the use of the public hydraulic domain. The tariffs applicable for the supply of treated wastewater for agricultural use are set in accordance with the regulations in force.

VI.4.7 Environmental Aspect

The sanitation of agglomerations aims to ensure the rapid and steady discharge of domestic and industrial waste water likely to give rise to nuisances and rainwater liable to submerge inhabited areas, under conditions compatible with public health and environmental requirements.

VI.4.8 Sanitation

In built-up areas, it is mandatory to connect to the sewerage system any dwelling or establishment discharging wastewater. Agglomerations of more than one hundred thousand (100,000) inhabitants must imperatively have wastewater treatment processes and systems, especially those located in the protection perimeters, upstream of the hydraulic works supplying the population with drinking water. It is forbidden to introduce into the sanitation installations any solid, liquid or gaseous matter likely to affect the health of the operating personnel or to cause a degradation or an interference with the operation of the drainage and treatment works. The conditions and standards for carrying out sanitation projects and for operating and maintaining wastewater evacuation and treatment facilities are set by the regulations.

VI.4.9 Soil Protection

The protection and preservation of soil requires the carrying out of sanitation and drainage works to combat, in particular:

- Prolonged flooding of agricultural land,
- Salination of agricultural land,
- Rising water tables on cultivated land,
- Soil erosion.

VI.4.10 Water Pollution Control

The protection of water resources is assessed in terms of quality and quantity. Pollution is understood as a harmful modification of the properties of water, produced directly or indirectly by human activities, making it unfit for normal established use. It is prohibited to discharge, reject or inject into the public water domain funds of materials of any kind and; in particular, urban and industrial effluents containing solid, liquid or gaseous substances, pathogens, in quantity and concentration of toxicity likely to harm public health, fauna and flora or to harm economic development (Executive Decree No. 93-160 of 10 July 1993 (OJ, 1993) and Executive Decree No. 06-141 of 19 April 2006 (OJ, 2006).

Any discharge or immersion in the bottom of the public hydraulic domain of material that does not present the expected risks is subject to a concession for the use of the public hydraulic domain, called discharge authorization. The conditions for issuing, modifying or withdrawing the discharge authorization are fixed by regulation. The discharge authorization is refused in particular when the discharged materials are likely to harm

- to the natural regenerative capacity of the waters,
- to the requirements of the use of the receiving waters,
- to the protection of public health.

VI.5 Wastewater Treatment and Recovery, The Relevant Challenge

Indeed, the mobilization of drinking water, its distribution, sanitation and the mobilization of the resource for the benefit of other sectors, including agriculture, were the main lines of the new strategy developed by the Minister of Water Resources. In order to improve the rate of wastewater collection, a vast programme of projects has been launched during the period 2000-2010. (Hannachi et.all, 2014) These projects, of national importance, consisted of the upgrading and extension of the national sewerage network, the protection of cities against flooding and the treatment of wastewater by building sewage treatment plants throughout the country.

As Algeria is semi-arid country, that had faced drought. To cope with water scarcity and make it available, Algeria has invested 25 billion dollars over the last sixteen years. However, water availability was not Algeria's only challenge since distribution was a problem, 30% of the water was lost due to the defective state of the networks, poor management and the lack of treatment plants (Hannachi et.all, 2014). As a reminder, in 1999 Algeria had only 45 treatment plants, built since independence, of which only 12 were in service in 2000 with a treatment capacity that did not exceed 90 million treated wastewater. (Hannachi et.all, 2014)

Having become aware of the urgency in terms of building and renovating sewerage networks and wastewater treatment infrastructures, "a Council of Ministers was reserved, in 2004, exclusively for sanitation. Since then, the problem has been seriously addressed and it has been decided to launch 158 new projects for the construction of wastewater treatment infrastructure, all programmes combined, for a total amount exceeding 200 billion dinars. As for treatment and purification works, their number has increased remarkably in recent years, with 200 WWTPs and 350 pumping stations registered in 2015. The annual volume of wastewater generated by the population is 927 million m3/year, of which 700 million m3/year is treated by ONA and reused by industrial activities (3.1 million m3/year) and agricultural irrigation (3.4 million m3/year). In 2014, ONA has 108 WWTPs in operation, including 60 SL. The MRE has 97 dams for the storage of 9.1 billion m3. (Bouchaala et.all, 2017)

VI.6 Integrated Management and Wastewater

The definition of integrated water resources management formulated by the Global Water Partnership is now authoritative. It states that "integrated water resources management is a process that promotes the coordinated development and management of water, land and associated resources to maximize the economic and social well-being that results in an equitable manner, without compromising the sustainability of vital ecosystems" (WWAP, 2009).

stakeholders, both public and private, have decisions to make about wastewater reuse in agriculture. They are faced with the need to exploit increasing quantities in order to meet ever-increasing demands. Factors such as demographic changes and high water requirements for agriculture further accentuate the challenges of wastewater reuse. When the traditional fragmented approach is no longer viable, an effective management approach is required. The integrated management of treated wastewater in Algeria, now institutionally recognised as a model of public-private partnership, is the best approach for efficient and sustainable development and management of treated wastewater in the face of increasing water demands.

