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Title

Study and implementation of a water treatment system

Using Electromagnetic Fields

publicly defended on / / , before a jury composed of:

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Dedication

I dedicate this work

To my **mother**, the light of my life, true love, the one she cares, with her prayers and quiet strength have been the foundation of every step I've taken.

To my **father**, biger supporter from first day with he's wise shaped my path, and whose steady support gave me the courage to pursue my dreams.

To my **brothers**, my first friends and lifelong allies, who stood beside me with belief when I doubted myself.

To **myself**, for enduring the struggles, embracing the growth, and never giving up — even when the road seemed impossible.

And to my doctors, whose guidance lit the way when everything seemed uncertain, and whose patience and faith in me left a mark I will carry forever.

Including :

DR Saad Saoud who was helping me he do all what he can he was like my bigest brother or even like a dad special thanks for him from my heart

DR Selmoune he helped me too with every thing he can he was gentlemen special thanks for him from my heart

DR Issam Ziyani who helped me like a brother i wish him the best in he's Academic Journey specail thanks for him from my heart

For every one helped me in whole life and i could not mention him here beleive me i swear to god you are all of you in the bottom of my heart

This achievement is not mine alone — it is a reflection of all of you.

Résumé

Ce mémoire explore une nouvelle approche de traitement de l'eau en s'éloignant des méthodes traditionnelles, en utilisant les champs électromagnétiques comme alternative. Cette méthode s'inscrit dans un contexte de rareté croissante de l'eau et de coûts élevés associés aux traitements classiques, ce qui rend nécessaire la recherche de solutions plus efficaces et économiques. Le travail expérimental s'est concentré sur l'application de champs électromagnétiques à des échantillons d'eau, avec un suivi des variations de certains paramètres physico-chimiques.

Mots clés : champs électromagnétique- traitement de l'eau- paramètres physico-chimiques

Abstract

This memory explores a novel approach to water treatment that moves away from traditional methods by utilizing electromagnetic fields as an alternative. This method is proposed in response to increasing water scarcity and the high cost of conventional treatment processes, highlighting the need for more efficient and economical solutions. The experimental work focused on applying electromagnetic fields to water samples while monitoring changes in various physicochemical parameters.

Keywords : electromagnetic fields - water treatment - physicochemical parameters

الملخص

تناول هذا البحث دراسة نهج جديد لمعالجة المياه بعيدًا عن الطرق التقليدية و بطريقة مستدامة، وذلك من خلال استخدام الحقول الكهرومغناطيسية كوسيلة بديلة. تأتي هذه المقاربة في ظل تزايد ندرة المياه وارتفاع تكاليف المعالجة باستخدام الطرق الكلاسيكية، مما يجعل من الضروري البحث عن حلول أكثر كفاءة واقتصادًا. تم في هذا العمل تطبيق المعالجة الكهرومغناطيسية على عينات من الماء، مع تتبع التغيرات الحاصلة في بعض المؤشرات الفيزيائية والكيميائية.

الكلمات المفتاحية : المجالات الكهرومغناطيسية - معالجة المياه - المعايير الفيزيائية والكيميائية

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•TS (Total Solids)
•SS (Suspended Solids)
•DS (Dissolved Solids)
•DO (Dissolved Oxygen)
•BOD (Biochemical Oxygen Demand)
• COD (Chemical Oxygen Demand)
• WHO (World Health Organization)
• DC (Direct Current)
• AC (Alternating Current)
• ELM (Electromagnetism)
• EFM (Electromagnetic Field)
• N (Number of coil turns)
• H (Time)
•V(Voltage)

General introduction

General introduction

Water is one of the most vital resources for life, essential to ecosystems, agriculture, industry, and human health. However, with increasing global demand, environmental pollution, and the growing impact of climate change, access to clean and safe water has become one of the major challenges of our time. Traditional water treatment methods, although effective, often require complex infrastructure, high operational costs, and the use of chemicals that may pose long-term environmental and health risks. In response to these challenges, new approaches have emerged in recent years, focusing on physical and non-chemical techniques. Among these, the use of electromagnetic fields for water treatment has shown promising potential due to its low energy requirements, non-intrusive nature, and possible effects on water structure and properties.

This research aims to study and implement a water treatment system based on electromagnetic fields, with the objective of analyzing their influence on selected physicochemical parameters of water. To achieve this, the thesis is structured into four main parts:

- Chapter 1 presents a general overview of water, including its types, natural sources, and the water cycle.
- Chapter 2 focuses on water pollution and the most widely used conventional treatment methods.
- Chapter 3 introduces the concept of electromagnetic fields and explores their potential effects on water through a review of the scientific literature.
- Finally, Chapter 4 is dedicated to the practical implementation of the experiment, including the setup, procedure, and analysis of the results obtained.

This work aims to contribute to the development of alternative and sustainable water treatment solutions by exploring the feasibility and performance of electromagnetic field-based treatment.

Chapter 1:

About water

1 Introduction

Water is the essence of life and one of the most vital natural resources essential for all living beings. It plays a fundamental role in daily activities such as drinking, agriculture, industry, and energy production. Additionally, water is a key component in maintaining ecological balance, as ecosystems rely on it for stability and sustainability. However, with increasing environmental challenges such as climate change, pollution, and water scarcity, the need for sustainable water management and conservation has become more crucial than ever. In this context, wastewater treatment and reuse emerge as effective solutions to address water shortages and minimize environmental pollution.

1.1 Definition of water

Water is a clear, colorless, odorless, and tasteless liquid that is essential for all forms of life. It is a chemical compound made up of two hydrogen atoms bonded to one oxygen atom (H_2O). Water is vital for various biological processes and exists in three states: solid (ice), liquid, and gas (vapor). It covers about 71% of the Earth's surface and plays a crucial role in regulating temperature, supporting ecosystems, and facilitating chemical reactions.

Water is primarily composed of:

Chemical components: H2O molecules, minerals, salts (Ca2+, Mg2+, Na+, K+) and dissolved gases (O2, CO2, N2)

Physical properties: “temperature , color and taste”

Biological elements: ”bacteria , fungi and algae”

1.2 Forms of water

We can identify three main physical forms of water:

1.2.1 Solid water

Ice is the solid state of water. It forms when water freezes at 0°C. During freezing, water molecules move farther apart, making ice less dense than liquid water, which is why ice floats. [1]

1.2.2 Liquid water

This is the most common and naturally occurring form of water. It is the state in which we encounter water in everyday life in rivers, lakes, rain, and drinking water.

1.2.3 Water as gas

Water vapor is the gaseous form of water. It can be observed when water is heated to its boiling point at 100°C, causing it to evaporate. This transformation from liquid to gas is a physical change known as vaporization. [1]

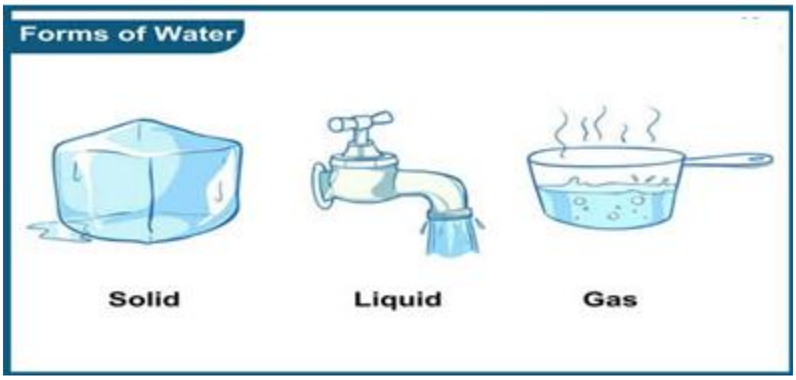


Figure 1 Forms of water

1.3 Types of water

There are various types of water, classified according to their physical, chemical, and even biological characteristics. The main categories include :

1.3.1 Potable water

This is the water we drink and depend on for life. It is clean, transparent, and safe for human consumption, posing no health risks. [2]

1.3.2 Fresh water

Freshwater typically exists in ice form (glaciers) or in natural sources such as lakes and rivers. It has a low salt concentration and is essential for agriculture and drinking water. [2]

1.3.3 Salt water

Saltwater is the most abundant form of water on Earth, covering approximately 71% of the planet. It includes ocean and sea water and contains high levels of dissolved salts. [2]

1.3.4 Hard water

Hard water contains high concentrations of dissolved minerals, especially calcium and magnesium salts. It can cause scaling in pipes and affect soap efficiency. [2]

1.3.5 Distilled water

Distilled water consists purely of H_2O molecules. It is purified through distillation, a process that removes impurities and dissolved salts. [2]

1.3.6 Wastewater

This refers to all types of used or contaminated water, including water from households, industries, and agriculture.

1.3.7 Black water

Black water is a type of wastewater contaminated with human waste, specifically feces and urine. It requires advanced treatment before reuse. [2]

1.3.8 Gray water

Gray water is domestic wastewater from sources such as sinks, showers, and washing machines. It is less polluted than black water and contains lower levels of nitrogen and phosphorus. [2]

1.4 The water cycle (hydrological cycle)

The water cycle is the continuous movement of water through the Earth's atmosphere, land, and oceans. This cycle plays a vital role in maintaining life on Earth by ensuring the redistribution and renewal of freshwater resources. It consists of several key stages:

1.4.1 Evaporation

Water from oceans, lakes, and rivers is converted into water vapor due to the heat of the sun.

1.4.2 Transpiration

Plants release water vapor into the atmosphere through small pores in their leaves, a process known as transpiration.

1.4.3 Condensation

Water vapor rises, cools in the upper atmosphere, and condenses into tiny droplets, forming clouds.

1.4.4 Precipitation

When these droplets combine and grow heavy, water falls back to Earth in the form of rain, snow, sleet, or hail.

1.4.5 Runoff
Precipitated water flows across the land surface, eventually entering rivers, lakes, and oceans.

1.4.6 Infiltration
A portion of the water seeps into the soil and permeates the ground, recharging underground aquifers..

1.4.7 Groundwater Flow
Water stored underground moves slowly through soil and rock layers and can eventually emerge in springs or feed into larger water bodies.

This natural cycle ensures a continuous and sustainable supply of fresh water for ecosystems, agriculture, and human life. [3]

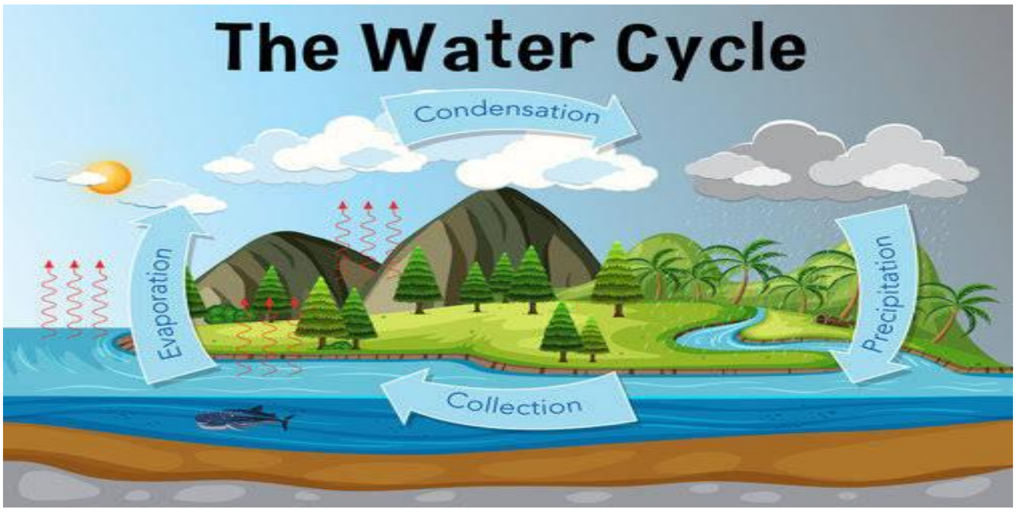


Figure 2 Water cycle

1.5 The sources of water
Water originates from various natural sources, which can be categorized into the following:

1.5.1 Surface Water
This includes rivers, lakes, ponds, and reservoirs that collect precipitation and runoff from the land. [3]

1.5.2 Groundwater
Stored beneath the Earth's surface, groundwater is found in underground aquifers and accessed through wells and natural springs. [3]

1.5.3 Rainwater
Rainwater is direct precipitation that can be collected through harvesting systems or naturally contribute to surface and groundwater recharge.

Glaciers and Ice Caps also fall under this category as large frozen water reserves that melt seasonally, feeding rivers and aquifers. [3]

1.5.4 Desalinated Water
This refers to seawater that has undergone desalination processes to remove salts and impurities, making it suitable for human consumption. [3]

1.5.5 Atmospheric Water

Water extracted from humidity in the air using condensation and atmospheric water generation technologies. [3]

1.6 Conclusion

In this chapter, we explored the fundamental characteristics of water, including its various physical states, different types, natural hydrological cycle, and primary sources. These foundational concepts are essential for understanding the broader environmental and chemical context of water usage and management.

In the following chapter, we will shift our focus to water pollution, examining its causes, types, and impacts. We will also introduce the main techniques used in water treatment, setting the stage for a deeper investigation into sustainable solutions and technological advancements in water purification.

Chapter 2:

Water pollution & Treat Methods

2. Introduction

Polluted water is water that has become contaminated with harmful substances, making it unsafe for human consumption and damaging to the environment. Pollution often results from human activities such as industrial waste discharge, oil spills, and sewage outflow.
Contaminated water can lead to serious health problems and environmental disasters. It poses a major global challenge that requires urgent attention and responsible action to protect both human health and ecological balance.

