

الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة عين تموشنت بلحاج بوشعيب
University of Ain Témouchent – Belhadj Bouchaib
Faculty of Science and Technology
Department of Biology



Final Year Project

In partial fulfillment of the requirements for the Master's degree in: **Applied Microbiology**

Field: Life and Natural Sciences

Major: Biological Sciences

Specialty: Applied Microbiology

Topic:

Assessment of the physicochemical and bacteriological quality of wastewater

Presented by:

- 1) M. BENMOUSSA MAHI Ilyes
- 2) M. BOUDJEMA Aymen

Before the jury composed of:

Pr .ZIANE Mohammed	Professeur	UAT.B.B (Ain Temouchent)	President
Dr .YAZIT Sidi Mohamed ...	M C A	UAT.B.B (Ain Temouchent)	Examiner
Dr.BOUCHACHIA Souad	M C B	UAT.B.B (Ain Temouchent)	supervisor

Academic Year 2024/2025

Acknowledgements

First and foremost, we would like to thank God Almighty and Merciful, who gave us the strength and patience to complete this work. Our sincere thanks go to our dear supervisor, **Mrs. BOUCHACHIYA .S**. Thank you for the quality education you provided us throughout our years at the university, and thank you for accepting to supervise this work. Your support, expertise, and positivity have been of invaluable help to us. We would also like to sincerely thank the members of the jury, **Mr. ZIANE. M** and **Mr. YAZIT. S**, who have done us the great honor of evaluating this work. Your knowledge, enthusiasm, and kindness have always inspired our deepest respect. Please accept here the expression of our heartfelt gratitude and high consideration. To our parents, families, and friends—through their prayers, love, support, patience, and encouragement—we were able to overcome all the obstacles throughout the preparation of this dissertation.

Dedication

With great pleasure, an open heart, and immense joy, I dedicate this work:

To my dear **mother**, my heroine, thank you for always being by my side through good times and bad. I am where I am today thanks to you—your positivity, unwavering support, and constant presence have only lifted me higher. I hope I’ve lived up to your expectations. I can never say it enough, but I love you more than anything in the world.

To my dear **father**, who has always been and will always be a role model for me through his love and sense of responsibility. Even if I don’t always say it, know that my heart is filled with love for you.

To all my brothers from the big **Fakherdinne** to the last one **Hadjer**, thank you for inspiring me with your strength and kindness. Your wisdom and support gave me the courage to move forward and believe in my dreams—simply put, I adore you.

And special thanks to Alaa and Mohamed and Osayed and Meriem, I dedicate this thesis to you with all the love I have for you, and I promise to always be by your side, my little bundle of joy.

To my dear **friends**, thank you for your presence, your encouragement, and all the moments we’ve shared that helped me stay on course.

Ilyes

Dedications

I dedicate this achievement to my parents, **Boudjema Boumediene** and **B. Malika**, whose unwavering support and love have guided me every step of the way. To my brother **B. Djawed**, thank you for your encouragement and believe in me. To my little sister **B. Alaa**, your innocence and joy reminded me of life's simple blessings. To my friend **B. Ilyes**, I'm grateful for your constant support your efforts I wish all the best for you my friend. And to **Madame Bouchachiya**, thank you for your guidance and inspiration throughout my academic journey.

And to all my friends and family who been through my joureny thank you

Aymen

Abstract

This study focused on evaluating the physicochemical and bacteriological quality of raw and treated wastewater from the Ain Témouchent wastewater treatment plant (WWTP), based on five samples (S1 to S5). Microbiological analyses were conducted using the Most Probable Number (MPN) method, alongside standardized physicochemical testing. The physicochemical results showed that pH values ranged between 7 and 8.28. The average temperature was 15.4 °C for raw wastewater and 10.8 °C for treated water. Turbidity exhibited a significant decrease, with a reduction exceeding 97%, reaching values below 4 NTU in the majority of treated samples. Conductivity showed a slight decrease after treatment. The average nitrite concentration was reduced from 0.199 mg/L in raw wastewater to 0.051 mg/L in treated water. Conversely, nitrate concentrations increased after treatment, rising from 0–0.88 mg/L in raw samples to 0–4.2 mg/L in treated effluents, a phenomenon attributed to the nitrification process. Ammonium levels experienced a substantial reduction, with an initial average concentration of 69.08 mg/L in raw wastewater. Phosphate concentrations slightly decreased following treatment. From a bacteriological perspective, a significant reduction in total coliforms was observed after treatment, indicating partial effectiveness of the treatment process. The treatment process at the Ain Témouchent WWTP ensures a highly effective reduction of organic pollution, with results conforming to standards for most analyzed physicochemical parameters. However, the insufficient removal of fecal coliforms highlights the need to optimize or supplement the treatment, notably by adding a disinfection step, to guarantee the sanitary quality of the effluents for potential reuse.

Keywords: Raw Wastewater, Treated wastewater, Bacteriological analyses, physicochemical, Effluents.

Résumé

Cette étude s'est penchée sur l'évaluation de la qualité physico-chimique et bactériologique des eaux usées brutes et traitées de la station d'épuration d'Ain Témouchent, à partir de cinq échantillons (S1 à S5). Les analyses microbiologiques ont été réalisées selon la méthode du Nombre le Plus Probable (NPP), parallèlement à des essais physico-chimiques standardisés.

Les résultats physico-chimiques ont montré que le pH variait entre 7 et 8,28. La température moyenne était de 15,4 °C pour les eaux usées brutes et de 10,8 °C pour les eaux traitées. La turbidité a connu une diminution significative, avec une réduction de plus de 97 %, atteignant des valeurs inférieures à 4 NTU dans la plupart des échantillons traités. La conductivité a légèrement diminué après traitement.

La concentration moyenne en nitrites a été réduite de 0,199 mg/L dans les eaux brutes à 0,051 mg/L dans les eaux traitées. En revanche, les concentrations en nitrates ont augmenté après traitement, passant de 0–0,88 mg/L dans les échantillons bruts à 0–4,2 mg/L dans les effluents traités, phénomène attribué au processus de nitrification. Le taux d'ammonium a subi une baisse importante, l'échantillon brut présentant une concentration moyenne initiale de 69,08 mg/L. Les concentrations en phosphates ont légèrement diminué suite au traitement.

D'un point de vue bactériologique, une réduction notable des coliformes totaux a été observée après traitement, témoignant de l'efficacité partielle du procédé. Le processus de traitement de la STEP d'Ain Témouchent assure une diminution très efficace de la pollution organique, avec des résultats conformes aux normes pour la plupart des paramètres physico-chimiques analysés. Toutefois, le retrait insuffisant des coliformes fécaux souligne la nécessité d'optimiser ou de compléter le traitement, notamment par l'ajout d'une étape de désinfection, afin de garantir la qualité sanitaire des effluents en vue d'un éventuel réemploi.

Mots-clés : Eaux usées brutes, eaux usées traitées, analyses bactériologiques, physico-chimique, effluents.

الملخص

ركزت هذه الدراسة على تقييم الجودة الفيزيائية-الكيميائية والجرثومية لمياه الصرف الصحي الخام والمعالجة بمحطة التطهير في عين تموشنت، وذلك اعتماداً على خمس عينات (S1) إلى (S5). تم إجراء التحاليل الميكروبيولوجية باستخدام طريقة "العدد الأكثر احتمالاً (MPN)"، إلى جانب اختبارات فيزيائية-كيميائية معيارية.

أظهرت النتائج الفيزيائية-الكيميائية أن قيم الرقم الهيدروجيني تراوحت بين 7 و8.28. أما درجة الحرارة المتوسطة فبلغت 15.4 °C لمياه الصرف الخام و10.8 °C للمياه المعالجة. سجلت العكارة انخفاضاً كبيراً بنسبة تجاوزت 97%، حيث وصلت في معظم العينات المعالجة إلى أقل من 4 NTU. وأظهرت التوصيلية انخفاضاً طفيفاً بعد المعالجة.

انخفض متوسط تركيز النتريت من 0.199 ملغ/لتر في المياه الخام إلى 0.051 ملغ/لتر في المياه المعالجة. في المقابل، ارتفعت تركيزات النترات بعد المعالجة من 0-0.88 ملغ/لتر في العينات الخام إلى 0-4.2 ملغ/لتر في المياه المعالجة، ويُعزى ذلك إلى عملية النتريجة. كما شهد تركيز الأمونيوم انخفاضاً ملحوظاً، حيث بلغ متوسطه الأولي 69.08 ملغ/لتر في المياه الخام. وانخفضت تركيزات الفوسفات بشكل طفيف بعد المعالجة.

من الناحية الجرثومية، لوحظ انخفاض كبير في عدد الكوليفورم الكلية بعد المعالجة، مما يدل على فعالية جزئية لعملية المعالجة. تضمن محطة التطهير بعين تموشنت تقيلاً فعالاً للتلوث العضوي، وكانت النتائج مطابقة للمعايير في معظم المعلمات الفيزيائية-الكيميائية المحللة. ومع ذلك، فإن الإزالة غير الكافية للكوليفورم البرازي تُبرز الحاجة إلى تحسين أو استكمال المعالجة، لا سيما بإضافة مرحلة تطهير لضمان الجودة الصحية للمياه المعالجة وإمكانية إعادة استخدامها.

الكلمات المفتاحية: مياه الصرف الخام، مياه الصرف المعالجة، التحاليل الجرثومية، فيزيائية-كيميائية، المياه المعالجة.

Table of Contents

INTRODUCTION	1
BIBLIOGRAPHICAL SUMMARY	
1. Definition of Wastewater	3
2. Origin of Wastewater	3
2..1. Domestic Wastewater	3
2..2. Industrial Wastewater	4
3. Characteristics of Wastewater	4
3.1. Physico-chemical Characteristics	4
3.2. Bacteriological Characteristics	6
3.2.1. Indicator Germs	7
4. Wastewater Treatment	8
5. Impacts of Discharge on the Environment	10
6. Public Health and Waterborne Diseases	10
7. Wastewater Impact on Agriculture	11
Materials and methods	
1.Presentation of the study area.....	14
1.1.Location of the Ain Temouchent wastewater treatment plant	14
1.2.Wastewater treatment plant capacity	15
2.Sampling	15
2.1. Operating Procedure	15
2.2. Preservation and Transport:	15
3. Physico-chemical Analyses	15
3.1. Hydrogen Potential (pH)	15
3.2.Temperature	16
3.4. Chemical Oxygen Demand (COD)	18
3.5. Biochemical Oxygen Demand (BOD ₅)	18
4.Bacteriological Analyses	22
4.1.Enumeration of Total and Fecal Coliforms	23

RESULTS AND DISCUSSION	
1. Physico-chemical Results	26
1.1• Ph	26
1.2• Temperature	27
1.3• Turbidity	28
1.4• Conductivity	29
1.5• BOD ₅	30
1.6• COD	31
1.7• Nitrites	32
1.8• Nitrates	33
1.8• Ammonium	34
1.9• Phosphates	35
2. Bacteriological Results	36
CONCLUSION	39
REFERENCES	41

List of Abbreviations

Abbreviation	Definition
E. coli	Escherichia coli
CMI	Concentration Minimal Inhibitrice
CMB	Concentration Minimal Bactéricide
BOD / DBO5	Biochemical Oxygen Demand (5 days)
COD / DCO	Chemical Oxygen Demand
SS	Suspended Solids
pH	Potential Hydrogen
NTU	Nephelometric Turbidity Unit
TC	Total Coliforms
FC	Fecal Coliforms
MPN / NPP	Most Probable Number / Number le Plus Probable
WWTP	Wastewater Treatment Plant

List of Figures

Figure 1: Wastewater treatment plant stages, from preliminary to advanced treatment processes

Figure 2: Exposure pathway representing serious health concerns from wastewater-irrigated crops

Figure 3: Geographical map of the location of the Ain Temouchent WTP.