VI.7 Conclusion

In Algeria, the presence of discharge standards specific to wastewater reuse in agriculture (Executive Decree No. 93-160 of 10 July 1993 and Executive Decree No. 06-141 of 19 April 2006) as well as the presence of regulatory texts setting the modalities for wastewater reuse and the list of crops and the conditions for their irrigation with treated wastewater (Executive Decree No. 07-149 of 20 May 2007 and the Interministerial Order of 2 January 2012) constitute a promotion of projects for the reuse of treated wastewater. Public and private managers have decisions to make regarding the reuse of wastewater in agriculture. They are faced with the need to exploit increasing quantities to meet ever-increasing demand. Integrated management of treated wastewater in Algeria, now institutionally recognized as a model of public-private partnership, is the best approach for efficient and sustainable development and management of treated wastewater in the face of increasing water demands.

VII. GENERAL CONCLUSION AND RECOMMENDATIONS

Reliability is a multi-disciplinary approach that provides a way of responding to system problems, thus meeting socio-environmental requirements that have become disruptive. This approach enables the control of technological systems as well as the evaluation of the reliability and safety of industrial installations, which essentially attempt to develop statistical approaches for the exploration of anomalies and to instruct modelling to better direct the unit and evolve the functionality in the WWTP. In this work, a performance reliability study was conducted on the WWTP of Ain Temouchent, which was taken as a model for activated sludge WWTPs. The objective of this work is to study some selected parameters such as pH, Temperature, conductivity, TSM, BOD, COD, NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, Dissolved Oxygen, Total phosphorus, Total Nitrogen in several samples of treated wastewater from the wastewater treatment plant with the application of the DFMEA, which allows the STEP system to be disassembled into components and to determine the most sensitive incidents according to the criticality calculation. The failure tree is finalized to indicate the set of event combinations and conditions that may lead to this event.

The interpretation of the results obtained and the study of the statistical analysis in the period from 2014 to 2020 led to the conclusion that:

The plant has functioned very well in the period after the launch of the station, particularly from 2014 to 2017; all the parameters were respecting the norm, only for orthphophates that exceeded the norm all the period of study. Which explains that the dephosphatation processes is not efficient.

In the last three years we noticed that some parameters have surpassed the norms which are TSM, BOD, COD, NO_3^- and PO_4^{3-} while:

The TSM have registered a remarkable overtaking in the winter of the years of 2017, 2018 and 2020.

In the case of BOD, the treated water overpasses the norm in autumn and winter time, while the overtaking ranges from 16% in October 2017 and 60% in February 2020. It is to highlight that this dysfunctioning is observed starting from autumn 2017.

In the case of COD, its amount in effluent is upper than the norm in the period from November 2017 to May 2020, with a minimum surpassing of 58% in January 2020 and a maximum with 322% in May of the same year.

Also the biodegradability factor has exceeded 2,5 the whole period of study, this means that the treated water is not biodegradable and has an industrial nature.

The NO_3^- was above the norms, this lead us to suspect the nitrification and denitrification process is not functioning well, also we found an overpassing in NH_4^+ starting from January 2020 which explain that the two phenomenon are presenting problem.

The principles failures detected are directly related to the exceeding of pollution parameter concentrations, as well as equipment failures, which lead to anomalies in the unit and in the operation of treatment processes. The failures we have recorded for WWTP are:

- ✓ Correct priority failures related to the parameters of TSM, NO3-, NH4+, COD, BOD5, in order to ensure a good quality of the discharge for the receiving environment so that it is not affected and to guarantee the correct operation of the system.
- ✓ A significant increase in sludge concentration in biological basins makes the sludge old, which causes the sludge to rise in the clarifier.

We propose the following solutions to be implemented to improve purification yields and strengthen plant reliability.

- ✓ The installation of a wall valve at the inlet of the WWTP, to ensure the flow measurements.
- ✓ The addition of adjuvants in the aeration basins as a preventive and curative solution to the rising sludge.
- ✓ Place dissolved oxygen and pH measuring devices in the aeration tank to ensure good degradation by microorganisms.
- ✓ Install detection devices for the sludge concentration in the settling tanks in order to know when the sludge must be extracted or recirculated.

DMFEA allowed to have a global vision on the whole of the studied instruction, and to detect the anomalies presented in the system, in order to have a strategy to answer the indispensable questions.

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