2.1 Definition of polluted water

Polluted water, also known as wastewater, refers to water that is no longer clean due to its use for specific purposes. It has undergone physical, chemical, or biological changes that make it unsuitable for direct use.
Wastewater originates from various sources, including households, industrial processes, and agricultural practices. If this water is not properly treated, it can lead to the spread of dangerous diseases such as cholera and typhoid, and cause widespread environmental damage.

Figure 3 Polluted water

2.2 Sources of wasted water

Wastewater originates from several key sources that contribute significantly to water pollution. These can be classified into five main categories:

2.2.1 Sewage and wastewater

Improper disposal of sewage and household wastewater is one of the primary causes of water pollution. Sewage consists of both gray water (from sinks, showers, and washing machines) and black water (from toilets, containing human waste).

When this wastewater is discharged untreated into the environment, it severely contaminates rivers, lakes, and oceans, posing serious health and ecological risks.

Additionally, industrial facilities are major contributors to water pollution. Many factories release untreated or inadequately treated wastewater containing toxic and heavy metals, which are highly harmful to aquatic ecosystems and human health. [4]

2.2.2 Agriculture pollution

Although agriculture is essential for food production and global sustenance, it is also a significant source of water pollution. The excessive use of chemical fertilizers and pesticides in farming leads to runoff and leaching into soil and groundwater, contaminating natural water sources.

In addition, animal waste from livestock operations contains harmful pathogens, organic matter, and nutrients such as nitrogen and phosphorus, which further contribute to water contamination.

Irrigation practices can also play a role by increasing water salinity, especially in poorly drained soils or arid regions, further degrading water quality. [4]

Figure 4 Farmer using pesticides

2.2.3 Industrial waste

According to numerous environmental studies, industrial activity is one of the leading sources of water pollution worldwide. For example, dye and textile factories often discharge wastewater containing toxic substances, such as heavy metals, dyes, and solvents, directly into water bodies without proper treatment.

This type of waste severely degrades water quality and harms aquatic ecosystems, threatening the survival of aquatic organisms.

Moreover, industrial waste often contains grease, oils, and other non-biodegradable materials. Over time, these substances accumulate and form surface layers that prevent oxygen from dissolving into the water, ultimately leading to dead zones and environmental disasters. [4]

Figure 5 duy factory

2.2.4 Oil pollution

Oil pollution is a major contributor to water contamination, posing serious threats to aquatic ecosystems and human health. It originates from both natural and anthropogenic (human-made) sources. While natural oil seeps from the ocean floor do exist, they account for only a small fraction of total oil pollution.

The majority comes from human activities such as oil spills resulting from tanker accidents, offshore drilling operations, and pipeline leaks. These events cause extensive damage to marine biodiversity and coastal environments, with long-lasting environmental impacts due to the difficulty of cleanup and the persistence of oil in ecosystems.

In addition, urban runoff significantly contributes to oil pollution when rainwater washes oil residues and other pollutants from roads and paved surfaces into nearby water bodies. Industrial discharges further exacerbate the issue when facilities release oily wastewater into rivers and oceans.

Another pathway is atmospheric deposition, where airborne oil particles or pollutants settle on water surfaces or are transported by rainfall, introducing oil into aquatic environments. [4]

Figure 6 oil leaks on the ocean

2.2.5 Radioactive waste

Radioactive waste is produced by many industries, the main source it's came from nuclear power stations or nuclear weapons factories.

That type of pollution is very dangerous for humans or animals or even for the plant itself cause it can be solid ,liquid or even in gas situation and if this waste leaks to oceans or river or groundwater or soil this will be a real disaster a big one.

Nuclear accidents for example Chernobyl(1986) and Fukushima (2011) show us how dangerous the leaks of radioactive is for the environment .this pollution has long term effects on marine life which calls for more serious management of this case.[4]

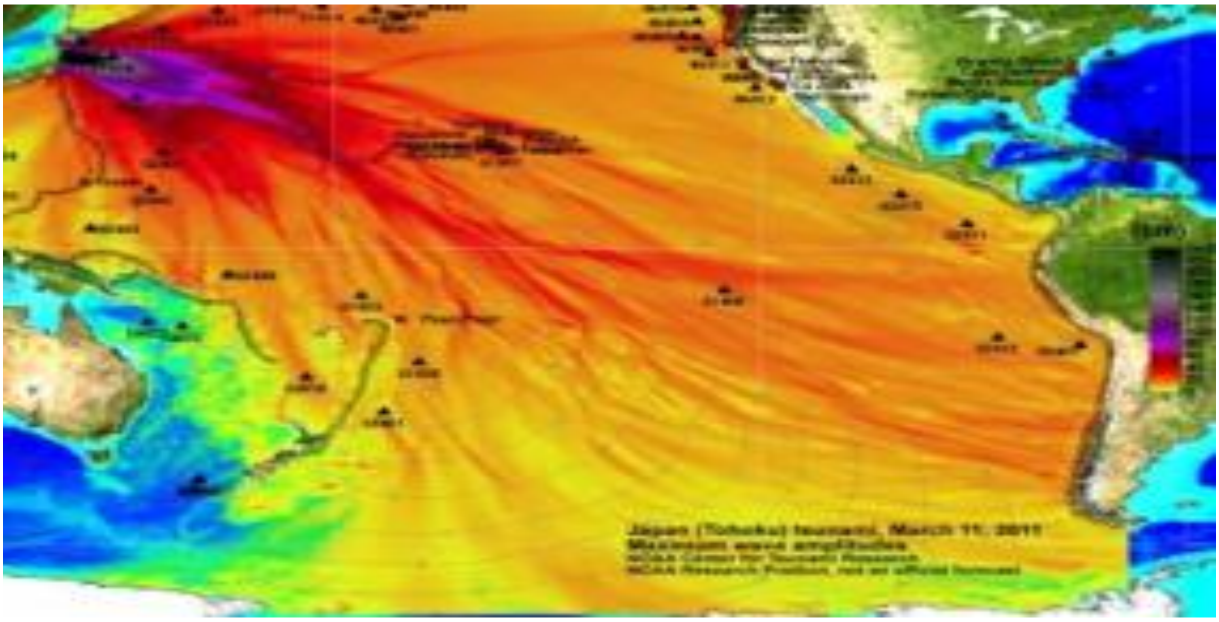


Figure 7 the radioactive leak from fukushima tsunami

2.3. Pollution of wastewater

Water pollution is defined as any alteration in the natural composition of water due to the presence of contaminants, which affect its physical, chemical, or biological properties. This degradation in quality poses a significant threat to the environment, aquatic life, and human health. [5]

There are several types of wastewater pollution, but the most common and critical categories include:

2.3.1 Mineral pollution

This type of pollution is characterized by the presence of high concentrations of minerals such as iron, zinc, and lead. It typically originates from steel manufacturing, mining operations, and related industrial processes.

2.3.2 Microbiological pollution

Wastewater often contains a wide range of microorganisms, some of which are harmless and naturally present in human and animal intestines, while others are pathogenic and responsible for causing diseases. [5]

These microorganisms are classified into four major groups based on size and structure:

- Viruses
- Bacteria

- Protozoa
- Helminths (parasitic worms)

Table 1 pathogenic germs found in wastewater

Category	Organisme	Associated Diseases
Pathogenic Bacteria	Salmonella, Shigella	Typhoid fever, Dysentery
Enterobacteriaceae & Vibrios	Colibacilli	Cholera,Tuberculosis
	Leptospira	Leptospirosis
	Mycobacterium	Tuberculosis
	Vibrio cholerae	Cholera
Viruses	Enteroviruses	Poliomyelitis
	Reoviruses	Meningitis
	Adenoviruses	Respiratory infections, Diarrhea
Parasites & Fungi	Taenia, Ascaris	Visceral lesions, Eczema, Skin diseases

2.3.3 Chemical water pollution

Chemical pollution occurs when hazardous substances primarily originating from industrial activities are discharged into water bodies. These chemicals alter the natural composition of water and pose serious risks to both ecosystems and public health. [5]

2.3.4 Physical Water Pollution

Physical pollution refers to the presence of solid particles, suspended debris, or sediments in water. This form of pollution disrupts the natural flow of water and degrades its quality. It commonly results from activities such as mining, wood processing, and tanning industries. The accumulation of these materials in water bodies disturbs the ecological balance and threatens aquatic organisms. [5]

2.4 Physical Characteristics of Wastewater

The physical characteristics of wastewater offer critical information about the pollutants it contains and their potential impact on the environment and human health. The main physical properties include:

2.4.1 Color

• The color of wastewater depends on the type and concentration of contaminants.[5]

• Domestic wastewater is usually gray or light brown, whereas industrial wastewater can be darker, sometimes appearing black or reddish due to specific pollutants.[5]

• Darker water often indicates a high concentration of organic or metallic substances, such as iron and manganese.[5]

2.4.2 Odor

• Unpleasant odors in wastewater result from the decomposition of organic matter and bacterial activity in anaerobic conditions.[5]

• Common odor-causing gases include hydrogen sulfide (H_2S), which produces a rotten egg smell, along with ammonia and methane.[5]

• The odor is usually more intense in untreated wastewater or when organic waste is abundant.[5]

2.4.3 Turbidity

• Turbidity refers to the cloudiness or clarity of wastewater, caused by suspended solid particles like clay, silt, and microorganisms.[5]

• Higher turbidity reduces water transparency, limiting light penetration and affecting biological activity in aquatic environments.[5]

• It is an important parameter for assessing wastewater quality and treatment feasibility.[5]

2.4.4 Temperature

• Wastewater temperature varies based on its source; domestic wastewater is usually near ambient temperature, while industrial wastewater can be significantly warmer due to heat discharges.[5]

• Higher temperatures decrease dissolved oxygen levels, affecting the survival of aquatic organisms.[5]

•Elevated temperatures also accelerate chemical reactions and biological decomposition processes.[5]

2.4.5 Total Solids (TS)

Wastewater contains different types of solid materials, classified into:

• Suspended Solids (SS): Insoluble particles that can settle or be filtered out, including clay, sand, and undissolved organic matter [5]

• Dissolved Solids (DS): Soluble substances such as minerals, salts, and organic compounds that cannot be removed by simple filtration.

• Total Solids (TS): The sum of suspended and dissolved solids, serving as an indicator of pollution levels in wastewater.[5]

2.5 Chemical Characteristics of Wastewater

The chemical characteristics of wastewater reflect the nature and concentration of dissolved pollutants, which influence its quality and treatment methods. The key chemical properties include:

2.5.1 pH Level

• Indicates the acidity or alkalinity of wastewater.[5]

• Typically ranges between 6.5 and 8.5 in domestic wastewater but can be more acidic or alkaline in industrial effluents.[5]

• Extreme pH values can affect treatment efficiency and harm aquatic life.[5]

2.5.2 Dissolved Oxygen (DO)

• Refers to the amount of oxygen available in water, essential for aquatic organisms.[5]

• Low DO levels indicate high organic pollution, as bacteria consume oxygen during decomposition.[5]

• Untreated wastewater often has very low dissolved oxygen levels.[5]

2.5.3 Biochemical Oxygen Demand (BOD)

• Measures the amount of oxygen consumed by microorganisms to break down organic matter in wastewater.[5]

• Higher BOD values indicate a greater organic pollution load, requiring more intensive treatment.[5]

• A key parameter for assessing wastewater quality and its environmental impact .[5]

2.5.4 Chemical Oxygen Demand (COD)

• Represents the total amount of oxygen required to chemically oxidize both organic and inorganic compounds.[5]

• COD values are usually higher than BOD, as they account for all oxidizable substances, not just biodegradable organic matter.[5]

• An important factor in designing wastewater treatment systems.[5]

2.5.5 Organic Compounds

• Includes carbohydrates, fats, proteins, and oils, as well as industrial pollutants such as solvents and pesticides.[5]

• These compounds contribute to increased BOD and COD, requiring advanced treatment processes.[5]

2.5.6 Inorganic Compounds

• Consist of dissolved salts like chlorides, sulfates, phosphates, and nitrates.[5]

• High concentrations of these compounds can contaminate groundwater and lead to environmental issues like eutrophication, which promotes excessive algal growth and depletes oxygen levels in water bodies.[5]

2.5.7 Heavy Metals

• Includes lead, mercury, cadmium, and chromium, often originating from industrial discharges.[5]

• The accumulation of heavy metals in the environment can be toxic to living organisms and contaminate the food chain.[5]

2.5.8 Dissolved Gases

• Includes gases such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), and ammonia (NH_3).[5]

• (H_2S) is responsible for the foul odor in wastewater, while ammonia indicates the presence of organic waste and nitrogen compounds.[5]

2.6 Standards Discharge

2.6.1 International Standards

International standards establish maximum permissible limits and minimum threshold values to ensure the safety and quality of water. Compliance with these standards is essential and is achieved when the measured values of specific water quality parameters fall within the defined acceptable ranges. These standards are typically enforced through laws, regulations, or official directives.

According to the World Health Organization (WHO), international wastewater standards are designed to protect environmental integrity and public health. They define allowable limits for the physical, chemical, and biological characteristics of wastewater. These limits are usually presented in standardized tables to guide effective wastewater treatment, reuse, and safe discharge into natural water bodies.[6]

Table 2 Presents some key wastewater quality standars by World Heath Organisation (who)

Parameter	Maximum Allowed Limit	Unit	Remarks
pH Level	6.5 - 8.5	/	Must remain within this range to maintain chemical balance.
Dissolved Oxygen (DO)	> 2	mg/L	Sufficient oxygen is needed to support aquatic life.
Biochemical Oxygen Demand (BOD_5)	< 30	mg/L	Indicates the amount of oxygen consumed to degrade organic matter.
Chemical Oxygen Demand (COD)	< 125	mg/L	Measures oxygen required to oxidize both organic and inorganic substances.
Total Suspended Solids (TSS)	<50	mg/L	Includes non-dissolved particles in wastewater.
Nitrate (NO_3^-)	< 50	mg/L	Excess levels can contaminate groundwater
Ammonia (NH_3)	< 1.5	mg/L	Can be toxic to aquatic life at high concentrations
Phosphate (PO_4^{3-})	< 5	mg/L	Contributes to eutrophication in water bodies.
Heavy Metals (Lead, Mercury, Cadmium, Chromium, etc.	Varies by element	mg/L	Should be kept at very low levels to prevent environmental toxicity.