Figure 4: Detection and enumeration of total and fecal coliform.

Figure 5: Variation of the pH of wastewater samples.

Figure 6: Temperature variation of wastewater samples.

Figure 7: Variation in turbidity of wastewater samples.

Figure 8: Variation of conductivity in wastewater samples.

Figure 9: Variation of Biochemical Oxygen Demand in wastewater samples.

Figure 10: Variation of Chemical Oxygen Demand in wastewater samples.

Figure 11: Variation of Nitrite in wastewater samples.

Figure 12: Variation of Nitrates in wastewater samples.

Figure 13: Variation of Ammonium in wastewater samples.

Figure 14: Variation of Phosphates in wastewater samples.

List of Tables

Table 1: Pollutants/Contaminants in wastewater, their sources, impacts, and treatment methods.

Table 2: Microbiological Analysis Results of Total and Fecal Coliforms in Wastewater Samples.

Introduction

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It includes domestic sewage, industrial effluents, stormwater runoff, and other liquid wastes discharged from residential, commercial, and industrial sources. Wastewater contains a mixture of organic and inorganic substances, pathogens, nutrients, and various pollutants that can pose risks to human health and the environment if not properly treated **(Metcalf & Eddy, 2014; Tchobanoglous *et al.*, 2014)**.

Urbanization and global population growth have significantly increased the demand for water resources, putting unprecedented pressure on natural water sources. Only about 0.5% of Earth's water exists in an accessible liquid form in rivers, lakes, ponds, and groundwater, which intensifies concerns about water scarcity¹. Additionally, water bodies such as rivers and lakes are increasingly contaminated by industrial, domestic, and agricultural effluents containing organic and inorganic pollutants, leading to environmental and water-related problems. In response to these challenges, wastewater treatment plants (WWTPs) play a crucial role in protecting water quality and mitigating environmental impacts. WWTPs are essential infrastructure designed to remove contaminants from wastewater to ensure public health, preserve ecological integrity, and promote water reuse. These plants treat polluted water through processes including primary (solid removal), secondary (biological treatment), and advanced treatments (filtration and disinfection), making the water safe for discharge or reuse in applications such as irrigation, industrial cooling, and landscaping **(Fernandes *et al.*, 2024)**.

Domestic water and treated wastewater contain various nutrients such as phosphorus, nitrogen, potassium, and sulfur. Among these, nitrogen and phosphorus are present in significant amounts and can be readily absorbed by plants. For this reason, treated wastewater is commonly used for irrigation. The abundant nutrients in reclaimed wastewater help reduce the need for synthetic fertilizers, enhance crop yields, improve soil fertility, and simultaneously lower the overall cost of crop production **(Kumar *et al.*, 2021)**.

This research takes place in a context where it is well established that the quality of wastewater, particularly its physico-chemical and microbiological characteristics, plays a crucial role in environmental protection and public health. However, the complexity and variability of wastewater, especially those originating from domestic and industrial sources, make its comprehensive assessment challenging. Moreover, inadequate treatment of this wastewater can lead to the pollution of water resources, endangering aquatic ecosystems and human populations. Therefore, it is essential to conduct precise and regular evaluations of

wastewater quality in order to optimize treatment processes and ensure compliance with environmental standards.

Evaluating the physico-chemical and bacteriological quality of wastewater is crucial for understanding its potential effects, ensuring its safe reuse, and informing effective treatment approaches. However, despite its significance, data on wastewater quality is often scarce in many areas, which poses challenges for developing suitable management and treatment strategies.

The main objective of this study is to evaluate the physico-chemical and bacteriological quality of wastewater to better understand its characteristics and potential impacts on public health and the environment.

The present study is organized into several sections. It begins with a literature review that includes definitions of wastewater, its sources, treatment methods, and its effects on human health. This is followed by a materials and methods section that describes the physico-chemical and microbiological analysis techniques used in the study. The results and discussion section presents the various findings and provides an in-depth analysis and interpretation of the data. Finally, the study concludes with a conclusion that summarizes the key outcomes and offers perspectives for future research and improvements.

BIBLIOGRAPHICAL **SUMMARY**

1. Definition of Wastewater

Wastewater is broadly defined as water whose quality has been negatively affected by human activities, encompassing a diverse range of used water that has been discarded after various processes. This includes domestic wastewater (sewage) from households, businesses, and institutions, which contains waste from toilets, sinks, showers, and laundry; industrial wastewater, which is used in manufacturing and can contain a variety of pollutants; agricultural wastewater, which may contain pesticides, fertilizers, and animal waste; and storm water runoff, which accumulates pollutants as it flows over urban and agricultural areas (**Renfrew *et al.*, 2024**).

2. The origin of wastewater:

Based on the nature of the pollutants entering domestic wastewater, two primary categories of sources can be identified.

2.1. Domestic wastewater:

Domestic wastewater, a ubiquitous byproduct of human settlements, encompasses water discharged from residential, commercial, and institutional establishments. This complex aqueous matrix carries a diverse array of organic and inorganic pollutants, notably including human excreta and residues from daily activities such as washing, cooking, and sanitation. The presence of pathogenic microorganisms within domestic wastewater poses significant environmental and public health challenges (**Metahri, 2012**).

The composition of domestic wastewater is so complex that a complete analysis is often impossible. However, since it is relatively straightforward to measure the amount of oxygen consumed by bacteria during the oxidation of the wastewater, the concentration of organic matter can be conveniently expressed in terms of the oxygen required for its oxidation. For instance, if bacteria consume 0.5 grams of oxygen to oxidize one liter of a specific wastewater sample, we say that this wastewater has an oxygen demand of 500 mg/L. This means that the amount of organic matter present in one liter of the wastewater requires 500 mg of oxygen for its complete oxidation (**Mara, 2003**).

2.2. Industrial wastewater

Industrial wastewater presents a significant environmental challenge due to its complex and often toxic composition, which starkly contrasts with that of domestic wastewater. It is characterized by a wide array of chemical substances, including organic and metallic compounds. Examples of these contaminants include greases and hydrocarbons, commonly found in refinery effluents, heavy metals discharged from metallurgical processes, acids and bases released by chemical industries, and radioactive materials originating from nuclear power plants and radioactive waste treatment facilities. A critical concern is that many of these substances possess high toxicity, posing substantial risks to both ecological systems and human health (Cristian *et al.*, 2015).

Industrial wastewater is often more toxic than municipal wastewater. It contains a variety of contaminants at concentrations that vary depending on the specific industry . Consequently, municipal wastewater treatment plants (WWTPs), which are primarily designed to remove biochemical oxygen demand (BOD), may not effectively treat industrial wastewater. To treat industrial wastewater efficiently, it is essential to analyze its characteristics, including the types and concentrations of pollutants, and to apply an appropriate treatment method. Given the diversity of industrial wastewaters, WWTPs are typically designed and implemented on a case-by-case basis, utilizing the most suitable available treatment technologies (Kato and Kansha, 2024).

3. Characteristics of Wastewater

In addition to visual characteristics such as odor, which is due to dissolved gases, and color, which depends on both the concentration of coloring materials and the pH of turbidity, wastewater is recognized by other physico-chemical and bacteriological characteristics.

3.1. Physico-chemical Characteristics

✎ **pH and Acidity:** The pH of wastewater varies according to its source and composition. Domestic wastewater generally exhibits a neutral to slightly alkaline pH, whereas industrial wastewater can be either acidic or alkaline, depending on the specific industrial processes involved. Variations in pH influence the solubility and toxicity of pollutants, as well as the efficiency of treatment methods. Therefore, maintaining proper

pH control is crucial to optimize wastewater treatment performance and reduce environmental impacts (**Etsuyankpa *et al.*, 2024**).

- ✎ **Temperature:** The temperature of wastewater can vary based on ambient conditions and its sources. Industrial effluents may release heated wastewater into natural water bodies, potentially causing thermal pollution and impacting aquatic ecosystems. Temperature plays a critical role in influencing biological activity, chemical reactions, and pollutant behavior within wastewater. Therefore, monitoring and controlling wastewater temperature is essential to safeguard water quality and maintain ecosystem health (**Etsuyankpa *et al.*, 2024**).
- ✎ **Total Suspended Solids (TSS):** TSS refers to the total amount of solid material that is suspended in the water, including both organic and inorganic particles. High levels of TSS can increase turbidity, reduce light penetration, and harm aquatic life. TSS can also contribute to the accumulation of sediment and pollutants in water bodies (**Metahri, 2012**).
- ✎ **Chemical Oxygen Demand (COD):** COD measures the amount of oxygen required to chemically oxidize all organic compounds in the water, both biodegradable and non-biodegradable. It provides an indication of the total organic pollution load in the wastewater (**Metahri, 2012**).
- ✎ **Biochemical Oxygen Demand (BOD):** BOD measures the amount of oxygen consumed by microorganisms as they decompose organic matter in the water. A high BOD indicates a large amount of organic pollution, which can deplete dissolved oxygen levels and harm aquatic life. BOD is typically measured over a period of 5 days (BOD₅) (**Metahri, 2012**).
- ✎ **Chemical oxygen demand:** chemical oxygen demand (COD) is a measure that indicates the amount of oxygen consumed by chemical reactions in a given solution . It is typically expressed as the mass of oxygen consumed per unit volume of solution, commonly in milligrams per liter (mg/L) according to SI units. The COD test provides a straightforward way to quantify the concentration of organic matter in water. Its most frequent application is to assess the level of oxidizable pollutants present in surface waters, such as lakes and rivers, or in wastewater. COD serves as an important water quality parameter, offering an estimate of the potential impact an effluent may have on

the receiving environment, similar to the biochemical oxygen demand (BOD) measurement (**Table1**) (**Li and Liu, 2019**).

Table1 : Pollutants/Contaminants in wastewater, their sources, impacts, and treatment methods (**Li and Liu, 2019**).

Pollutant/Contaminant	Description	Main Sources	Potential Environmental/Health Impacts	Common Treatment Methods
Organic Matter	Biodegradable materials such as food waste and fecal matter	Domestic wastewater, industrial effluents	Oxygen depletion, unpleasant odors	Biological treatment, chemical oxidation
Nutrients	Nitrogen, phosphorus, and potassium compounds	Domestic sources, agricultural runoff	Eutrophication, algal blooms	Biological nutrient removal, chemical precipitation
Heavy Metals	Toxic elements like lead, mercury, cadmium, chromium, arsenic	Industrial discharges, urban runoff	Toxicity, bioaccumulation in organisms	Precipitation, filtration, ion exchange
Pathogens	Disease-causing microorganisms: bacteria, viruses, parasites	Sewage, animal waste	Spread of waterborne diseases	Disinfection (e.g., chlorination, UV treatment)
Suspended Solids	Soil, sediment, organic particles, debris	Urban runoff, erosion, industrial processes	Habitat degradation, lowered water quality	Sedimentation, filtration, settling ponds

3.2. Bacteriological Characteristics

Bacteriological characteristics refer to the types and amounts of microorganisms present. These can be indicators of pollution and potential health risks. Key aspects include

- ▲ **Types of Microorganisms:** Wastewater can contain a wide variety of microorganisms, including bacteria, viruses, protozoa, and helminths (parasitic worms);

- ▲ **Pathogens:** Many of these microorganisms can be pathogenic, meaning they can cause diseases in humans and animals. These pathogens can cause a range of illnesses, including gastrointestinal infections, cholera, typhoid fever, and dysentery;
- ▲ **Indicator Organisms:** The presence of certain microorganisms, such as coliform bacteria, can indicate fecal contamination and the potential presence of other, more harmful pathogens;
- ▲ **Concentration of Microorganisms:** The number of microorganisms present in wastewater can vary widely depending on the source and treatment of the wastewater. High concentrations of microorganisms can pose a greater risk of infection (**Table 1**) (**Ochuko and Adewuyi, 2024**).