2.6.2 Algerian standards

Algeria has established specific regulatory standards for the discharge and reuse of treated wastewater, particularly in the agricultural sector, with the aim of protecting public health and preserving the environment. These standards are detailed in several legal texts, most notably:

- Executive Decree No. 93-160 of July 10, 1993, which outlines general conditions for the discharge of wastewater into the environment.
- Executive Decree No. 06-141 of April 19, 2006, which sets the technical conditions for the reuse of treated wastewater in agriculture. [7]

These legal frameworks provide clear limits on the physical, chemical, and microbiological characteristics of treated wastewater, ensuring its safe application and minimizing risks to human health and natural ecosystems.

Table 3 presents some key wastewater quality standars by Algerian Regulations

Parameter	Maximum Allowed Limit	Unit
pH Level	6.5 - 8.5	/
Biochemical Oxygen Demand (BOD_5)	< 30	mg/L
Chemical Oxygen Demand (COD)	< 90	mg/L
Total Suspended Solids (TSS)	< 30	mg/L
Nitrate (NO_3^-)	< 50	mg/L
Ammonia (NH_3)	< 1	mg/L
Phosphate (PO_4^{3-})	< 2	mg/L
Electrical Conductivity (EC)	< 3	dS/m

Wastewater treatment is a vital process for protecting public health and preserving the environment from the harmful effects of pollution. Through ongoing advancements in treatment technologies, it is now possible to significantly reduce pollutant concentrations to safe levels, allowing for the sustainable reuse of water in various sectors without posing risks to ecosystems or human well-being.

Nevertheless, the strict application of international and national standards remains essential to ensure the efficiency and safety of treatment processes. This is particularly important in light of escalating environmental challenges and increasing water scarcity in many regions of the world.

Having explored the sources and impacts of water pollution, the next section of this chapter will focus on the methods used for wastewater treatment.

2.7 Wastewater treatment

Wastewater treatment is the process of removing contaminants and pollutants from used or discharged water, making it safe for environmental release or reuse in various applications. This process plays a critical role in protecting the environment from pollution, safeguarding public health against waterborne diseases, and ensuring environmental sustainability.

As urban populations increase and industrial activities expand, the demand for efficient and reliable wastewater treatment systems becomes increasingly essential. These systems help manage water resources responsibly, reduce ecological damage, and support the long-term health of both natural ecosystems and human communities.

2.8 Historical overview of wastewater treatment

Many ancient civilizations developed early forms of drainage systems, primarily designed to divert rainwater from rooftops and paved streets rather than to treat wastewater. A notable example is found in ancient Rome, which featured one of the earliest and most advanced drainage infrastructures of its time.

The Roman system included numerous surface conduits that channeled runoff into a central vaulted sewer known as the Cloaca Maxima ("Great Sewer"). This massive stone structure carried drainage water to the Tiber River and stands today as one of the oldest surviving examples of Roman civil engineering. Built on a grand scale, the Cloaca Maxima highlights the ingenuity and architectural sophistication of Roman urban planning.[8]

Figure 8 Cloaca maxima in old Rome

During the Middle Ages, there was limited advancement in urban drainage or sewerage systems. Privy vaults and cesspools were commonly used for waste disposal, but in many cases, waste was simply discharged into open gutters and carried away only by rainwater or floods.

In the early 19th century, toilets (water closets) began to be installed in homes; however, they were often connected to cesspools rather than to municipal sewer systems. In densely populated areas, these cesspools were rarely emptied and frequently overflowed, creating unsanitary conditions and posing serious public health risks.

The dangers became evident in mid-19th century England, where repeated outbreaks of cholera were traced to well-water contamination by human waste from privy vaults and cesspools. In response, authorities required that water closets in major towns be connected directly to storm sewers, effectively moving sewage away from homes and into nearby rivers and lakes. However, this practice introduced a new environmental issue: widespread surface water pollution. [8]

2.9 Definition of Wastewater Treatment

Wastewater treatment is the process of removing contaminants and impurities from water that has already been used, in order to make it safe for reuse or discharge into the environment. [9] This process typically involves three main treatment stages:

- Physical treatment
- Biological treatment
- Chemical treatment

2.10 Treatment Steps

The treatment of wastewater generally follows eight essential steps, each contributing to the effective removal of pollutants:

2.10.1 Screening and Pumping

Incoming wastewater first passes through screens that remove large objects such as rags, wood, plastics, and rocks. The captured debris is then washed, pressed, and disposed of in a landfill. [10]

Figure 9 sceening and pumping step

2.10.2 Grit Removal

In this step, heavy but fine material such as sand and gravel is removed from the wastewater. This material is also disposed of in a landfill.

Figure 10 Grit Removal Step

2.10.3 Primary Settling

In large circular clarifiers, heavier solids settle to form primary sludge, which is pumped away for further treatment. Floating materials like oil and grease are skimmed off. Chemical agents may also be added at this stage to remove phosphorus.

Figure 11 Tank of Primary Settling Step

2.10.4 Activated Sludge

Here, biological treatment takes place. Microorganisms break down organic pollutants, converting them into biomass, nitrogen, and water. This step simulates the natural purification process found in lakes and rivers but significantly accelerates it.

Figure 12 Activated Sludge

2.10.5 Secondary Settling

In secondary clarifiers, biological solids are separated from the treated water. The activated sludge is collected and mostly recycled back to the aeration tanks to maintain biological activity. The remaining water is now over 90% purified.

Figure 13 Secondary Settling Step

2.10.6 Filtration

The clarified effluent passes through 10-micron polyester media filters to remove any remaining suspended particles. The captured solids are backwashed and returned to the start of the process.

Figure 14 Filtration Step

2.10.7 Disinfection

To eliminate pathogenic bacteria, the water is subjected to ultraviolet (UV) disinfection. This ensures that the final effluent meets microbiological safety standards for discharge.

2.10.8 Oxygen Uptake

Finally, the treated water is aerated if needed to raise dissolved oxygen levels to regulatory limits before discharge. The water is then released into a natural body—such as the Oconomowoc River—in compliance with DNR regulations, achieving pollutant removal rates of 98% or more.

2.11 Conclusion

In this chapter, we explored the concept of wastewater, its sources, and the different types of pollution it may contain—namely physical, chemical, mineral, and microbiological contaminants. This formed the first part of the chapter, which aimed to highlight the causes and dangers of water pollution.

In the second part, we focused on wastewater treatment processes, outlining the key steps involved in restoring water quality to safe levels. These steps include screening, grit removal, biological treatment, filtration, and disinfection, among others.

In the next chapter, we will shift focus to a more innovative approach by examining the effects of electromagnetic fields on water, and evaluating their potential in enhancing water treatment efficiency.

Chapter 3:

Electromagnetic Effects on Water

3. Introduction

Electromagnetic waves are a form of radiation consisting of electric and magnetic fields that oscillate perpendicular to each other and propagate through space or various media. This topic is highly relevant across multiple scientific disciplines—physics, chemistry, biology, and environmental engineering—due to the potential influence of these waves on the physical and chemical properties of substances, particularly water.

One of the most well-documented effects is the absorption of specific wavelengths by water molecules, particularly in the microwave and infrared regions of the electromagnetic spectrum. This absorption leads to molecular vibrations, which result in heating. This principle is commonly utilized in technologies such as microwave ovens and other household appliances.

Furthermore, several studies suggest that prolonged exposure to certain electromagnetic fields may alter the hydrogen bonding structure in water. Such structural modifications could potentially impact water's chemical behavior, reactivity, or biological functions.

Ongoing research seeks to better understand the precise mechanisms through which electromagnetic radiation interacts with water. The focus lies on evaluating both the potential benefits, such as enhanced treatment processes or non-chemical purification methods, and the possible environmental or health risks that may arise. This growing field of study may contribute to the development of sustainable and innovative water treatment solutions.

3.1 Definition of electricity

Electricity is a fundamental form of energy that exists in positive and negative forms. It occurs naturally—such as in lightning—or can be artificially generated using electrical generators. Electricity is essentially the result of the movement and interaction of electrons, and it is a core concept in many scientific and engineering disciplines. [11]

This leads us to the key elements that define how electricity operates within systems:

3.1.1 Current:

Electric current refers to the flow of electric charge, typically carried by electrons in a conductor. This movement occurs due to a potential difference (voltage) across the two ends of a circuit. The unit of electric current is the ampere (A). [11]

There are two primary types of electric current:

3.1.1.1 Direct Current (DC): In direct current, electric charge flows in one constant direction. A common example of DC is the current provided by batteries. [11]

3.1.1.2 Alternating Current (AC): In alternating current, the direction of electric charge flow reverses periodically. This type of current is used in household and industrial power systems, such as the electric grid. [11]

3.1.2 Voltage

Voltage, also known as electric potential difference, is the driving force that pushes electric charges through a conductor. It is measured in volts (V) and represents the energy per unit charge available in a circuit. Without voltage, no current would flow. [12]

After examining the first key component of electromagnetism electricity we now turn to the second fundamental aspect: magnetism. Magnetism is a physical phenomenon produced by the motion of electric charges, which gives rise to magnetic fields and forces. It plays a crucial role in the behavior of

electromagnetic waves and is essential to understanding how electromagnetic fields interact with matter, including water.
In the following sections, we will define magnetism, explore the types of magnets, and examine how magnetic fields are generated and measured

3.2 Definition of the magnate

A magnet is a material that has the ability to attract or repel other materials, particularly those containing iron, nickel, cobalt, or certain steel alloys. [13]
Magnets have two distinct poles: north and south. These poles generate an invisible magnetic field, which is responsible for the attractive or repulsive forces observed in magnetic interactions.

3.3 Types of magnets

3.3.1 Permanent Magnets: These magnets retain their magnetic properties indefinitely without the need for an external power source. Example (bar magnets). [14]
3.3.2 Transient magnets: These materials exhibit magnetic properties only in the presence of an external magnetic field. Once the external field is removed, they lose their magnetism. A common example is soft iron, used in the cores of electromagnets.[14]
3.3.3 Electromagnets: These magnets are created by passing an electric current through a coil of wire wound around a magnetic core (usually soft iron). The magnetic field can be turned on or off by controlling the electric current, making electromagnets highly useful in various applications such as electric motors, transformers, and magnetic locks.[14]
By integrating the principles of electricity and magnetism, we arrive at the concept of the electromagnetic field—a fundamental physical phenomenon that results from the interaction between electric currents and magnetic fields.

3.4 Definition of electromagnetic field

For centuries, electricity and magnetism were regarded as two separate forces. It wasn’t until the 19th century that scientists began to suspect a deeper connection between them. In 1905, Albert Einstein’s Special Theory of Relativity confirmed beyond doubt that both are, in fact, aspects of a single universal phenomenon. Despite this unification, electric and magnetic forces operate in distinct ways at the practical level and are governed by different physical laws.

Electric forces are produced by electric charges, whether at rest or in motion. In contrast, magnetic forces are produced only by moving charges and act exclusively on other charges that are also in motion. [15]

When an electric charge moves through space, it generates an electromagnetic field (EMF) a combination of both an electric field and a magnetic field. This field can propagate as an electromagnetic wave, which travels at the speed of light and carries energy through space or a medium.

The behavior and interactions of electromagnetic fields are mathematically described by Maxwell's equations and the Lorentz force law, which explain how electric charges and currents give rise to electromagnetic phenomena. In wave propagation, a moving charge first produces electric and magnetic fields, which in turn interact with each other, reinforcing and sustaining the wave. These fields exert forces on other electric charges, causing further movement—thus continuing the cycle of propagation. [15]

3.5 Fundamental Equations of Electromagnetic Theory

Electromagnetic theory is governed by a set of four fundamental equations, known collectively as Maxwell's Equations, along with the Lorentz Force Law. These equations describe the behavior and interaction of electric and magnetic fields in space and time.[16]

3.5.1 gauss law:

$$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon 0}$$

This law states that the electric flux out of a closed surface is proportional to the electric charge density (ρ) enclosed within that surface. It describes how electric fields are generated by point charges.

3.5.2 Gauss law for magnetism:

$$\vec{\nabla} \cdot \vec{B} = 0$$

This equation indicates that there are no magnetic monopoles magnetic field lines always form closed loops, and the total magnetic flux through a closed surface is zero.

3.5.3 Faraday's law of induction:

$$\vec{\nabla} \times \vec{E} = - \frac{\partial \vec{B}}{\partial t}$$

Faraday's Law states that a changing magnetic field over time induces an electric field. This principle underlies the operation of electric generators and transformers.

3.5.4 Ampere-Maxwell Law:

$$\vec{\nabla} \times \vec{B} = \mu 0 \vec{J} + \mu 0 \varepsilon 0 \frac{\partial \vec{E}}{\partial t}$$

This equation describes how magnetic fields are generated both by electric currents (J) and by changing electric fields. Maxwell's addition of the second term accounts for electromagnetic wave propagation.

3.5.6 Lorentz Force Law

$$\vec{F} = \mathrm{q}(\vec{E} + \vec{V} \times \vec{B})$$

The Lorentz Force Law expresses the force ($\vec{F}$) experienced by a charged particle (q) moving with velocity $\vec{v}$ in the presence of an electric field $\vec{E}$ and a magnetic field $\vec{B}$. This is the fundamental law of motion in electromagnetism.

These laws form the theoretical foundation for understanding electromagnetic wave behavior, which leads us to explore their potential effects on water—the central focus of our study.

3.6 Electric effects on water

Water is a dipolar molecule, and can therefore be partially aligned by the application of an electric field, as demonstrated by its movement under an electrostatic source [17]. Strong electric fields (greater than 2.5×10^{9}V/m) have been shown to dissociate water into liquid and hexagonal ice phases. At slightly higher field strengths (2.36×10^{10} V/m), a continuous proton flow in ice can be observed [18].

The effects of strong electric fields on the dissociation and formation of ice are complex. Molecular dynamics simulations suggest that electric fields ranging from (0.45 V/m to 3×10^{9}V/m) can accelerate the freezing of water into cubic ice by influencing the orientation of neighboring molecules, particularly in the second coordination shell [19].

Conversely, more intense fields (5×10^{9} V/m) can align water molecules in such a way that prevents freezing, while less intense fields (~10^{5} V/m) have been found to induce freezing in supercooled water by destabilizing existing hydrogen bonds [20].

Even partial alignment of water molecules in response to an electric field can distort or break hydrogen bonds, which rebalances the competition between hydrogen bonding and van der Waals forces. This often results in a reduction of hydrogen-bonded clustering. Additionally, electric fields affect various molecular properties such as:

- Bond lengths: For example, a field strength of (2.5×10^{8} V/m) can cause a (~6%) change in the O–H bond length.
- Bond angles : Changes of approximately (+1.6%) and (– 0.2%) in the H–O–H bond angle have been reported.
- Vibrational frequencies and dissociation energies are also influenced depending on the molecular orientation relative to the field [21].

Overall, the electric field induces anisotropic changes in the hydrogen-bond network, significantly altering the structural and dynamic behavior of water at the molecular level.

3.6.1 Effect of Electric Field on Viscosity

High electric fields at charged interfaces ($E > 10^{9}$ V/m, significantly exceeding thermal energy) can induce phase transformations in water, resulting in ordered molecular layering with densities comparable to those of ice phase X. Field-dependent compression pressures may promote either freezing or melting, analogous to conventional phase transitions [22].

Such intense electric fields ($E \approx 1$ V/nm) are also present at the surfaces of hydrophilic molecules due to partial atomic charges and within the first hydration shell. These fields exert anisotropic effects on the hydrogen bonding network by aligning hydrogen bonds parallel to the field direction and disrupting bonds that are oriented perpendicularly [23].

This anisotropic influence has been validated through molecular dynamics simulations, which have demonstrated that it plays a key role in determining the dynamic viscosity of water.

At lower field intensities, the translational and rotational motion of water molecules can be significantly hindered. Moreover, electric fields are predicted to enhance the differences between ortho- and para-water spin isomers and to reduce the dielectric constant of water, primarily due to partial or complete disruption of the hydrogen bond network [24].

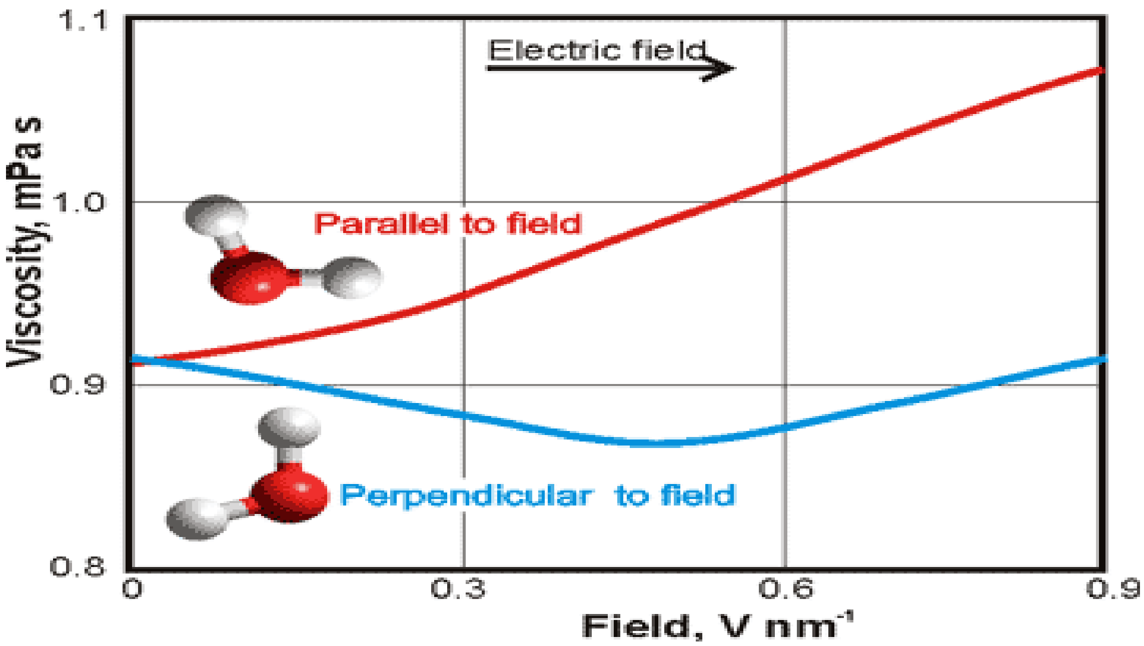


Figure 15 effect of electric filed on viscosity

3.6.2 Distilled water

Water is not considered a good electrical insulator due to the presence of ions resulting from its inherent self-dissociation. When an electric current is applied, electrolysis occurs, producing oxygen (O_2) at the anode and hydrogen (H_2) at the cathode. The resulting ion concentration gradient created by electrolysis can persist for hours, significantly altering the chemical composition of the water [25].

Even relatively low voltages applied at metal electrodes can influence the orientation of water molecules and the distribution of ions. For instance, a negative potential of (–0.23 V) aligns the hydrogen atoms in water molecules toward the electrode, while a positive potential of (+0.52 V) causes the opposite orientation. These electrostatic effects lead to partial disruption of hydrogen bonds and a localized increase in water density. Additionally, ion movement becomes charge-directional, as electrostatic forces cause ions to migrate toward or away from the electrodes.

Similar effects are observed on the surfaces of alternating positive and negative charge minerals. Experimental evidence shows the formation of a stable, structured water layer on highly polar metal oxides such as titanium dioxide (TiO_2).

Molecular modeling has further revealed the potential to form monolayer ice structures at room temperature on fully hydroxylated hydrophilic silica surfaces, where donor hydrogen bonds orient themselves toward surface oxygen atoms [26]. This structured arrangement, often referred to as "ice tessellation," is likely responsible for the formation of ordered water layers on complex silicate surfaces.

Research also indicates that strong electric fields (approximately 333 kV/m) enhance water activity in dough, improving gluten hydration and promoting shear thinning, which has practical implications in the baking industry [27]. More remarkably, electric fields as intense as (1 MV/m) have been shown to increase the surface tension of water by up to 2%, a counterintuitive phenomenon with potential applications in industrial processes and chemical engineering.

In our own study, we investigated the effect of alternating current (AC) within the frequency range of (100 GHz to 1000 GHz)on the static and dynamic characteristics of water. Specifically, when applying low-frequency AC (between 4 and 20 Hz) to deionized distilled water using platinum electrodes, we observed a decrease in temperature [28]. This phenomenon is intriguing and warrants further investigation to confirm its mechanisms.

This reduction in water entropy may be attributed to the presence of low-density water states.

Additionally, we examined the "floating water bridge" phenomenon a cylindrical-shaped column of water, typically (1–2 mm) in diameter and capable of spanning up to (25 mm) between two beakers containing ultrapure water when subjected to a high-voltage difference (between 15–25 kV). We will now explain this experiment in greater detail.

3.6.3 The floating water bridge

"Water is undoubtedly the most important chemical substance in the world," stated Elmar Fuchs and colleagues from the Graz University of Technology (Austria) in a notable study on the subject. Over the past years, the interaction between water and electric fields has become an area of increasing scientific interest. In this context, they reported an extraordinary and visually striking effect: the floating water bridge.

This phenomenon occurs when a high-voltage DC electric field (typically 15–25 kV) is applied between two beakers of deionized water. Upon application, water spontaneously rises from each container, extending into the space between them, eventually forming a stable cylindrical bridge. Visually, the bridge appears as if taken from a science fiction film, defying gravity and connecting the two containers without physical support.

Experimental observations revealed that water typically flows from the anode to the cathode, and that the bridge often with a diameter of (1 to 3 mm) can remain stable even when the beakers are separated by a distance of up to (25 mm.)

Mechanism Behind the Phenomenon

The researchers attributed the formation of the bridge to the unique molecular properties of water and its interaction with strong electric fields. Specifically, the initial bridge formation is driven by electrostatic forces. Once the bridge is formed, the electric field becomes concentrated within the bridge itself. This causes the water molecules to align and stabilize due to their dipolar nature, resulting in a cohesive and mechanically robust structure.

Additionally, high-frequency oscillations were detected within the bridge. Using high-speed camera imaging, researchers noted that these oscillations did not originate from surface waves, which are typically slower. Instead, it was hypothesized that the oscillations may be induced by fluctuations from the voltage source or internal dynamic effects within the bridge.

Another interesting observation was the appearance of secondary structural changes. Although the experiment was initiated under identical conditions each time, structural evolution was noted within minutes of bridge formation. The team proposed that these changes could result from external contaminants, such as dust, or from thermal effects caused by continuous current flow.

Ultimately, the bridge collapsed after approximately (45 minutes) of continuous operation, primarily due to the temperature rise of the water from (20 °C to 60 °C. This thermal increase likely altered the physical properties of the water, destabilizing the bridge structure.

Thermodynamic and Molecular Considerations

Subsequent investigations into the phenomenon focused on the non-equilibrium thermodynamics and collective vibrational modes of liquid water under inhomogeneous electric fields. Using a high-voltage (20 kV) point-to-plane electrode system, researchers observed that field gradients as high as

($\nabla^2 E \approx 10^{10} V\cdot m^{-2}$) can restrict the rotational motion of water molecules, aligning their dipole moments and thereby modifying heat flow dynamics and chemical potential gradients. This restriction in molecular rotation also caused changes in the refractive index of the bridge region [29].

Moreover, under electric fields of ($\sim 10^9$ $V\cdot m^{-1}$), one-dimensional water nanowires have been observed in water vapor. These structures consist of square or pentagonal prism-like arrangements, further illustrating how extreme electric fields can lead to novel self-organized states of water at the molecular scale.

Figure 16 flaoting water bridge

3.7 Magnetic effects on water

Liquid water is known to be affected by magnetic fields [30, 31], and several studies suggest that such fields can be used to clean and purify water [32]. Due to its diamagnetic nature, water can interact with very strong magnetic fields, up to 10 Tesla (T)—a magnitude far greater than the Earth's magnetic field, which is approximately 50 microteslas (µT).

Molecular dynamics simulations have shown that even moderate magnetic fields (0.2 T) can increase the number of monomeric water molecules. Unexpectedly, these simulations also revealed that magnetic fields may promote the formation of tetrahedral structures in water, suggesting a more ordered molecular arrangement under such conditions.

Other studies have indicated that magnetic fields can lead to an increase in cluster size in liquid water. Additionally, in the presence of magnetic fields ranging from (0.16 to 0.53 T), a reduction in the coefficient of friction has been observed in thin water films. This reduction is thought to be associated with the weakening of hydrogen bonds, which in turn affects the structural dynamics of the water [33].

Furthermore, the air–water interface can be deformed under strong magnetic fields due to a phenomenon known as the Moses effect, wherein magnetic forces cause visible deformation of diamagnetic liquids such as water.

3.7.1 The moses effect

The Moses Effect refers to the deformation of the surface of a diamagnetic liquid, such as water, when exposed to a magnetic field. When subjected to a magnetic field of approximately 0.5 Tesla (T), the surface of the liquid experiences a localized depression or near-surface dip, typically with a depth on the order of several tens of micrometers.

This phenomenon arises due to the repulsive interaction between the diamagnetic liquid and the applied magnetic field, which modifies the liquid's equilibrium surface shape. The name "Moses Effect" metaphorically refers to the observed depression or parting of the water surface, eminiscent of the Qur'anic story of Prophet Musa (moses).