3.2.1. Indicator Germs in Wastewater from Domestic Sources

Indicator organisms are defined as microorganisms whose presence in water provides evidence of probable contamination by pathogens, which are microorganisms capable of causing disease. These indicator organisms themselves are generally not pathogenic but serve as stand-ins, or surrogates, to indicate the potential for the presence of harmful microbes. The fundamental principle behind their use is that indicator organisms are selected because they are significantly easier and more cost-effective to detect and enumerate in water samples than the potentially wide array of diverse pathogens that could be present. This practicality allows for routine monitoring of water quality without the need for complex and expensive tests for each specific pathogen of concern. For instance, the historical recognition of *Escherichia coli* (*E. coli*) as an indicator of fecal pollution in water, dating back to the late 19th century, highlights the long-standing reliance on these surrogate markers for assessing water safety. The detection of such indicator organisms prompts further investigation and potential action to mitigate risks associated with waterborne diseases (**Mayer and Bofill-Mas, 2016**).

Indicator germs in domestic wastewater, such as total coliforms, fecal coliforms (e.g., *Escherichia coli*), *Enterococci*, *Clostridium perfringens*, and bacteriophages, serve as critical microbial markers to assess fecal contamination, treatment efficiency, and public health risks. While total coliforms broadly indicate water quality, *E. coli* is a gold-standard fecal indicator due to its specificity to warm-blooded animals, whereas *Enterococci* and *C. perfringens* spores provide insights into contamination persistence, particularly in harsh or marine environments. Bacteriophages act as surrogates for enteric viruses, addressing gaps in traditional bacterial

indicators. Emerging genetic markers (e.g., *Bacteroides* spp.) via microbial source tracking (MST) enhance specificity by distinguishing human vs. animal fecal sources. Despite their utility, traditional indicators may not fully correlate with viral or parasitic pathogens, necessitating combined approaches for robust risk assessment. Regulatory frameworks leverage these indicators to set wastewater treatment standards, ensure safe reuse, and monitor environmental contamination, balancing limitations with complementary tools to safeguard water quality and public health (Olaolu and Akpor, 2014).

4. Wastewater treatment

The impacts and consequences cited above demonstrate the need for wastewater treatment. The characteristics of a treatment plant and the degree of treatment must be compatible with hygiene requirements and the requirements of various uses (e.g., agriculture, industry, navigation, and sports activities).

The initial pretreatment stage in wastewater treatment is critical for the removal of large solids, debris, and abrasive materials from the incoming wastewater flow. This preliminary step serves to protect the sensitive mechanical equipment used in downstream treatment processes, such as pumps and valves, from potential damage or blockages. It also enhances the overall efficiency of the subsequent purification phases by removing coarse materials that could hinder their performance. Pretreatment typically involves two main processes: screening and grit removal.

Screening: is the first line of defense in the pretreatment of wastewater. The incoming wastewater is passed through screens with openings of varying sizes, which can be broadly classified as coarse, fine, and micro screens. The selection of the appropriate screen type is determined by the specific characteristics of the wastewater being treated, the nature of the sludge present, and the types of treatment processes that will follow. Within each category, various screening methods are available, and the screens can be designed for either automatic or manual cleaning. Modern wastewater treatment plants often utilize mechanical cleaning systems to ensure efficient and continuous removal of captured materials. The primary function of screening is to remove large objects that commonly enter the sewer system, such as rags, pieces of wood, plastics, and grease. The material that is removed by the screens is typically subjected to washing and pressing to reduce its volume before being ultimately disposed of in a landfill. The main pollutants targeted and removed during the screening process are large

solids, including general rubbish, plant matter, trees, animals, and other bulky items, as well as floating materials like grease that can clog or damage downstream equipment.

Biological Processes Biological treatment relies on the activity of bacteria in the water, which break down organic matter. These techniques can be anaerobic in the absence of oxygen, or aerobic requiring a supply of oxygen (**Boukhalfa and Kafi, 2013**).

- **Activated Sludge** At a concentration of several grams per liter, microorganisms thrive in a solution kept agitated and supplied with oxygen through stirring or insufflation. Wastewater is continuously introduced, and the retention time in the biological reactor varies from a few hours to a few days (**Vendevenne, 1982**).
- **Trickling Filters (or Bacterial Beds)** In a trickling filter, a culture of microorganisms attaches and develops to form a true biological film (biofilm). The wastewater effluent is distributed by spraying over the surface where it will be treated (**Ghedbane, 2007**).
- **Rotating Biological Contactors (or Biological Discs)** In a rotating biological contactor system, the pre-settled effluent is admitted into a basin where the discs are partially submerged. These discs rotate at a speed of 1 revolution per minute in the direction of water flow. They are grouped on shafts. The rotation allows contact between the microorganisms attached to the disc that develop and the effluent, followed by the aeration of this biomass (**Ghedbane, 2007**).

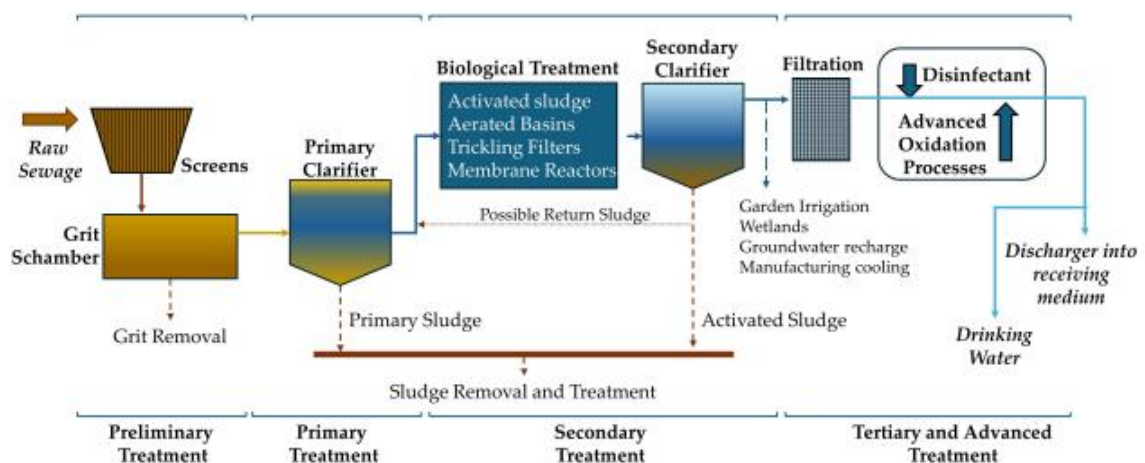


Figure 1: Wastewater treatment plant stages, from preliminary to advanced treatment processes (**Fernandes et al., 2024**).

5.Impacts of Wastewater Discharge on the Receiving Environment

The direct discharge of wastewater into the natural environment has a negative impact on several levels:

- ✓ **Environmental Impact** The direct discharge of wastewater into the natural environment disrupts the aquatic balance, transforming rivers into open-air sewers. This pollution causes a decrease in biodiversity and the deterioration of water quality (**Chelle et al., 2005 in Bodenne, 2012**), (**Carnavale, 2006**).
- ✓ **Health Impact Wastewater** is a medium for the transport, growth, and development of several diseases and pathogens known as Waterborne Diseases (WBDs) (Enteric fever, Cholera, Leptospirosis) due to biological bacterial, viral, and zoo-parasitic pollution.
- ✓ **Socio-economic Impact** These can have several aspects:For drinking water production; water pollution can reduce the number of usable resources and increase the cost of drinking water treatment or the cost of water transport.The degradation of resources can become a hindrance to industrial development, as industry consumes a lot of water and the requirements for water quality are sometimes very high.

Poor water quality has consequences for agricultural production, as agriculture uses raw, untreated water for crop irrigation.

The unaesthetic appearance of polluted watercourses leads to a decline in the tourism industry. Furthermore, it should be noted that a polluted watercourse no longer has (or hardly any) fish, and the decrease in fishing activity reduces the income of fishermen and has an impact on the national economy (**Baok, 2007**).

6.Public Health and Waterborne Diseases

Contaminated water is a major source of **waterborne diseases**, caused by pathogens like bacteria (*Vibrio cholerae*, *Salmonella typhi*), viruses (Hepatitis A, norovirus), and protozoa (*Giardia lamblia*, *Cryptosporidium parvum*). These can lead to severe illnesses, especially in vulnerable populations, and contribute to millions of deaths globally (**WHO, 2021; UNICEF, 2019**). Microbiologists are vital in **detecting and monitoring** these pathogens in water sources to prevent outbreaks (**APHA, 2017**).

7. Wastewater Impact on Agriculture

The agriculture sector is the largest consumer of water globally, accounting for nearly 70% of total water use. An estimated 20 million hectares worldwide are irrigated using wastewater, highlighting its significance as an irrigation source. However, the majority of wastewater used for irrigation is untreated. This practice is especially common in developing countries, where partially treated or untreated wastewater is frequently applied for irrigation. Untreated wastewater often contains a wide array of chemical contaminants originating from waste sites, industrial discharges, heavy metals, fertilizers, textile, leather, paper, sewage, food processing waste, and pesticides. The World Health Organization (WHO) has issued warnings about the significant health risks associated with the direct use of untreated wastewater for irrigation. These contaminants pose serious health hazards to communities living near wastewater sources and irrigated areas, including farmers, agricultural workers, their families, and consumers of crops grown with wastewater. In addition to chemical pollutants, untreated wastewater contains various organic compounds, some of which are toxic, carcinogenic, or harmful to embryonic development. The pathways through which untreated wastewater used in irrigation leads to health effects are illustrated in Fig. 2 (**Kumar *et al.*, 2021**).

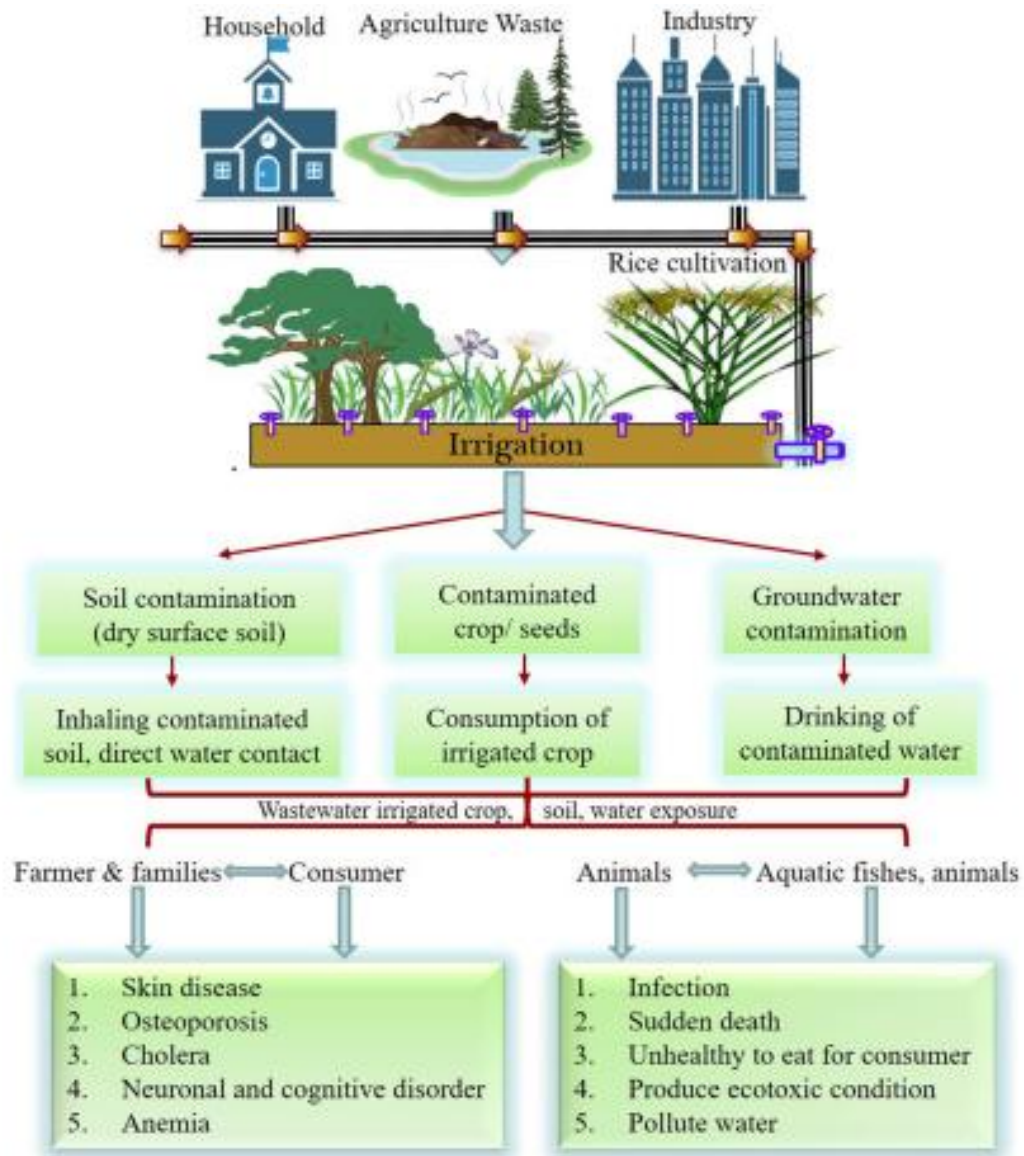


Fig. 2: Exposure pathway representing serious health concerns from wastewater-irrigated crops (Kumar *et al.*, 2021).

Materials and methods

The objective of this study is to evaluate the physico-chemical and microbiological quality of wastewater in order to better understand its composition and potential impact on the environment.

This work was carried out in a first phase at the wastewater treatment plant, where wastewater samples were collected and physico-chemical analysis was performed in The city of **Ain Témouchent**. The second phase took place at the teaching laboratory of the University of Ain Temouchent.

1. Presentation of the study area

1.1. Location of the Ain Temouchent wastewater treatment plant

The wastewater treatment plant of Ain Témouchent is situated at the geographic coordinates 35.3037°N latitude and -1.1427°W longitude. It is strategically located on the outskirts of the city to ensure efficient collection and treatment of municipal wastewater while minimizing environmental and public health risks to nearby populations. This location allows for optimal accessibility for maintenance and monitoring, while also being suitably distanced from residential zones to reduce odor and noise disturbances.



Figure 3: Geographical map of the location of the Ain Temouchent WTP

1.2. Wastewater treatment plant capacity

The wastewater treatment plant is designed to serve a population of approximately 81,400 inhabitants, corresponding to a population equivalent (PE) of 100,500. The average daily wastewater flow is estimated at 12,210 cubic meters per day (m³/day), with an average hourly flow of 508.75 cubic meters per hour (m³/h). During peak conditions, such as rainy weather, the flow can increase significantly, reaching up to 1,526.25 m³/h.

2. Sampling

Wastewater samples were collected from the Ain Temouchent wastewater treatment plant (WWTP) during the period from 17/03/2025 to 2/04/2025. A total of 5 sampling collections were carried out at two specific locations: the first at the WWTP inlet (raw wastewater) and the other at the outlet (treated wastewater)

2.1. Operating Procedure:

Samples were collected in clean bottles, previously rinsed several times with the water to be analyzed. For bacteriological analyses, sterile bottles were used, and sampling was carried out under aseptic conditions.

2.2. Preservation and Transport:

Immediately after collection, the samples were stored in a cool box at a temperature of approximately 4°C and transported quickly to the laboratory for analysis in order to minimize physico-chemical and bacteriological changes.

3. Physico-chemical Analyses

The following physico-chemical parameters were measured according to standard methods:

3.1. Hydrogen Potential (pH)

pH is the potential difference between a glass electrode and a reference electrode both immersed in the same solution. The electrode potential is related to the activity of H⁺ ions (**Rodier *et al.*, 2009**).

pH measurements were performed using a Lovibond pH-meter (model pH-110). The water sample was brought into contact with the electrode by circulation. The reading was taken after the pH value stabilized.

3.2. Temperature

Temperature was measured using a thermometer (type Tempé Mètre PDO-408). The electrode was immersed approximately 15 cm deep in the sample for 10 minutes, and the displayed value was recorded. The result is expressed in degrees Celsius (°C).

3.3. Turbidity

Turbidity, which is an indicator of the presence of suspended particles, is measured using a turbidimeter by introducing the sample into a clean cuvette free of air bubbles

3.4. Chemical Oxygen Demand (COD)

COD measures the amount of oxygen required to oxidize all oxidizable substances in water whether organic or inorganic, biodegradable or not. The oxidation is carried out by heating the sample with strong oxidizing agents at 150°C for 2 hours (Ouali, 2001).

COD is then determined photometrically.

➤ Procedure:

Add 2 mL of the water sample into a COD reagent tube:

- Lr (0–150 mg/L) for treated water
- Mr (0–1500 mg/L) for raw water

☞ Sealing and Mixing:

- Seal the tubes tightly.
- Mix gently to avoid splashing or pressure build-up.

☞ Oxidation (Digestion):

- Place the tubes in a reactor.
- Heat at 150°C for 120 minutes (2 hours).

☞ Cooling:

- Allow the tubes to cool to room temperature.

☞ Measurement:

- Insert the tubes into a photometer (**DR 5000**).
- The instrument measures light absorbance to determine the COD value.

❖ Expression of Results:

- COD is expressed in **mg/L of O₂**.
- It reflects the total quantity of oxygen required to chemically oxidize the substances in the sample.
- Higher COD = higher pollution level (organic/inorganic load).

Oxidation occurs by an excess of potassium dichromate in an acidic medium and under boiling, in the presence of silver sulfate (Ag₂SO₄) and mercury sulfate (HgSO₄). The excess dichromate is titrated with ferrous ammonium sulfate solution, which changes color to reddish-violet in the presence of a ferroin indicator.

The COD, expressed in mg/L of oxygen, is given by the following formula:

$$\text{COD} = 8000 \cdot (V_0 - V_1) \cdot TV$$

- V_0 : Volume of ferrous ammonium sulfate used for the blank test (in mL)
- V_1 : Volume of ferrous ammonium sulfate used for the actual sample (in mL)
- V : Volume of the water sample (in mL)
- T : Titer of the ferrous ammonium sulfate solution

3.5. Biochemical Oxygen Demand (BOD₅)

The determination of BOD₅ involves measuring the oxygen consumption by biological activity at a constant temperature of 20°C over a standard period of 5 days (Ouali, 2001).

The reduction of oxygen at a suitable cathode generates a current proportional to the partial pressure of oxygen in the solution (**Rodier, 1996**).

∞ Procedure:

We used a Lovibond BOD meter. The procedure for measuring BOD₅ is as follows:

For treated water:

- In a BOD bottle with a magnetic stir bar, add 428 mL of the water sample to be tested.
- Add 10 drops of nitrification inhibitor.
- In the rubber seal, add 3 drops of potassium hydroxide (KOH).
- Place the BOD probe on the bottle.
- Incubate the mixture at 20°C for 5 days in the dark.

☞ Expression of Results

After the 5-day incubation period at 20°C in the dark, the **BOD₅ value** is obtained by calculating the difference between the initial dissolved oxygen (DO) and the final DO measured at the end of the 5 days.

The result is expressed in milligrams of oxygen consumed per liter of sample (mg/L).

Formula:

$$\text{BOD}_5 = \text{DO}_{\text{initial}} - \text{DO}_{\text{final}}$$

- **DO₁ (initial):** Measured before incubation
- **DO₂ (final):** Measured after 5 days of incubation
- **BOD₅:** Amount of oxygen consumed over 5 days

3.6. Dosage of Different Types of Anions and Cations

3.6. 1. Nitrates (NO₃⁻)

☞ Principle

In the presence of sodium salicylate, nitrates form para-nitrosalicylate sodium, which is yellow-colored and can be measured spectrophotometrically (**Rodier et al., 2009**).

☞ Procedure

In a beaker, introduce 10 mL of the water sample and 1 mL of sodium salicylate. The mixture is evaporated at 75 °C until complete vaporization of the liquid. After cooling, 2 mL of sulfuric acid is added. The solution is left to stand for 10 minutes to allow the reactions to complete. Then, 15 mL of distilled water and 15 mL of sodium tartrate solution (NaOH) are added. After another **10-minute rest**, the final solution is analyzed using a spectrophotometer at a wavelength of 415 nm (**Rodier, 1996**).

☞ Expression of Results

For a 10 mL test sample, the calibration curve directly provides the nitric nitrogen content, expressed in milligrams per liter of water.

To obtain the nitrate concentration (NO_3^-), this result is multiplied by **4.43**.

3.6. 2.Nitrate

☞ Reflectometric dosage method

The nitrate ions (NO_3^-) present in the sample are first reduced to nitrite ions (NO_2^-) by a specific reducing agent. In an acidic medium, the nitrite ions react with an aromatic amine to form a diazonium salt. This salt then reacts with N-(1-naphthyl)-ethylenediamine to produce a red-violet azo dye. The intensity of the coloration is measured by reflectometry, which allows the quantification of the nitrate concentration in the sample.

3.6.3. Ammonium

☞ Colorimetric method (Nessler or indophenol):

Ammonium (NH_4^+) reacts with a specific reagent (e.g., Nessler's reagent or the indophenol method) to form a colored compound whose intensity is proportional to the ammonium concentration. The measurement is performed by spectrophotometry or reflectometry.

3.6.4. Phosphate

Phosphate determination in wastewater mainly relies on colorimetric methods based on the formation of a blue complex, the phosphomolybdate complex, which is then reduced to produce a measurable coloration.

Orthophosphate (PO_4^{3-}) reacts with ammonium molybdate in the presence of antimony to form a phosphomolybdate complex. This complex is then reduced by a reducing agent, often ascorbic acid, to produce a blue compound whose intensity is proportional to the phosphate concentration.

Measurement:

The coloration is measured by spectrophotometry, generally at a wavelength around 820 nm, or b

4. Bacteriological Analyses

Bacteriological analyses of various raw and treated wastewater samples consisted of enumerating indicator microorganisms of fecal contamination. The targeted microorganisms were:

- ✓ Total and fecal coliforms (TC and FC);

Several methods exist for determining fecal pollution indicators. In this study, bacterial counts were performed using an indirect enumeration method based on the Most Probable Number (MPN) technique.