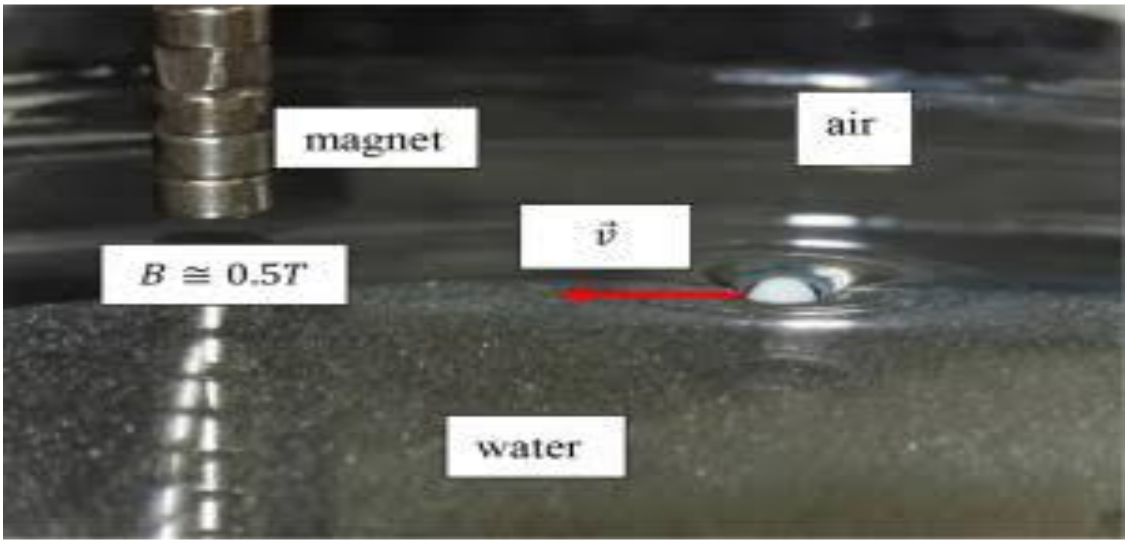


Figure 17 moses effect

3.7.2 The effect of magnetic fields on water and its hydrogen bonds

Magnetic fields of approximately 0.5 Tesla (T) or higher can cause surface depressions in diamagnetic liquids like water, with dip depths ranging from (10 to 104 micrometers (µm). Notably, magnetic treatment of water has demonstrated multiple practical benefits, including:

- Reduction of limescale accumulation on metal surfaces,
- Enhancement of cement hydration,
- Acceleration of plant growth when irrigated with magnetically treated water,
- Increased calcium ion efflux through biological membranes, and
- Modulation of the structure of model liposomes.

When salt ions are exposed to strong magnetic fields (typically between 1 and 10 T), the increased ionic mobility leads to disruption in the hydrogen bonding network of water molecules [34].

However, this effect depends strongly on the concentration of salts:

- In high salt concentrations (5 M NaCl), the hydrogen bond network is weakened due to disorder caused by increased ion movement.
- In lower concentrations (1 M NaCl), this disorder is compensated by the strengthening of hydrogen bonds, as the magnetic field enhances the ordering of water molecules, thereby maintaining structural stability [34].

3.7.2.1 The refractive index : An increase in the refractive index under magnetic fields is associated with the strengthening of hydrogen bonding among water molecules, indicating a more structured liquid phase**.**

3.7.2.2 Increased evaporation rate : Experiments with low magnetic fields (~15 mT) and moderate vertical magnetic fields (~75 mT) have shown enhanced evaporation rates of water.
This effect is more noticeable at lower temperatures, where weakened van der Waals forces make it easier for water molecules to overcome surface tension and escape into the gas phase..

3.8 Mechanism of magnetic field effects on water

Magnetic fields reduce the thermal motion of electrical charges in water by generating Lorentz forces that decelerate ion movement. This effect causes water molecules to become more closely aligned, enhancing molecular cohesion [35].
Additionally, weakened van der Waals forces can shift the balance toward stronger hydrogen bonding, which plays a key role in maintaining the structural integrity of water clusters.

3.8.1 Additional implications of the effect of magnetism on water

High melting temperature of water
(+5,6mK) at 6Tesla for ordinary water (H2O)
(+21,8 mK) at 6Tesla for heavy water (D2O)
Increased ease of supercooling
1 degree C when (5mT) is applied

3.8.2 The magnetic susceptibility of water

The magnetic susceptibility of water, normally negative (diamagnetic), can shift toward positive (paramagnetic) values under certain conditions.
Studies indicate that under normal temperature and pressure, water becomes paramagnetic at frequencies ranging from 0.4 to 1 MHz, likely due to alignment of molecular dipoles in response to alternating magnetic fields.

3.9 Effects of Static Magnetic Fields on Water

3.9.1 Strengthening Hydrogen Bonds

Scientific studies have shown that static magnetic fields can enhance the strength of hydrogen bonds between water molecules. This effect may also promote the formation of more ordered molecular structures around hydrophobic compounds and colloids, as indicated by increased fluorescence in specific molecular probes used to assess structural ordering [36].

3.9.2 Effect on Animals

Water treated with magnetic fields may exhibit both beneficial and adverse physiological effects on animals. These effects depend significantly on the intensity and duration of magnetic field exposure during the treatment of drinking water or food. Responses include changes in metabolism, hydration, and nutrient absorption, but further research is needed to standardize results across species and experimental setups.

3.9.3 Effects on Solubility

Even low-intensity magnetic fields in the range of 20 to 50 microteslas (μT) can influence the solubility of gases in water, particularly in marine and brackish environments. These changes may affect dissolved oxygen and carbon dioxide concentrations, with implications for aquatic life and gas exchange dynamics [37].

3.9.4 Effect on Proton Spin

Static magnetic fields can influence the relaxation rate of proton spin, potentially leading to faster proton transfer reactions in water-based systems. This effect may be particularly relevant in biochemical pathways and catalytic processes involving hydrogen bonding and ion exchange mechanisms.

3.9.5 Effect on Sterilization

Preliminary findings suggest that the application of continuous, transversely directed magnetic or electric fields may enhance the sterilization capacity of water. These fields may contribute to the disruption of microbial cell membranes or alter the viability of bacteria, offering a non-chemical alternative for improving water microbiological quality.

3.10 Electromagnetic effects

Numerous studies have demonstrated that electric and magnetic fields exert distinct yet significant effects on the structure and behavior of water. Water with a lower density of hydrogen bonds often referred to as "unstructured water" forms a highly reactive environment. In contrast, a more interconnected hydrogen bond network increases viscosity, reduces molecular diffusivity, and limits the participation of water molecules in chemical and biological reactions. Consequently, any factor that disrupts or weakens hydrogen bonding—such as the application of electric or magnetic fields can enhance the chemical reactivity of water.

It has been reported that electric fields reduce the average size of water molecular clusters, as detected by ^{17}O nuclear magnetic resonance (NMR) [38], and increase solubility, hydration capacity, and reaction rates [39]. These findings suggest that both electric and magnetic fields can disrupt hydrogen bonding and induce molecular reorientation in water.

Microwave radiation, for example, has been shown to exert its primary effects through its electric field component rather than its magnetic counterpart [40]. The ability of electromagnetic fields to enhance water's hydration potential is also evident in phenomena such as enzyme dimer dissociation, which can lead to gel formation under microwave radiation exposure from mobile devices.

Such field-induced aqueous restructuring appears to be kinetically stable and may significantly alter solubility behavior, gas content, and the reactivity of water. These alterations can lead to the formation of reactive oxygen species such as singlet oxygen ($^1O_2$), transformation of hydroxyl radicals (OH•), or phase transitions like nanobubble formation. Additionally, small quantities of hydrogen peroxide (H_2O_2) may be generated, mimicking effects observed under mechanical agitation.

This raises the ongoing debate surrounding the so-called "memory effect" of water, as electromagnetic exposure may result in long-term structural changes. For example, some saline and ethanol solutions exhibit dynamic structural rearrangements lasting from several days to months. In homeopathic preparations, structural changes have been observed to persist for hundreds of days. Clathrate-like structures and restructuring from infrared radiation have also shown persistence for more than a day.

Moreover, photoluminescence changes in water possibly attributed to impurities at the gas-liquid interface may evolve over time [42].

In addition to disrupting hydrogen bonds, electromagnetic fields can influence the gas–liquid interface, altering dissolved gas concentrations and affecting pH through changes in CO_2 hydration. The discovery of nanobubbles (nanocavities)—containing only a few hundred gas molecules—has further emphasized the significance of gas interactions in water chemistry [43, 44, 45]. Nanobubbles have been shown to adhere to hydrophobic surfaces and contribute to the unique properties of magnetized water. In ceramic processing and industrial applications, the elimination of dissolved gases has been found to suppress the effects of magnetic or electromagnetic treatment [42].

Another striking observation is the impact of weak electromagnetic fields on biological systems. For example, exposure to weak fields has been shown to affect the morphology and chirality of bacterial colonies, with the effect lasting for at least 20 minutes post-exposure [46]. Some studies propose that even extremely weak alternating magnetic fields (40 nT) combined with static magnetic fields (40 µT) may influence biomolecules by promoting transitions between coherent (ES) and incoherent (CS) domains of hydrogen bonding [47].

Low-frequency electromagnetic fields (ELF-EMF) also demonstrate measurable effects. For instance, a 45 µT field applied to glutamic acid solutions resulted in pH changes and formation of deprotonated species [48].

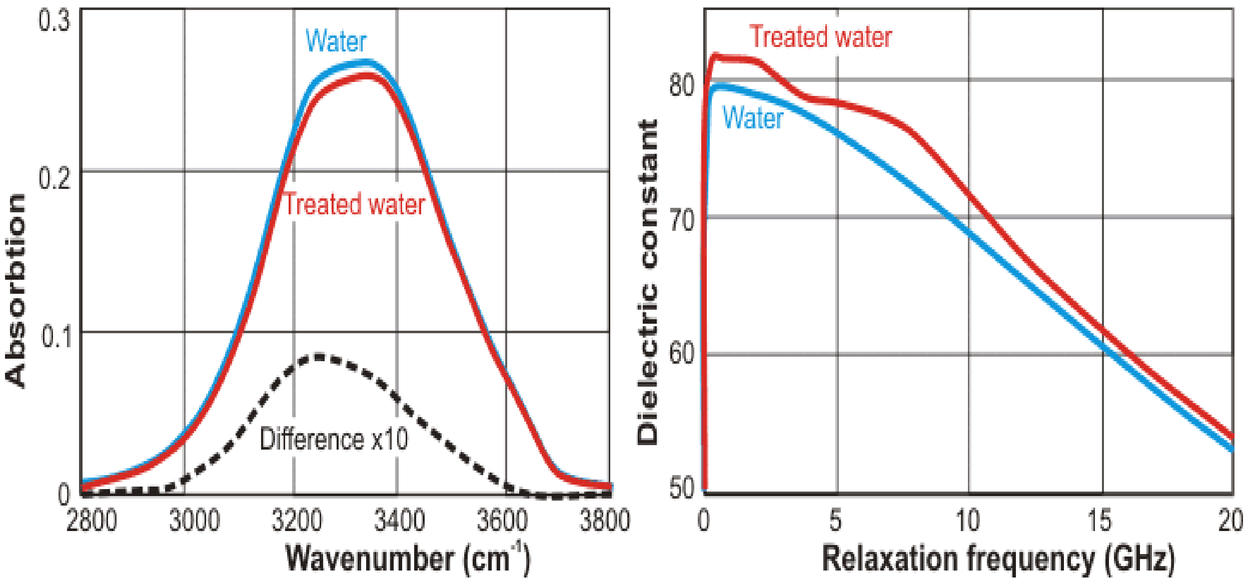


Figure 18 the effects of ELM and EFM on liquid water

Furthermore, FTIR-ATR spectroscopy showed a decrease in the coherent hydrogen-bonded population specifically in the lower-energy region of the O-H stretching band (~3250 cm^{-1}), providing molecular-level evidence for altered hydrogen bonding.

When stronger ELF-EMF fields (~0.15 T) were applied to pure water, the relative permittivity (dielectric constant) increased by approximately (3.7% over a 1–10 GHz) frequency range compared to untreated water. This indicates a higher degree of molecular polarization, further supporting the claim that electromagnetic exposure can modify water's dielectric and chemical properties.

These structural changes may have important biological implications. Although microwave radiation is traditionally evaluated based on its thermal effects, there is increasing evidence suggesting that non-thermal mechanisms such as field-induced molecular reorientation could affect membrane function and protein–water interactions [49]. Similar effects have been proposed for both magnetic and electric field exposures.

Finally, even low-level alternating electric fields have been shown to influence the electrical conductivity of pure water [50], suggesting that long-term exposure to electromagnetic sources such as power lines or communication towers may warrant reconsideration regarding health and environmental safety. Variations in the geomagnetic field itself may also have biological consequences over extended periods.

3.11 Advantages of Using Electromagnetic Waves for Wastewater Treatment

3.11.1 High Efficiency in Pollutant Removal

Electromagnetic waves break down complex organic compounds, such as chemical pollutants and pesticides, significantly improving water quality.

They assist in breaking apart suspended solid particles, facilitating filtration and enhancing overall treatment efficiency.

3.11.2 Reduction in Chemical Usage

They minimize the need for chemical disinfectants like chlorine, reducing the risk of harmful byproducts that could affect health and the environment.

Lower reliance on chemicals decreases operational costs related to purchasing, storing, and disposing of chemical agents.

3.11.3 Low Operational Costs

This method does not require expensive consumables, making operational and maintenance costs lower than those of conventional treatment systems.

It consumes less energy compared to other purification techniques such as distillation and reverse osmosis.

3.11.4 Environmentally Friendly

The process does not generate toxic waste or harmful chemical residues that could contaminate groundwater or soil.

It helps reduce the carbon footprint since it does not rely on harmful chemical reactions or combustion processes.

3.11.5 Improvement of Water Quality

Electromagnetic waves enhance the physical, chemical, and biological properties of water by reducing turbidity and increasing dissolved oxygen levels.

They contribute to producing cleaner water, making it more suitable for drinking, irrigation, and industrial applications.

3.11.6 Effective Against Microorganisms and Bacteria

These waves disrupt the DNA of bacteria and viruses, preventing them from multiplying and leading to their elimination.

This method provides an effective alternative for water sterilization without the need for antibiotics or chemical disinfectants that may contribute to bacterial resistance.

3.11.7 Easy Integration with Existing Systems

Electromagnetic wave technology can be easily incorporated into existing wastewater treatment plants without requiring significant infrastructure modifications.

It can be used as an additional purification stage to enhance overall efficiency and improve the quality of treated water.

3.12 Conclusion

In this chapter, we explored the various effects of electric, magnetic, and electromagnetic fields on water. We examined how these fields influence the physical structure, chemical behavior, and hydrogen bonding network of water molecules. From changes in refractive index and solubility to the generation of reactive oxygen species and the “memory effect” of water, each type of field was shown to produce unique and sometimes synergistic impacts.