4.1. Enumeration of Total and Fecal Coliforms

Microbiological analyses were performed on five wastewater samples, including both raw and treated water. Among these analyses, total and fecal coliforms were enumerated using Lactose Bile Broth with Brilliant Green (BLBVB) medium, equipped with Durham tubes to detect gas production. The Most Probable Number (MPN) method was applied using three series of dilutions: the first with 10 mL of sample, the second with 1 mL, and the third with 0.1 mL. Sampling constraints limited the collection to three raw and treated wastewater samples. For the confirmation of fecal coliforms, only the BLBVB medium was used due to the unavailability of indole-free peptone water (**Figure 4**).

After incubation for 24 to 48 hours at 37°C, a positive culture with gas production is considered presumptive for total coliforms. The detection of fecal coliforms, and especially *E. coli*, is performed from the positive tubes using the confirmatory test, which involves a BLBVB tube with a Durham tube, followed by incubation for 24 hours at 44°C.

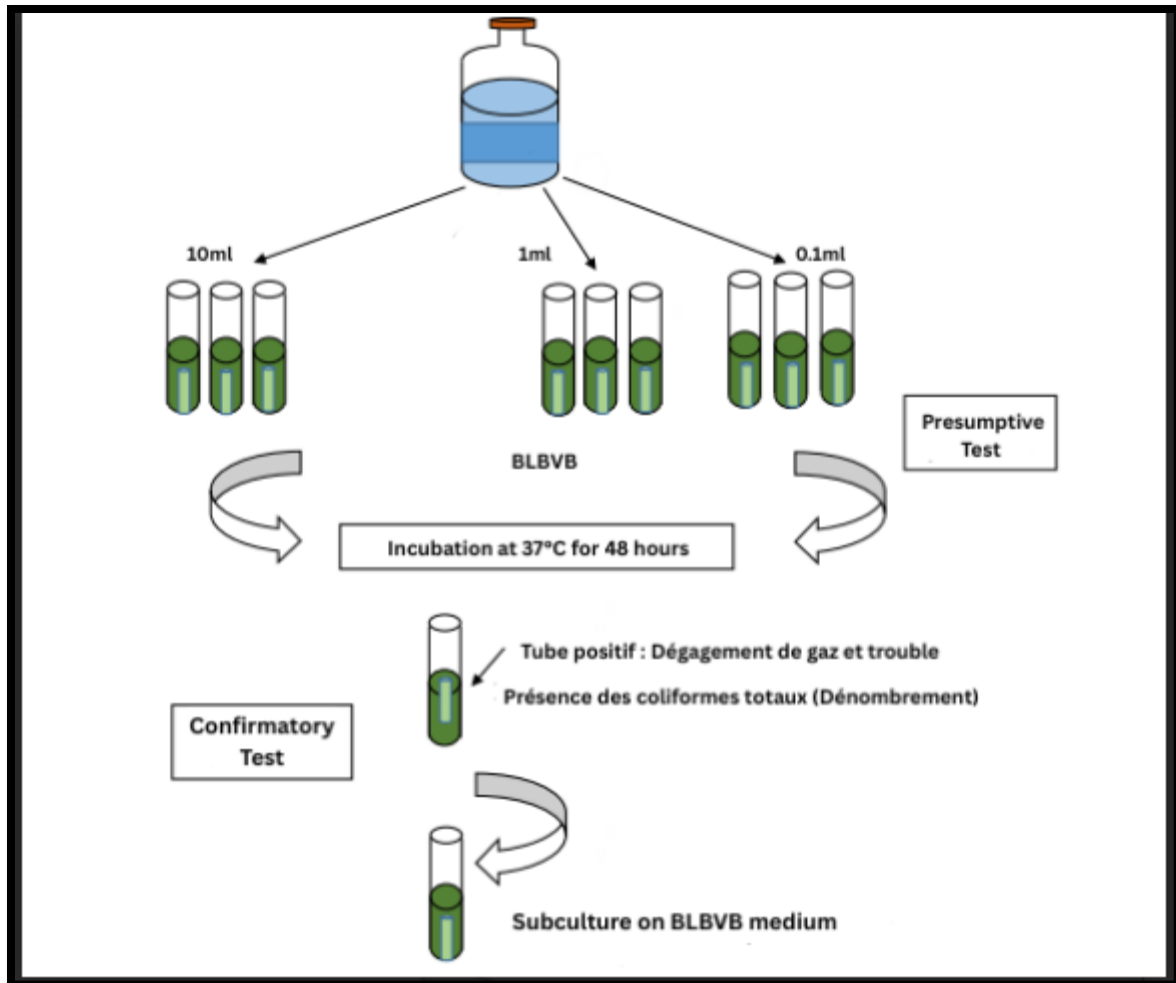


Figure 4: Detection and enumeration of total and fecal coliform

Results and discussion

1. Physico-chemical analysis results

1.1. Potential of hydrogen (pH)

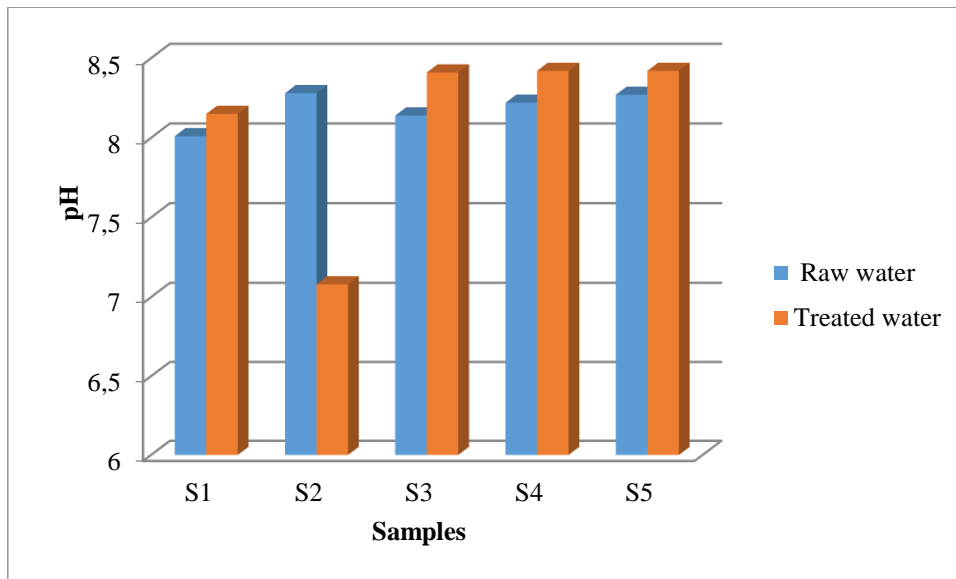


Figure 05: Variation of the pH of wastewater sample

The pH levels across all samples indicate varying behavior before and after treatment. Sample S1 shows a slight increase from 8.01 in the raw state to 8.15 in the treated state, remaining within a stable, slightly alkaline range. Sample S2 experiences a notable decrease from 8.28 to 7.08, suggesting possible acidification, which could be due to chemical additions or metabolic byproducts from biological treatment. In contrast, Sample S3 shows an increase from 8.14 to 8.41, and similarly, Sample S4 rises from 8.22 to 8.42. Sample S5 also follows this trend, going from 8.27 to 8.42. The overall trend shows that while most samples maintain or slightly increase in pH, Sample S2 deviates with a sharp drop, indicating a unique chemical or biological response during treatment (**Figure 05**).

The comparison with Algerian standards N°41(2012) and those of the WHO(2016), which recommend a pH range between 6.5 and 8.5 for treated wastewater discharges, shows that the majority of the samples comply with this regulatory range, although three treated values (8.41 and 8.42) reach the upper limit.

Belhamidi et al. (2021) and **Brahimi et al. (2020)** reported pH values in the wastewater treatment plants of Bouira (~7.6) and Beni Messous (between 7.3 and 8.3). These results are consistent with our observations, which recorded pH values ranging from 7 to 8.28.

Overall, these results confirm the conformity of the applied treatment and emphasize the importance of regularly monitoring the pH to ensure continuous compliance with environmental requirements.

The pH is also an important factor in interpreting corrosion in the pipelines of wastewater treatment facilities (**Belghyti *et al.*, 2009**).

1.2. Temperature

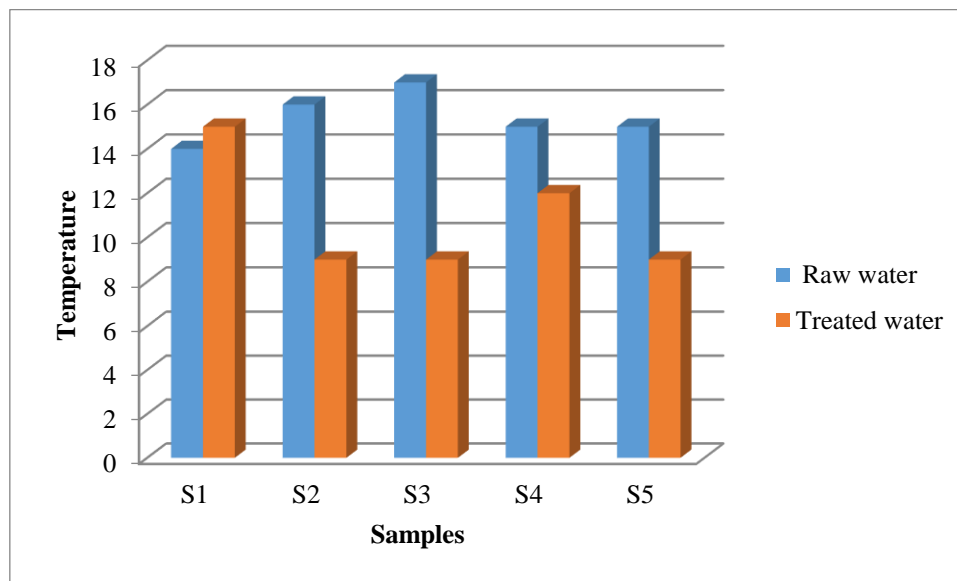


Figure 6: Temperature variation of wastewater samples

The temperatures measured in the five samples of raw wastewater are 14, 16, 17, 15, and 15 °C, resulting in an average of 15.4 °C. For the treated wastewater, the recorded temperatures are 15, 9, 9, 12, and 9 °C, with an average of 10.8 °C (**Figure 2**). According to the standards of the **Algerian Official Journal N° 26 (2006)** and those of the **World Health Organization (WHO)**, the temperature of discharged wastewater must be below 30 °C to protect receiving environments and ensure the effectiveness of biological treatment processes. The measured temperatures fully comply with this regulatory requirement (**Figure 6**).

A high temperature promotes the growth of microorganisms and can enhance taste, odor, and color (**WHO, 1994**). On the other hand, a temperature below 10°C slows down chemical reactions in the various water treatment processes (**Rodier *et al.*, 2009**).

1.3.Turbidity

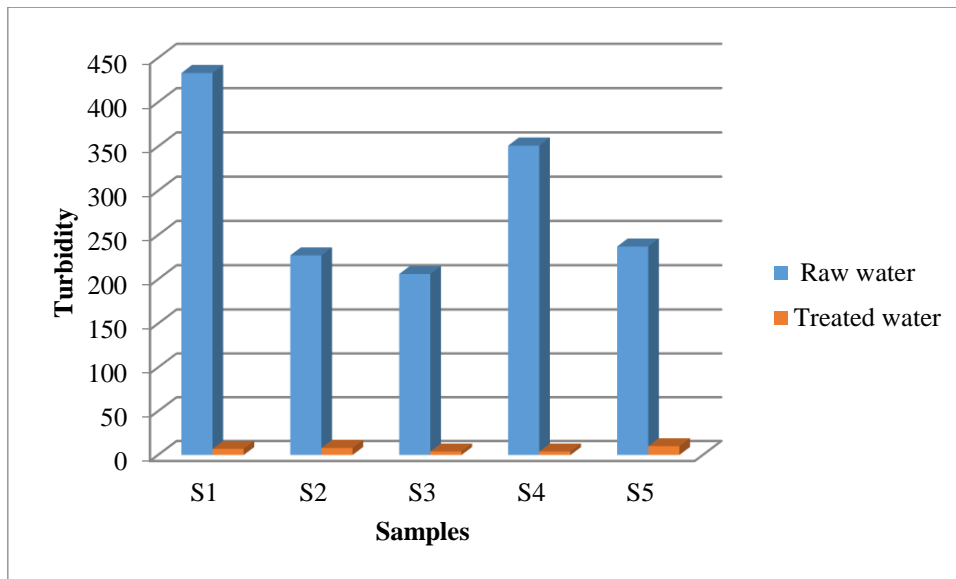


Figure 7 : Variation in turbidity of wastewater samples

Turbidity values exhibit significant decreases from the raw to the treated state, underscoring the effectiveness of the treatment process in removing suspended particles and improving clarity. Sample S1's turbidity drops dramatically from 433 NTU to just 7NTU. Sample S2 follows with a reduction from 227 to 8 NTU, and Sample S3 from 206 to 4 NTU. Sample S4 decreases from 351 to 4 NTU, while Sample S5 shows a reduction from 237to 10 NTU (**Figure 7**). This consistent and substantial turbidity removal across all samples confirms high clarification efficiency, likely through filtration, sedimentation, or coagulation processes.

Turbidity serves as a crucial water quality parameter, since elevated turbidity levels are commonly linked to the presence of particulate matter, microorganisms, and potential pathogens.

Belhamidi et al. (2021) reported that the Bouira wastewater treatment plant exhibits high turbidity in the treated effluent due to inefficient clarification. In contrast, our treated samples showed a turbidity reduction of over 97%, reaching values below 4 NTU, reflecting excellent efficiency in removing suspended solids. These results indicate that our process provides superior solid-liquid separation, thereby contributing to improved treated water quality.

Turbidity is a reduction in water clarity because of the presence of suspended matter absorbing or scattering downwelling light, and water is considered turbid when the presence of suspended particles becomes conspicuous. Inorganic suspended materials, suspensoids or tripton, reduce light penetration, form adsorption and desorption surfaces, and are able to aggregate with dissolved substances, bacteria, and algae (Grobbelaar, 2009).

1.4. Conductivity

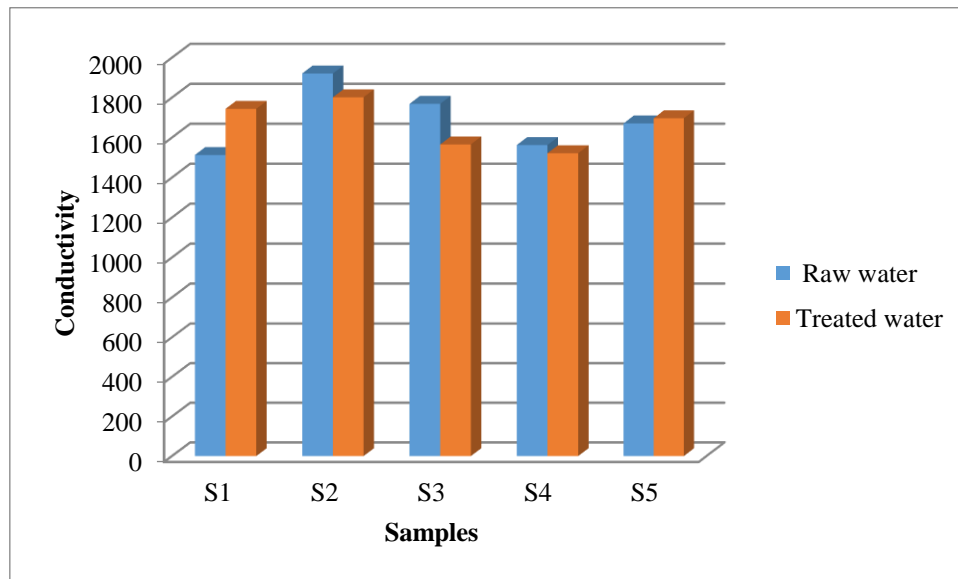


Figure 8: Variation of conductivity in wastewater samples

The conductivity values measured in the raw wastewater samples (S1 to S5) range from 1513 $\mu\text{S/cm}$ to 1921 $\mu\text{S/cm}$, with an average of approximately 1687 $\mu\text{S/cm}$. The highest conductivity was recorded in sample S2 with a value of 1921 $\mu\text{S/cm}$, while the lowest value corresponds to sample S1 at 1513 $\mu\text{S/cm}$. For the treated wastewater, conductivity values fluctuate between 1522 $\mu\text{S/cm}$ and 1802 $\mu\text{S/cm}$, with an average of about 1666 $\mu\text{S/cm}$. These results indicate a slight decrease in conductivity after treatment, but the values remain relatively close between raw and treated wastewater (**Figure 8**).

Following treatment, conductivity values exhibited only a slight decline, ranging from 1522 to 1802 $\mu\text{S/cm}$, with an average of approximately 1666 $\mu\text{S/cm}$. This marginal decrease indicates that the treatment process had a limited effect on the dissolved ions contributing to conductivity. Consequently, these conductivity results highlight the need to supplement conventional wastewater treatment with specialized technologies when the removal of dissolved ionic species is essential to meet effluent quality standards and support water reuse applications.

Conductivity is a measurement of the ability of an aqueous solution to transfer an electrical current. The current is carried by ions and therefore the conductivity increases with the concentration of ions present in solution, their mobility and temperature of the water. Conductivity measurements are related to ionic strength, however, this is not a qualitative exercise (Zhuiykov, 2012).

1.5. Biochemical Oxygen Demand (BOD)

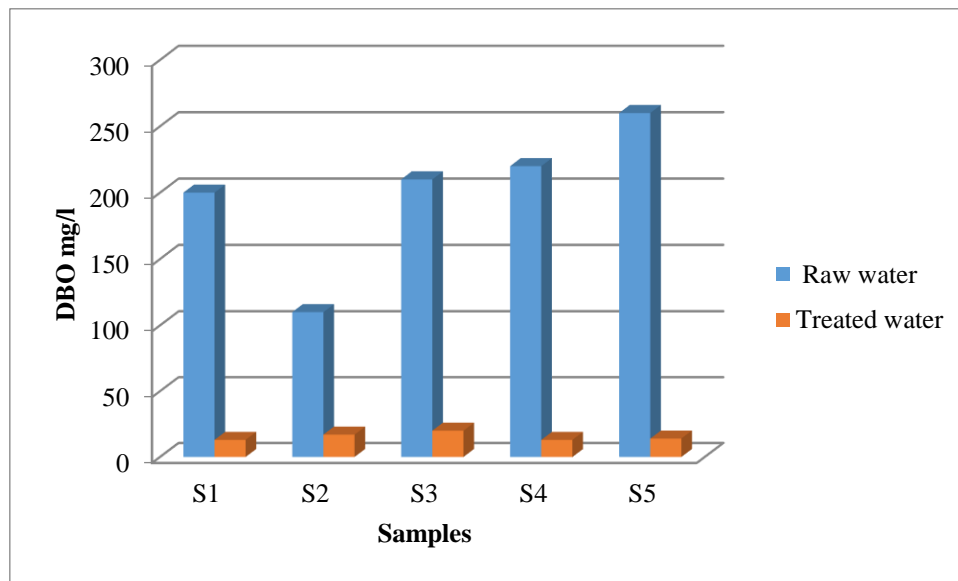


Figure 9: Variation of Biochemical Oxygen Demand in wastewater samples

The Biochemical Oxygen Demand (BOD) values measured in raw wastewater samples range from 110 mg/L to 260 mg/L, with specific measurements of 200, 110, 210, 220, and 260 mg/L. These high values indicate a significant organic load characteristic of untreated wastewater. In contrast, treated wastewater samples show much lower BOD₅ values, between 13 mg/L and 20 mg/L (13, 17, 20, 13, 14 mg/L), reflecting a substantial reduction in organic pollution after treatment. The average BOD₅ for raw wastewater is about 200 mg/L, while for treated wastewater it is approximately 15.4 mg/L, demonstrating the effectiveness of the treatment process (**Figure 9**). These reductions across all samples demonstrate that the treatment process is highly effective in reducing the oxygen demand of the effluent, which is critical for protecting downstream aquatic environments from oxygen depletion.

According to the Algerian Official Journal N°41 (2012), the maximum allowable limit for BOD in wastewater discharged into the natural environment is set at 30 mg/L. The obtained results for treated wastewater comply well with these standards, confirming the conformity of the applied treatment. Conversely, the raw wastewater values greatly exceed these thresholds, highlighting the need for effective treatment prior to any discharge or reuse.

In the study by **Mezghiche et al. (2018)**, treated effluents frequently exhibited Biochemical Oxygen Demand (BOD) levels around 20 mg/L. This finding aligns with our results, which showed BOD values ranging between 13 and 20 mg/L, indicating comparable treatment performance in reducing organic load.

The BOD is interpreted as a measure of the concentration of organic material that can serve as a substrate to support the growth of microorganisms. The BOD test, as used for assessing the efficiency of wastewater treatment, is intended to measure some fraction of the carbonaceous oxygen demand, i.e., the oxygen consumed by heterotrophic microorganisms that utilize the organic matter of the waste in their metabolism, and not the oxygen demand exerted by autotrophic nitrifying bacteria (**Kumar, 2005**).

1.6. Chemical Oxygen Demand (COD)

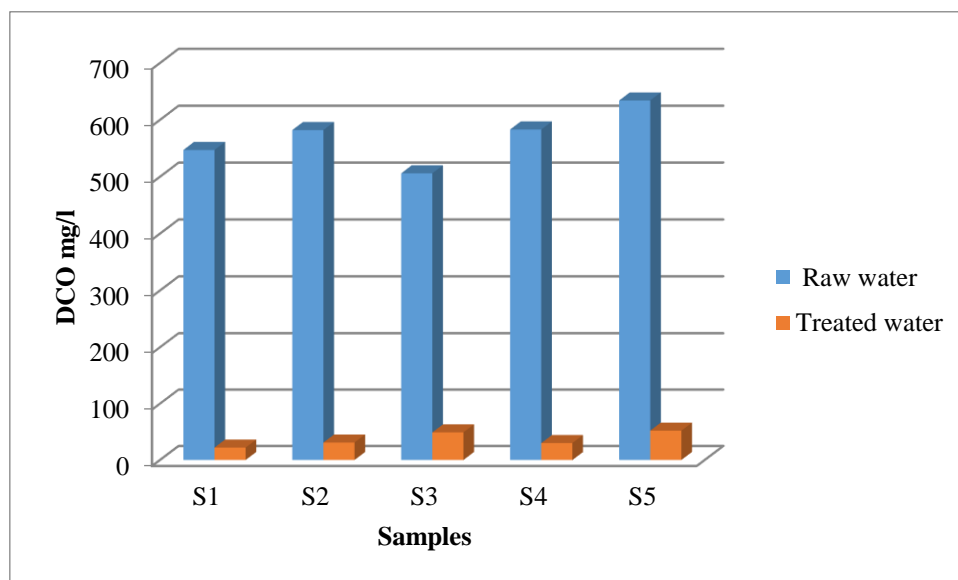


Figure 10: Variation of Chemical Oxygen Demand in wastewater samples

Chemical Oxygen Demand values, which represent both biodegradable and non-biodegradable organic content, also show marked reductions. The Chemical Oxygen Demand (COD) values measured in raw wastewater samples (S1 to S5) range from 506 mg/L to 634 mg/L, with respective measurements of 547, 582, 506, 583, and 634 mg/L. These results indicate a very high organic load, characteristic of untreated wastewater. In contrast, treated wastewater samples show significantly lower COD values, ranging from 22 mg/L to 52 mg/L (22, 31, 49, 30, 52 mg/L), reflecting a substantial reduction in organic pollution after treatment. The average COD for raw wastewater is approximately 570 mg/L, while that of treated wastewater is about 37.2 mg/L, illustrating the effectiveness of the applied treatment process (Figure 10).