Having gained a theoretical understanding of these phenomena, we are now ready to apply this knowledge in practice. The next and final chapter will focus on the experimental implementation of electromagnetic fields in water treatment, where we will observe the practical outcomes of these effects and evaluate their efficiency.

Chapter 4: Experimental and Results

4. Main Objective

The primary objective of this project is to investigate the effects of electromagnetic fields on water treatment. By exposing water to a controlled magnetic field generated by a coil system, we aim to assess the changes in physical and chemical parameters and evaluate the potential of this method as an alternative or complementary treatment technique.

4.1 Description of the Experimental Procedure

In this experiment, a glass tube is used as the main conduit through which 40 mL of raw groundwater is passed. The water sample is sourced from a well located in Ouled Sidi Brahim, extracted from a depth of approximately 120 meters.

Around the glass tube, a copper coil with a wire diameter of 0.5 mm and a total of 152 turns (N = 152) is uniformly wrapped. This coil is connected to a DC power supply, which delivers direct current to generate a steady magnetic field, functioning analogously to a permanent magnet.

The water remains under the influence of the magnetic field for a fixed duration of two hours. During this period, several experimental parameters are varied, including:

- Electric current (I)
- Voltage (V)
- Electrical resistance (R)

Each experimental run maintains a consistent coil configuration while altering electrical inputs to observe the corresponding effects on the water sample.

After two hours of treatment, the water samples are collected and analyzed using a conductivity meter. The following parameters are measured:

- Salinity (g/L) indicating the concentration of dissolved salts
- conductivity (ms/cm) reflecting the water's ability to conduct electric current due to the presence of ions

Total Solids Bodies (TSB) (mg/L) representing the concentration of undissolved solid particles

These results are then compared with the initial values (before treatment) to assess the effectiveness of electromagnetic field application on water quality.

4.2 Explanation of Analytical Parameters

4.2.1 TSB

Total Solid Bodies (TSB) refer to the overall concentration of solid matter present in water, encompassing both dissolved and suspended substances. These may include:

- Inorganic minerals (e.g., calcium, magnesium)
- Organic compounds
- Micro-particulates and other impurities

TSB is commonly measured in milligrams per liter (mg/L) and serves as a key indicator of water quality and purity. Elevated TSB levels suggest a higher degree of contamination, which may affect water usability for domestic, agricultural, or industrial purposes.

4.2.2 Conductivity

Electrical conductivity is a measure of water's ability to conduct an electric current, which directly depends on the concentration of dissolved ions such a :

- Sodium (Na^+)
- Chloride (Cl^-)
- Calcium (Ca^{2+})
- Potassium (K^+)

Conductivity is measured in microsiemens per centimeter (µS/cm or ms/cm) and serves as an indirect indicator of:

- Ionic strength
- Mineral content
- Salinity levels

Higher conductivity indicates greater ionic concentration, which may result from natural mineral leaching, pollution, or treatment processes.

4.2.3 Salinity

Salinity refers to the total concentration of dissolved salts in water, primarily sodium chloride (NaCl) but also including other ionic compounds such as sulfates, bicarbonates, and nitrates.

It is typically expressed in:

- Grams per liter (g/L) or
- Parts per thousand (ppt)

Salinity is a critical factor influencing:

- Taste and potability
- Agricultural irrigation compatibility
- Industrial process efficiency
- Survivability of aquatic organisms

Changes in salinity can significantly impact both water chemistry and its end-use applications.

4.3 Tools used in the experiment

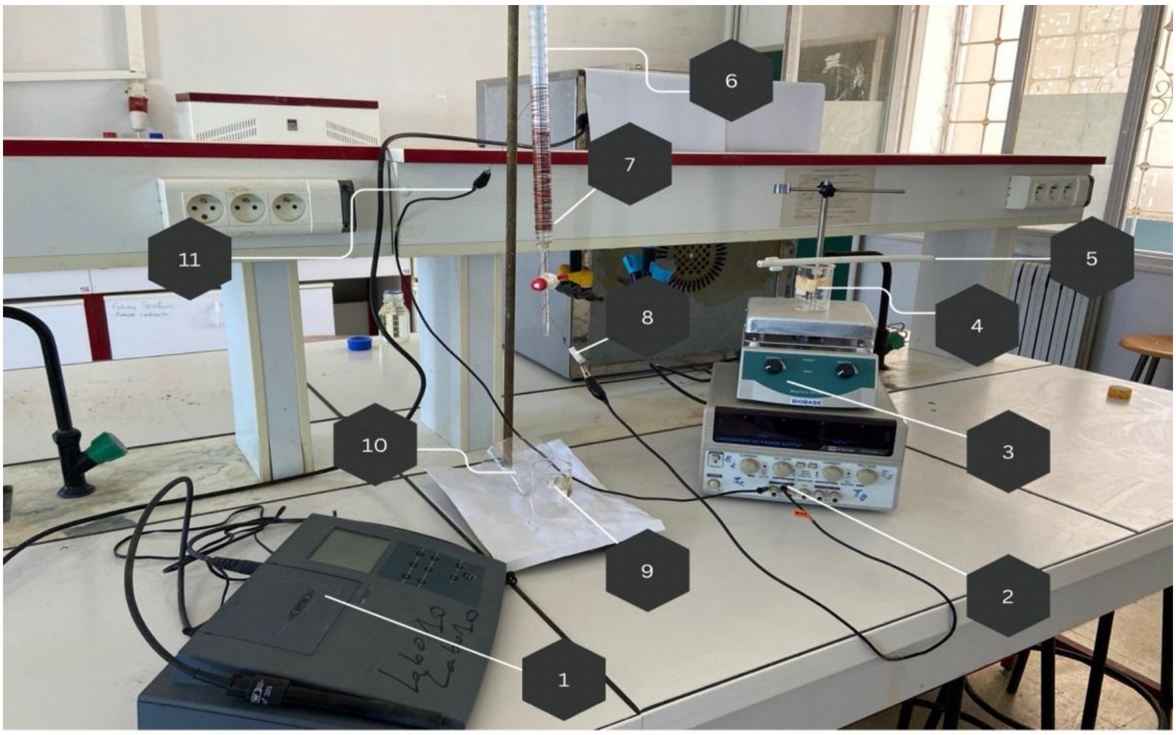


Figure 19 Tools of Expirementes

Tool	Number
Conductivity meter	1
Dc generator (30V/3A)	2
Magnetic stirrer	3
Beaker	4
Magentic wand	5
Glass pipe	6
Copper coil	7
Resistance power (18 ohm /4w)	8
Beaker	9
Glass funnel	10
Cables	11

Table 4 Tools used in expriment

4.4 Physicochemical Analyses

As part of this study, a comprehensive set of physicochemical analyses was conducted on well water and tap water samples to evaluate and compare their qualitative and quantitative characteristics. These analyses aim to assess:

- The purity of each water source,
- The presence and concentration of salts, minerals, and total solids, and
- The suitability of each source for drinking, agricultural, or industrial use.

This comparative evaluation provides valuable insights into the degree of required treatment for each water type and supports the selection of the most appropriate treatment techniques based on national and international water quality standards.

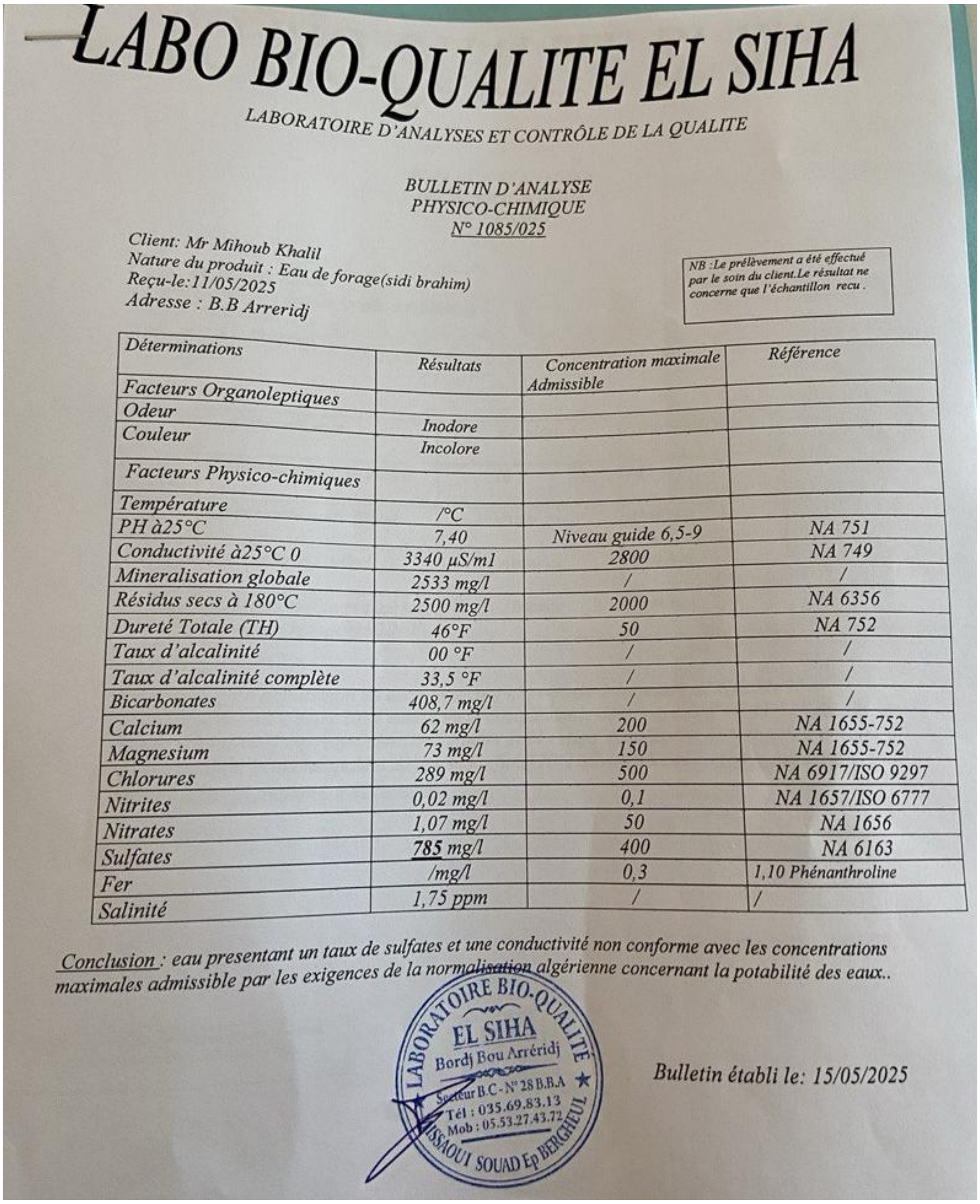
4.4.1 Physical Analyses (Well Water)

Physical analysis involves the assessment of water properties that can be measured or observed without altering the chemical composition of the sample. These parameters serve as essential indicators of aesthetic quality and help identify potential signs of pollution or degradation.

The primary physical parameters examined include:

- Temperature: Influences biological activity, chemical reaction rates, and solubility of gases.
- Turbidity: Indicates the presence of suspended solids, affecting light penetration and potential microbial contamination.
- Color: May result from dissolved organic substances, metals, or algae.
- Odor: Can be a sign of microbial growth, chemical pollution, or decomposition of organic matter.
- Electrical Conductivity (EC): Reflects the total concentration of dissolved ions and is a proxy for salinity and mineral content.

These tests help determine the sensory acceptability and technical suitability of the water for human consumption, irrigation, and industrial use. Physical changes in water may result from natural sources, storage conditions, or human-induced contamination, making this form of analysis a fundamental step in water quality assessment.



LABO BIO-QUALITE EL SIHA

LABORATOIRE D'ANALYSES ET CONTRÔLE DE LA QUALITE

BULLETIN D'ANALYSE
PHYSICO-CHIMIQUE
N° 1085/025

Client: Mr Mihoub Khalil
Nature du produit : Eau de forage(sidi brahim)
Reçu-le:11/05/2025
Adresse : B.B Arreridj

NB :Le prélèvement a été effectué par le soin du client.Le résultat ne concerne que l'échantillon recu .

Déterminations	Résultats	Concentration maximale Admissible	Référence
Facteurs Organoleptiques			
Odeur	Inodore		
Couleur	Incolore		
Facteurs Physico-chimiques			
Température	/°C		
PH à25°C	7,40	Niveau guide 6,5-9	NA 751
Conductivité à25°C 0	3340 µS/m1	2800	NA 749
Mineralisation globale	2533 mg/l	/	/
Résidus secs à 180°C	2500 mg/l	2000	NA 6356
Dureté Totale (TH)	46°F	50	NA 752
Taux d'alcalinité	00 °F	/	/
Taux d'alcalinité complète	33,5 °F	/	/
Bicarbonates	408,7 mg/l	/	/
Calcium	62 mg/l	200	NA 1655-752
Magnesium	73 mg/l	150	NA 1655-752
Chlorures	289 mg/l	500	NA 6917/ISO 9297
Nitrites	0,02 mg/l	0,1	NA 1657/ISO 6777
Nitrates	1,07 mg/l	50	NA 1656
Sulfates	785 mg/l	400	NA 6163
Fer	/mg/l	0,3	1,10 Phénanthroline
Salinité	1,75 ppm	/	/

Conclusion : eau presentant un taux de sulfates et une conductivité non conforme avec les concentrations maximales admissible par les exigences de la normalisation algérienne concernant la potabilité des eaux..