According to the Algerian Official Journal No. 41 (2012), the maximum allowable limit for COD in wastewater discharged into the natural environment is set at 90 mg/L. The results obtained for treated wastewater generally comply with these standards, confirming the conformity of the treatment performed. Conversely, the raw wastewater values exceed these limits by a wide margin, highlighting the necessity of effective treatment before any discharge or reuse.

1.7. Nitrites

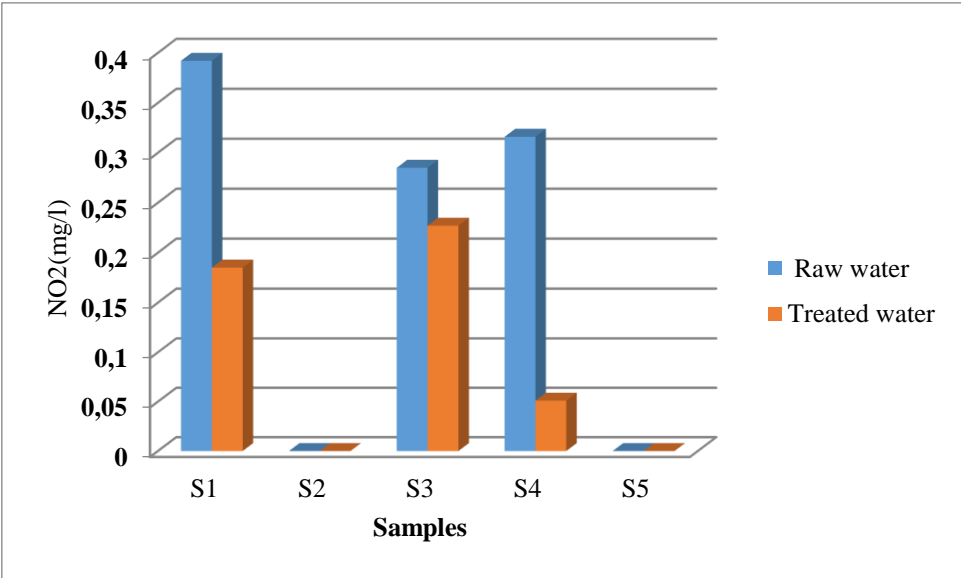


Figure 11: Variation of Nitrite in wastewater samples

The nitrite concentrations measured in the raw wastewater samples (S1 to S5) show notable variations, ranging from 0 to 0.392 mg/L. The highest value was recorded in sample S1 with 0.392 mg/L, while samples S2 and S5 contained no detectable nitrites (0 mg/L). For the treated wastewater, nitrite concentrations are generally lower, ranging between 0 and 0.185 mg/L, with the maximum value observed in sample S1 (0.185 mg/L) and nearly zero values in S2 and S5. The average nitrite concentration for raw wastewater is approximately 0.199 mg/L, whereas for treated wastewater it is reduced to about 0.051 mg/L, indicating a partial efficiency of the treatment process. These nitrite concentrations are notably lower than those reported by **Benhabib *et al.* (2019)** at Ain Sefra, where the average nitrite level was 0.63 mg/L

According to the Algerian Official Journal No. 36 (2009), the maximum allowable concentration of nitrites in treated wastewater discharged into the natural environment is set at 0.1 mg/L. This value was exceeded in the analyzed purified water samples S1 and S3. These results indicate that although the treatment significantly reduces the nitrite concentration, it sometimes remains above the permissible limit.

1.7. Nitrates

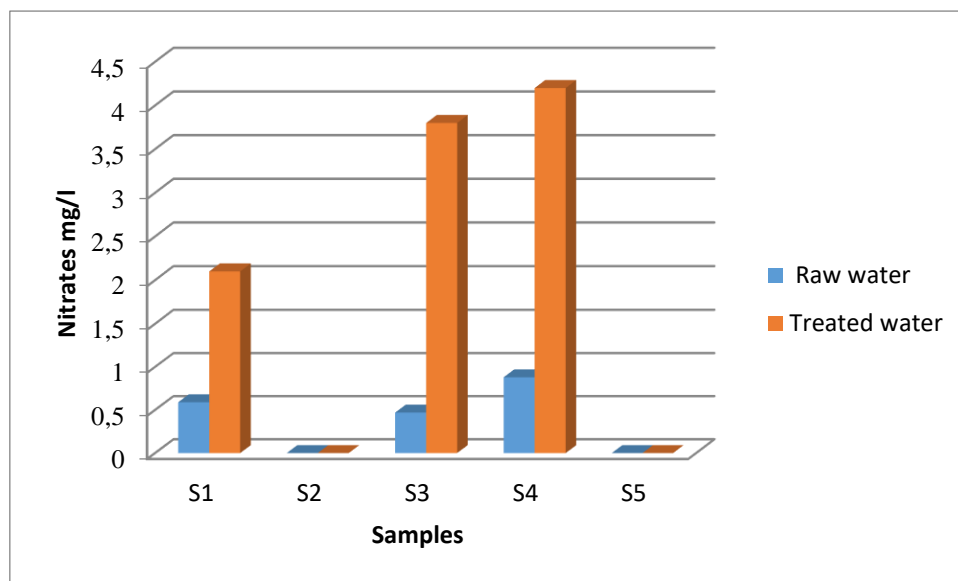


Figure 12: Variation of **Nitrates** in wastewater samples

The nitrate concentrations measured in the raw wastewater samples (S1 to S5) range from 0 to 0.88 mg/L, with respective values of 0.59 mg/L for S1, 0 mg/L for S2, 0.47 mg/L for S3, 0.88 mg/L for S4, and 0 mg/L for S5. After treatment, the nitrate concentrations in the treated wastewater show a significant increase, ranging from 0 to 4.2 mg/L: 2.1 mg/L for S1, 0 mg/L for S2, 3.8 mg/L for S3, 4.2 mg/L for S4, and 0 mg/L for S5. This rise in nitrate levels after treatment can be explained by nitrification processes occurring during the biological treatment of wastewater.

The observed increase in nitrate concentrations from raw to treated wastewater samples highlights the effectiveness of the nitrification process during biological treatment. However, elevated nitrate concentrations in effluents may pose environmental concerns, such as eutrophication in receiving water bodies, if not managed properly.

1.8. Ammonium

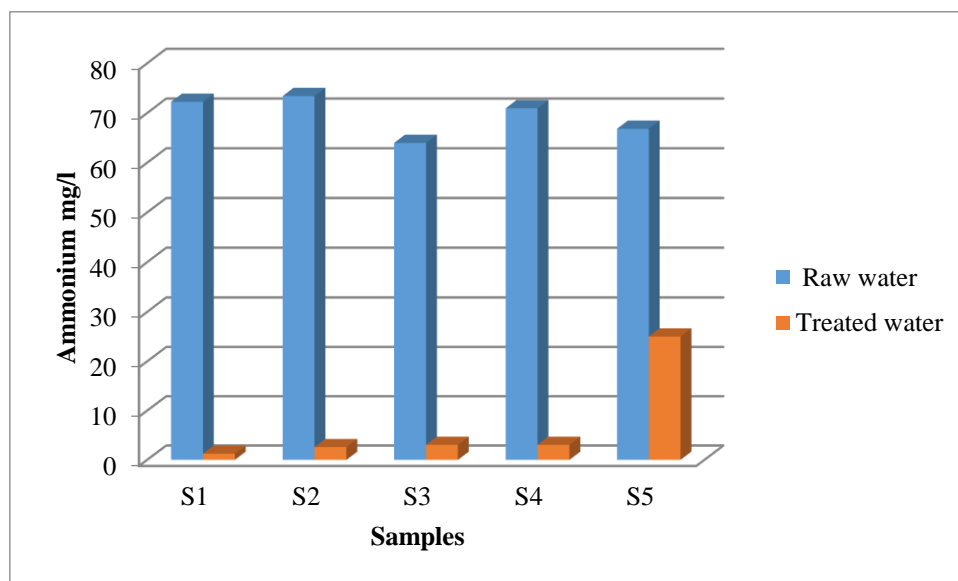


Figure 13: Variation of **Ammonium** in wastewater samples

The ammonium concentrations measured in the raw wastewater samples (S1 to S5) range from 63.98 mg/L to 73.40 mg/L, with an average of approximately 69.08 mg/L. These values indicate a high ammonium load, characteristic of untreated wastewater. In contrast, the concentrations in the treated wastewater show a significant decrease, with values ranging from 1.25 mg/L to 25.02 mg/L, and an average of 6.78 mg/L. This substantial reduction demonstrates the effectiveness of the applied treatment. However, it is noteworthy that the treated sample S5

exhibits a relatively high ammonium concentration (25.02 mg/L), suggesting a possible local inefficiency or malfunction in the treatment process (**Figure 13**)

Benhabib et al. (2019) reported residual ammonium concentrations around 6.3 mg/L at the Ain Sefra wastewater treatment plant. In comparison, our results suggest that the treatment system under study achieves comparable or even superior ammonium removal efficiency. However, the elevated ammonium concentration observed in sample S5 highlights the need for continuous monitoring and optimization of certain operational aspects to ensure consistent performance across all treatment units.

1.9. Phosphates

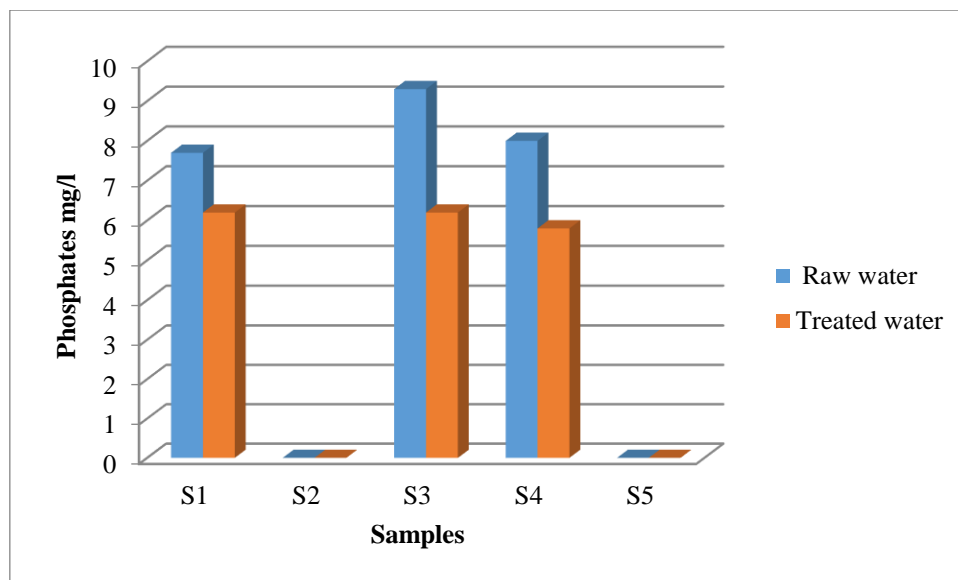


Figure 14: Variation of Phosphates in wastewater samples

The phosphate concentrations measured in the five raw wastewater samples (S1 to S5) range from 0 to 9.3 mg/L. After treatment, the concentrations decrease slightly, reaching 6.2 mg/L, 0 mg/L, 6.2 mg/L, 5.8 mg/L, and 0 mg/L respectively. These results remain well below the maximum limit of 50 mg/L set by the **Algerian Official Journal N° 36 (2009)** for wastewater discharges into the public network or receiving environments. This significant margin relative to the official standard highlights that, despite partial treatment efficiency, the phosphate levels in these wastewaters do not pose a risk of regulatory exceedance according to the current Algerian regulations. However, it is advisable to continue monitoring and optimizing the treatment processes in order to minimize environmental impact, particularly to prevent eutrophication of aquatic environments.