LABORATOIRE BIO-QUALITE
EL SIHA
Bordj Bou Arréridj

Bulletin établi le: 15/05/2025

Figure 20 physicale analyis of well water

The water exceeds the acceptable limits for sulfate concentration and electrical conductivity based on the Algerian standards for drinking water potability. Therefore, it does not comply with the maximum admissible concentrations set by national regulations.

4.4.2 Microbiological Analysis (Well Water)

Microbiological analysis is essential for assessing the sanitary quality of water, particularly when evaluating its suitability for human consumption. This analysis focuses on the detection, identification, and enumeration of microorganisms such as:

- Bacteria
- Fungi
- Algae
- Viruses

The presence of pathogenic or indicator organisms poses serious health risks, especially when water is used for drinking, food preparation, or irrigation of edible crops.

Special emphasis is placed on detecting indicator organisms of fecal contamination, particularly:

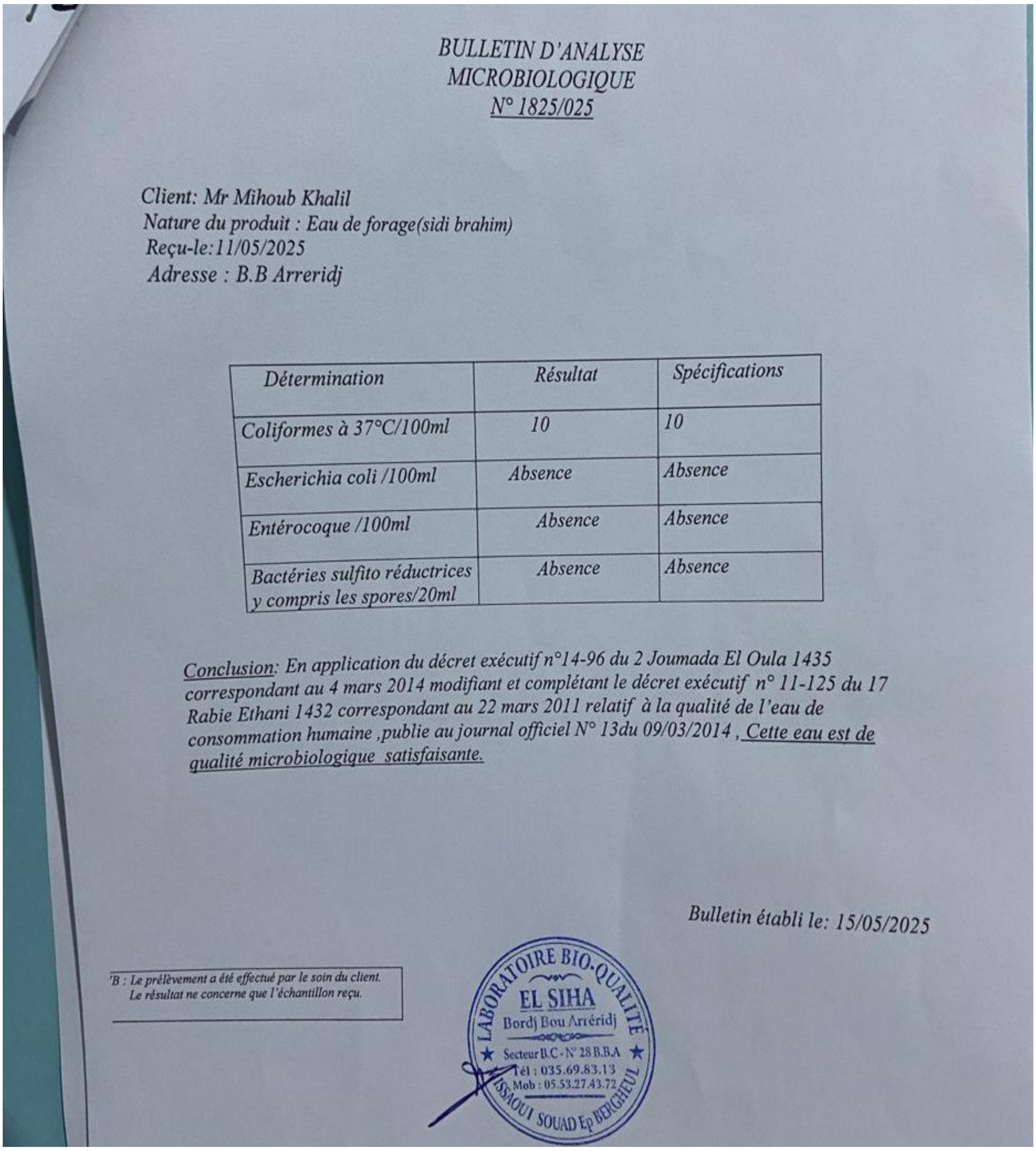
- Total coliforms
- Fecal coliforms (Escherichia coli)

These bacteria serve as indirect markers of sewage or organic pollution, indicating a potential presence of pathogens capable of causing waterborne diseases (cholera, typhoid, dysentery).

Microbiological results are critical in determining:

- Whether disinfection is necessary (chlorination, UV treatment),
- The urgency of treatment, and
- The safety level of the water for various uses.

Regular microbiological monitoring of well water is especially important in rural and agricultural areas, where surface contamination, animal waste, or inadequate sanitation infrastructure may affect groundwater quality.



BULLETIN D'ANALYSE
MICROBIOLOGIQUE
N° 1825/025

Client: Mr Mihoub Khalil
Nature du produit : Eau de forage(sidi brahim)
Reçu-le:11/05/2025
Adresse : B.B Arreridj

Détermination	Résultat	Spécifications
Coliformes à 37°C/100ml	10	10
Escherichia coli /100ml	Absence	Absence
Entérocoque /100ml	Absence	Absence
Bactéries sulfito réductrices y compris les spores/20ml	Absence	Absence

Conclusion: En application du décret exécutif n°14-96 du 2 Joumada El Oula 1435 correspondant au 4 mars 2014 modifiant et complétant le décret exécutif n° 11-125 du 17 Rabie Ethani 1432 correspondant au 22 mars 2011 relatif à la qualité de l'eau de consommation humaine ,publie au journal officiel N° 13du 09/03/2014 , Cette eau est de qualité microbiologique satisfaisante.

Bulletin établi le: 15/05/2025

B : Le prélèvement a été effectué par le soin du client.
Le résultat ne concerne que l'échantillon reçu.

LABORATOIRE BIO-QUALITÉ
EL SIHA
Bordj Bou Arréridj
Secteur B.C - N° 28 B.B.A
Tél : 035.69.83.13
Mob : 05.53.27.43.72
ISSAOUI SOUAD Ep BERGHEUL

Figure 21 Microbial analysis(well water)

In application of Executive Decree No. 14-96 of 2 Joumada El Oula 1435 (March 4, 2014) modifying and supplementing Decree No. 11-125 of 17 Rabie El Thani 1432 (March 22, 2011) relating to the quality of water intended for human consumption, published in the Official Journal No. 13 of 09/03/2014:

This water is of satisfactory microbiological quality.

4.5 Physicochemical Analysis (Potable Water)

To establish a meaningful comparison, potable (drinkable) water—compliant with national and international water quality standards—was selected as a reference in this study. The purpose of this comparison is to evaluate the efficacy of electromagnetic field treatment applied to well water by analyzing how closely its quality approaches that of standardized drinking water.

Physicochemical analysis of potable water includes the measurement of parameters such as:

- Total Dissolved Solids (TDS)
- Salinity
- Electrical Conductivity
- pH
- Turbidity
- Temperature

These parameters reflect the water's ionic content, mineral load, and physical properties, all of which influence its taste, safety, and suitability for consumption. By comparing these indicators with those of treated well water, it becomes possible to:

- Assess improvements in water quality after treatment,
- Identify remaining deficiencies, and
- Determine the effectiveness of the electromagnetic process in bringing non-potable water closer to drinkable standards.

This analysis serves as a benchmark for validating the treatment's potential in real-world applications, particularly in areas where access to safe drinking water is limited.

4.5.1 Physical Analyses (Potable Water)

Physical analysis of potable water focuses on the evaluation of observable and measurable characteristics that do not alter the chemical composition of the sample. These include:

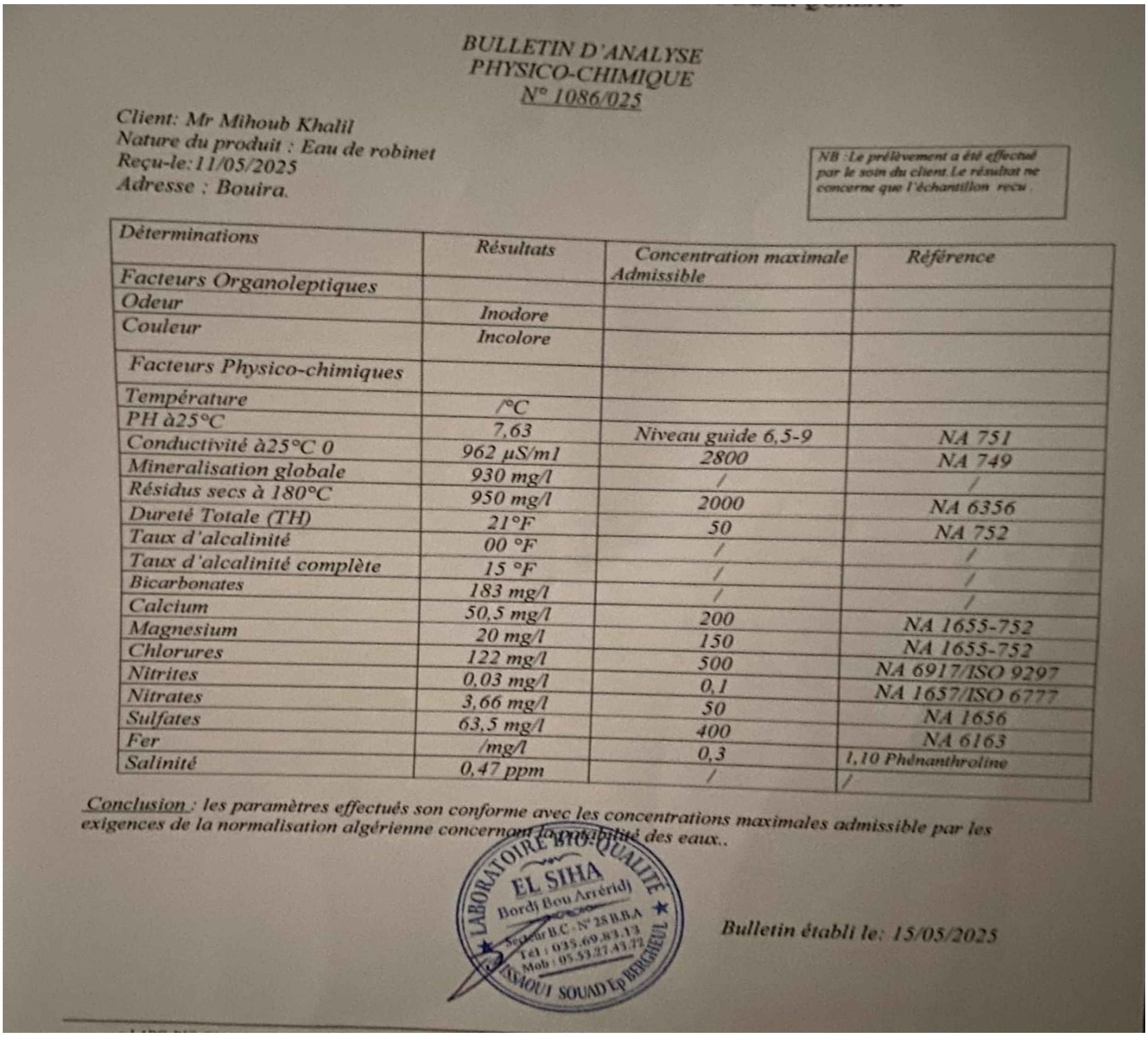
- Temperature
- Turbidity
- Color
- Odor
- Electrical Conductivity

These parameters serve as primary indicators of water quality, influencing both its aesthetic acceptability and its functional suitability for domestic consumption, industrial use, and agricultural applications.

Monitoring these physical properties is essential for:

- Verifying compliance with drinking water standards,
- Detecting early signs of contamination or degradation, and
- Assessing the influence of environmental and storage conditions.

In this study, the physical properties of potable water are analyzed and documented in order to serve as a baseline reference for comparison with treated well water. This allows for a quantitative and qualitative assessment of the effectiveness of electromagnetic field-based treatment techniques in improving water quality.



BULLETIN D'ANALYSE
PHYSICO-CHIMIQUE
N° 1086/025

Client: Mr Mihoub Khalil
Nature du produit : Eau de robinet
Reçu-le: 11/05/2025
Adresse : Bouira.

NB : Le prélèvement a été effectué par le soin du client. Le résultat ne concerne que l'échantillon reçu .

Déterminations	Résultats	Concentration maximale Admissible	Référence
Facteurs Organoleptiques			
Odeur	Inodore		
Couleur	Incolore		
Facteurs Physico-chimiques			
Température	/°C		
PH à25°C	7,63	Niveau guide 6,5-9	NA 751
Conductivité à25°C 0	962 µS/ml	2800	NA 749
Mineralisation globale	930 mg/l	/	/
Résidus secs à 180°C	950 mg/l	2000	NA 6356
Dureté Totale (TH)	21°F	50	NA 752
Taux d'alcalinité	00 °F	/	/
Taux d'alcalinité complète	15 °F	/	/
Bicarbonates	183 mg/l	/	/
Calcium	50,5 mg/l	200	NA 1655-752
Magnesium	20 mg/l	150	NA 1655-752
Chlorures	122 mg/l	500	NA 6917/ISO 9297
Nitrites	0,03 mg/l	0,1	NA 1657/ISO 6777
Nitrates	3,66 mg/l	50	NA 1656
Sulfates	63,5 mg/l	400	NA 6163
Fer	/mg/l	0,3	1,10 Phénanthroline
Salinité	0,47 ppm	/	/

Conclusion : les paramètres effectués son conforme avec les concentrations maximales admissible par les exigences de la normalisation algérienne concernant la potabilité des eaux..