2. Bacteriological Analysis Results

Monitoring the bacteriological quality of wastewater involves the detection and enumeration of the following microorganisms: total coliforms (TC) and fecal coliforms). These microorganisms have been selected by the World Health Organization (WHO) as indicators of fecal contamination.. The results of the bacteriological analyses are presented in the Table 2

Table2: Microbiological Analysis Results of Total and Fecal Coliforms in Wastewater Samples

Sample	Parameter	Raw Wastewater	Treated Wastewater
S1	Total Coliforms (TC) TC/100ML	1.1×10^3	2.1×10^2
S1	Fecal Coliforms (FC) FC/100ML	28	28
S2	Total Coliforms (TC) TC/100ML	2.1×10^2	28
S2	Fecal Coliforms (FC) FC/100ML	28	21
S3	Total Coliforms (TC) TC/100ML	1.1×10^3	1.5×10^2
S3	Fecal Coliforms (FC) FC/100ML	20	20

Bacteriological analyses conducted on three samples of raw and treated wastewater revealed variable concentrations of total and fecal coliforms. For total coliforms, a significant reduction was observed after treatment, for example, from 1.1×10^3 TC/100 mL to 2.1×10^2 TC/100 mL in sample S1, and from 2.1×10^2 to 28 TC/100 mL in sample S2, indicating a certain

effectiveness of the treatment process. However, fecal coliforms, which are key indicators of sanitary contamination, showed very little or no reduction in some cases, with stable values around 20 to 28 FC/100 mL before and after treatment. These results suggest that the applied treatment does not effectively eliminate fecal bacteria.

Compared to the World Health Organization (WHO) 2006 guidelines, which set thresholds of 5000 total coliforms (TC) per 100 mL and 2000 fecal coliforms (FC) per 100 mL, the results for the treated wastewater can be considered compliant. However, according to the Algerian Official Journal of 2012, which establishes much stricter standards—specifically a maximum limit of 100 CFU/100 mL for fecal coliforms in treated wastewater used for irrigation—the measured concentrations remain concerning. Although total coliforms generally meet these standards, the persistence of fecal coliforms above the recommended limits indicates a potential health risk and highlights the need to optimize treatment processes to improve the microbiological quality of the treated water.

According to **Dupray and Derrien (1995)** The abundance of coliforms in treated effluents depends, on one hand, on the microbiological quality of the raw wastewater and, on the other hand, on the effectiveness of the treatment process in eliminating coliforms. The presence of coliforms results from their abundance in the fecal matter of warm-blooded animals and serves as a primary fecal indicator of contamination.

In the study conducted by **Luoyao *et al.* (2023)**, the results demonstrated that the wastewater treatment plant (WWTP) achieved a reduction in the concentration of fecal coliform bacteria (FCB) by 3 to 5 logs units, resulting in a residual concentration in the effluent ranging from 10⁴ to 10⁵ CFU/L. However, despite this significant decrease in bacterial load, the antibiotic resistance rate of FCB species increased markedly after treatment within the WWTP.

Coliforms, notably total coliforms and fecal coliforms, are essential microbiological indicators used to assess the quality of wastewater and detect fecal contamination. Their presence potentially signals the presence of pathogens in the water.

Conclusion

Physico-chemical and microbiological analyses of wastewater are essential for assessing the quality of effluents and their impact on the environment and public health. Physico-chemical parameters such as pH, temperature, chemical oxygen demand (COD), as well as concentrations of ammonium (NH_4^+), nitrates (NO_3^-), and nitrites (NO_2^-) help characterize the organic and chemical pollution of wastewater. At the same time, microbiological analyses, notably the detection of coliforms, provide information about bacterial contamination.

These analyses not only allow verification of the efficiency of treatment plants and the design of treatment processes but also ensure that discharges comply with environmental and health standards. They thus contribute to the protection of aquatic environments and human health by preventing the spread of chemical and microbiological pollutants into the environment.

Physico-chemical and microbiological analyses of wastewater are complementary and indispensable tools to ensure effective treatment, reduce environmental impact, and enable the safe reuse of treated water.

For further improve effluent quality and meet the most stringent standards, it would be relevant to consider:

- The integration of a final disinfection process (UV) to ensure the elimination of pathogenic germs, particularly fecal coliforms.
- The optimization of nitrification/denitrification stages to control total nitrogen concentrations and reduce the risks of eutrophication.
- Enhanced monitoring of critical parameters (e.g., ammonium, fecal coliforms) to anticipate and quickly correct any process deviations

Reference

- Belghyti, D., El Guamri, Y., Ztit, G., Ouahidi, M., Joti, M. B., Harchrass, A., Amghar, H., Bouchouata, O., El Kharrim, K., & Bounouira, H. (2009). Caractérisation physico-chimique des eaux usées d'abattoir en vue de la mise en œuvre d'un traitement adéquat : cas de Kénitra au Maroc. *Afrique Science*, 5(2), 199–216.
- Benaricha, B., & Abdelkader, E. F. (2015). Physico-chemical characterization of effluent from activated sludge WWTPs in Saïda, Algeria. *ResearchGate*.
- Boukhalfa, S., & Kafi, Y. (2013). Biological treatment processes: a comparative overview. *Environmental Technology*, 24(2), 99–110.
- Cristian, G., et al. (2015). Toxic industrial waste and its environmental implications. *Environmental Contamination Review*, 58(4), 227–245.
- Dupray, E., & Derriena, A. (1995). Influence du passage de *Salmonella* spp, et *Escherichia coli* en eaux usées sur leur survie en eau de mer. *Water Research*, 29(4), 1005–1011.
- Etsuyankpa, M. B., Augustine, A. U., & Mathew, M. (2024). An overview of wastewater characteristics, treatment and disposal: A review. *J. Appl. Sci. Environ. Manage.*, 28(5), 1553–1572.
- Etsuyankpa, V., et al. (2024). The role of pH and temperature in wastewater treatment efficiency. *Environmental Engineering Journal*, 12(3), 145–160.
- Fernandes, J., Ramísio, P. J., & Puga, H. (2024). A comprehensive review on various phases of wastewater technologies: Trends and future perspectives. *Engineering*, 5, 2633–2661. <https://doi.org/10.3390/eng5040138>
- Ghedbane, S. (2007). Trickling filters and rotating biological contactors in practice. *Water Engineering Journal*, 16(3), 211–224.
- Grobbelaar, J. U. (2009). Turbidity. In *Encyclopedia of Inland Waters* (pp. 699–704). <https://doi.org/10.1016/B978-012370626-3.00075-2>
- Kato, S., & Kansha, Y. (2024). Comprehensive review of industrial wastewater treatment techniques. *Environmental Science and Pollution Research*, 31, 51064–51097. <https://doi.org/10.1007/s11356-024-34584-0>
- Khechekhouche, A., Bouchema, F., Kaddou, Z., Khechana, S., & Miloudi, A. (2020). Performance of a wastewater treatment plant in south-eastern Algeria (El Oued). *International Journal of Environmental and Chemical Analysis*, 5(2).
- Kumar, K. K., Soni, R., Jamal, Q. M., Tripathi, P., Lal, J., Jha, N. J., Siddiqui, M. H., Kumar, P., Tripathi, V., & Ruokolainen, J. (2021). Wastewater treatment and reuse: A review of its applications and health implications. *Water Air Soil Pollut.*, 232, 208. <https://doi.org/10.1007/s11270-021-05154-8>
- Kumar, R., & Kumar, A. (2005). Water analysis | Biochemical oxygen demand. In *Encyclopedia of Analytical Science* (2nd ed., pp. 315–324). <https://doi.org/10.1016/B0-12-369397-7/00662-2>

- Lamri, N., & Bachouche, N. (2022). Evaluation of the treatment of purified wastewater in the city of Bouira (Algeria). *Technium Social Sciences Journal*, 37(1), 573–591. <https://doi.org/10.47577/tssj.v37i1.7695>
- Li, D., & Liu, S. (2019). Detection of river water quality. In *Water Quality Monitoring and Management* (pp. 211–220). <https://doi.org/10.1016/B978-0-12-811330-1.00007-7>
- Li, Y., & Liu, M. (2024). Pollutant types and treatment methods in wastewater. *Engineering*, 5, 2633–2661. <https://doi.org/10.3390/eng5040138>
- Luoyao, W., Cui, Y., & Huang, L. (2024). Changes of composition and antibiotic resistance of fecal coliform bacteria in municipal wastewater treatment plant. *Journal of Environmental Sciences*, 146, 241–250.
- Mara, D. (2003). *Domestic Wastewater Treatment in Developing Countries*. London: Earthscan.
- Mayer, B., & Bofill-Mas, S. (2016). Indicator organisms in water: history and application. *Water Quality Monitoring Review*, 31(4), 123–139.
- Metahri, N. (2012). Human excreta and wastewater characteristics: pollutant load and treatment implications. *Journal of Environmental Science*, 45(2), 89–102.
- Metahri, N. (2012). Physico-chemical indicators of wastewater: BOD, COD, TSS. *Journal of Water Research*, 37(1), 45–60.
- Metcalf & Eddy, Inc. (2014). *Wastewater engineering: Treatment and resource recovery* (5th ed.). McGraw-Hill Education.
- Moussaoui, T., Derdour, A., Hosni, A., Ballesta de los Santos, M., Legua, P., & Pardo Picazo, M. Á. (2023). Assessing the quality of treated wastewater for irrigation: A case study of Ain Sefra wastewater treatment plant. *Sustainability*, 15(14), 11133. <https://doi.org/10.3390/su151411133>
- Rekrak, A., & Fellah, A. C. (2020). Dependability and purification performance of a semi-arid zone: A case study of Algeria's wastewater treatment plant (Ain Temouchent). *Egyptian Journal of Aquatic Research*, 46(1), 41–47. <https://doi.org/10.1016/j.ejar.2020.02.001>
- Renfrew, D., Vasilaki, V., Nika, E., Harris, E., & Katsou, E. (2024). Systematic assessment of wastewater resource circularity and sustainable value creation. *Water Research*, 251, 121141. <https://doi.org/10.1016/j.watres.2024.121141>
- Rodier, J. (2009). *L'analyse de l'eau : eaux naturelles, eaux résiduaires, eau de mer* (9e éd.). Paris : Dunod.
- Tchobanoglous, G., Stensel, H. D., & Tsuchihashi, R. (2014). *Wastewater engineering: Treatment and reuse* (5th ed.). McGraw-Hill Education.
- Vendevienne, P. (1982). *Activated Sludge Process*. Paris: Presses Universitaires.

Wikipedia contributors. (2025). *Wastewater*. Wikipedia.
<https://en.wikipedia.org/wiki/Wastewater>

Zhuykov, P. S. (2012). Solid-state sensors monitoring parameters of water quality for the next generation of wireless sensor networks. *Sensors and Actuators B: Chemical*, 161(1), 1–20. <https://doi.org/10.1016/j.snb.2011.10.078>