LABORATOIRE BIO-QUALITE EL SIHA Bordj Bou Arréridj

Bulletin établi le: 15/05/2025

Figure 22 Physical analyses(potable water)

As evidenced by the measured parameters, this potable water complies with the Algerian standards for drinking water quality

4.5.2 Microbial Analysis (Potable Water)

Microbiological analysis plays a vital role in verifying the microbial safety and hygiene of potable (drinking) water. This type of analysis aims to detect, identify, and quantify microorganisms that could compromise water quality, including:

- Pathogenic bacteria
- Fungi
- Viruses

- Protozoa and algae

Of particular concern are indicator organisms of fecal contamination, such as:

- Total coliforms
- Fecal coliforms, especially *Escherichia coli* (*E. coli*)

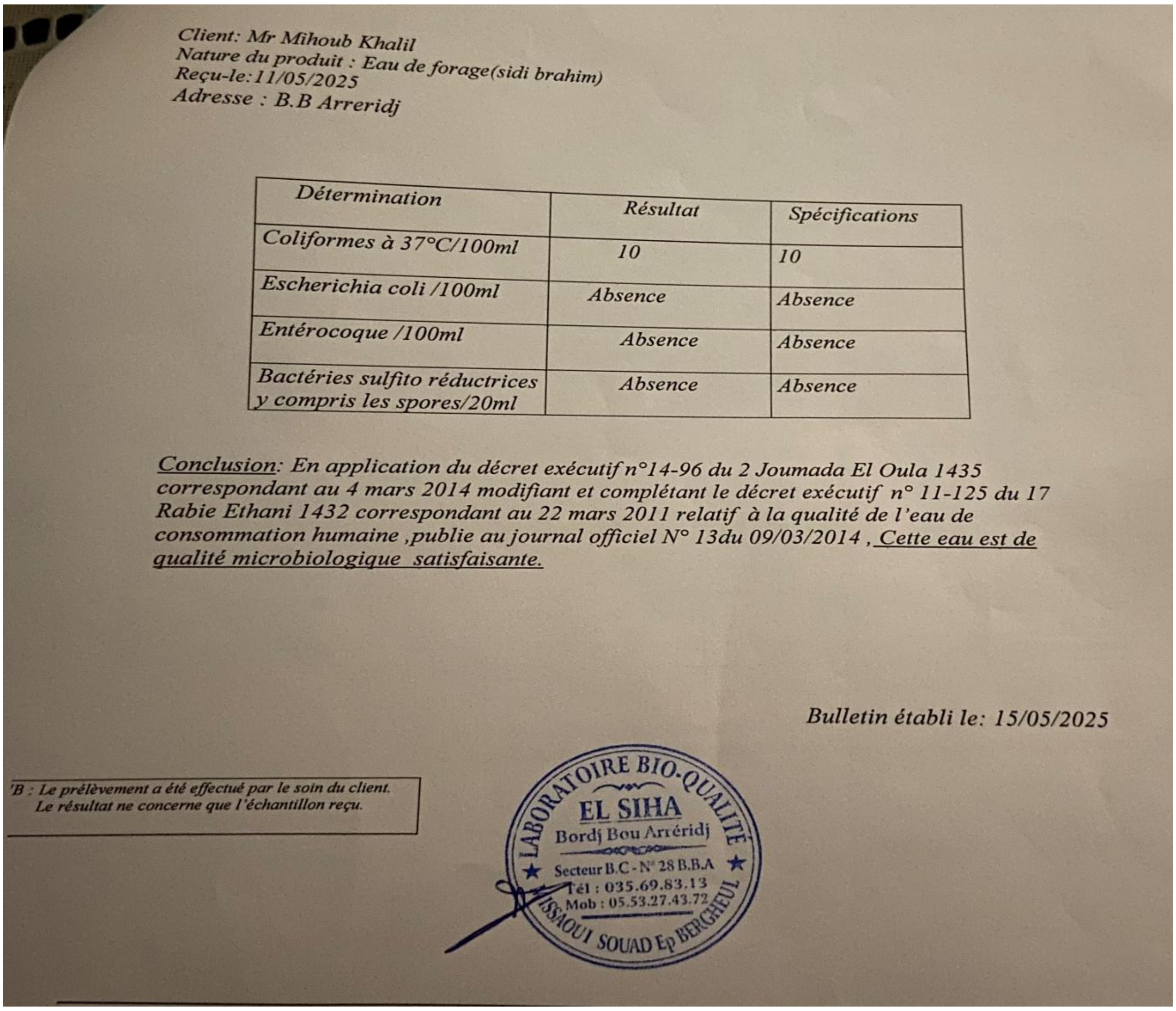
These microbial indicators are widely used as indirect evidence of sewage intrusion or organic pollution, both of which can introduce pathogens responsible for waterborne illnesses (e.g., gastrointestinal infections, cholera, dysentery, and hepatitis A).

For potable water to be considered compliant with Algerian national standards and World Health Organization (WHO) guidelines, zero detection of fecal coliforms per 100 mL is typically required.

The outcomes of microbiological testing are crucial for:

- Confirming the safety and fitness of the water for human consumption
- Identifying the need for preventive or corrective actions, such as disinfection
- Supporting regulatory compliance and public health protection

Routine microbiological surveillance is indispensable, particularly in urban distribution networks, where even small breaches (e.g., pipe leaks, storage tank contamination) may result in the reintroduction of pathogens into treated water.



Client: Mr Mihoub Khalil
Nature du produit : Eau de forage(sidi brahim)
Reçu-le: 11/05/2025
Adresse : B.B Arreridj

Détermination	Résultat	Spécifications
Coliformes à 37°C/100ml	10	10
Escherichia coli /100ml	Absence	Absence
Entérocoque /100ml	Absence	Absence
Bactéries sulfito réductrices y compris les spores/20ml	Absence	Absence

Conclusion: En application du décret exécutif n°14-96 du 2 Joumada El Oula 1435 correspondant au 4 mars 2014 modifiant et complétant le décret exécutif n° 11-125 du 17 Rabie Ethani 1432 correspondant au 22 mars 2011 relatif à la qualité de l'eau de consommation humaine ,publie au journal officiel N° 13du 09/03/2014 , Cette eau est de qualité microbiologique satisfaisante.

Bulletin établi le: 15/05/2025

B : Le prélèvement a été effectué par le soin du client. Le résultat ne concerne que l'échantillon reçu.

LABORATOIRE BIO-QUALITE EL SIHA Bordj Bou Arréridj Secteur B.C - N° 28 B.B.A Tél : 035.69.83.13 Mob : 05.53.27.43.72 ISSAOUI SOUAD Ep BERGHEUL

Figure 23 Microbial analysis(Potable Water)

In application of Executive Decree No. 14-96 of 2 Joumada El Oula 1435 (March 4, 2014) modifying and supplementing Decree No. 11-125 of 17 Rabie El Thani 1432 (March 22, 2011) relating to the quality of water intended for human consumption, published in the Official Journal No. 13 of 09/03/2014:

This water is of satisfactory microbiological quality.

4.6 The results

Due to the limited capacity of the glass treatment pipe and the high level of pollution in the well water, the amount of treated water obtained in each trial was relatively small. As a result, it was not feasible to perform a complete analysis, particularly for Total Solid Bodies (TSB), in every experimental run.
Given these constraints, we focused our analysis primarily on two measurable parameters:

- Salinity
- Electrical Conductivity (formerly referred to as transmission)

During preliminary measurements, the TSB concentration in the raw well water was found to be exceptionally high, to the extent that the conductivity meter could not register a valid reading due to sensor limitations.
To address this issue, a dilution protocol was adopted:
We prepared a diluted sample consisting of 40 mL of distilled water and 10 mL of treated water. This dilution was necessary to bring the conductivity level within the measurable range of the device and to ensure accurate and reliable readings.
Despite these limitations, the data obtained from conductivity and salinity tests offered insightful trends regarding the effects of electromagnetic treatment on water quality. These results will be presented in the subsequent discussion section.

4.6.1 Test A

In this initial test, 40 mL of well water (sourced from a depth of 120 meters in Ouled Sidi Brahim) was introduced into a glass pipe. The pipe was externally wrapped with a copper coil of 152 turns (N = 152) and 0.5 mm wire diameter to act as the electromagnetic inductor.
The coil was energized using a direct current (DC) power supply, with the following electrical parameters:

- Current (I) = 1.6 A
- Voltage (V) = 16.5 V
- Duration = 2 hours

After the 2-hours electromagnetic exposure, the treated water sample was analyzed using a conductivity meter to assess the changes in water quality
The results of this experiment are summarized below:

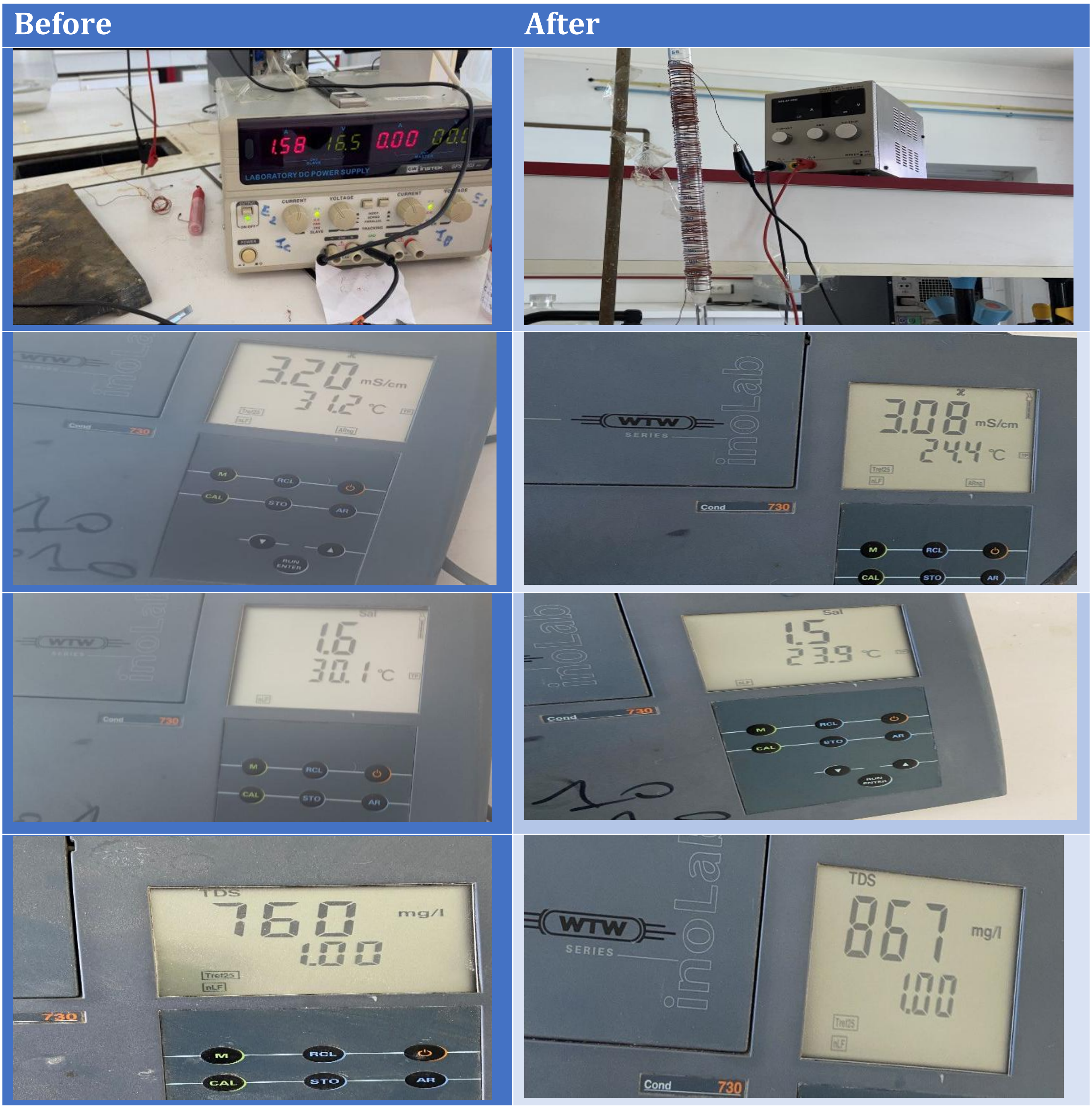


Figure 24 Test A (Before/After) treatment

Table 5 Variation of Physicochemical Parameters Before and After Electromagnetic Treatment (Test A)

I=1.6A V=16.5V N=152 T=2H	Before treatment	After treatment directly	After treatment with a while (72 h)
TSB	760mg/l	747 mg/l	867mg/l
Salinity	1.6g	1.6g	1.5g
Conductivity	3.20ms/cm	3.25ms/cm	3.08ms/cm

This table presents the measurements of Total Solid Bodies (TSB), salinity, and electrical conductivity of well water treated under a magnetic field generated by a copper coil (N = 152 turns) powered with direct current (I = 1.6 A, V = 16.5 V) for 2 hours. The data include values recorded before treatment, immediately after treatment, and 72 hours later, to observe any delayed effects of the electromagnetic field on water properties

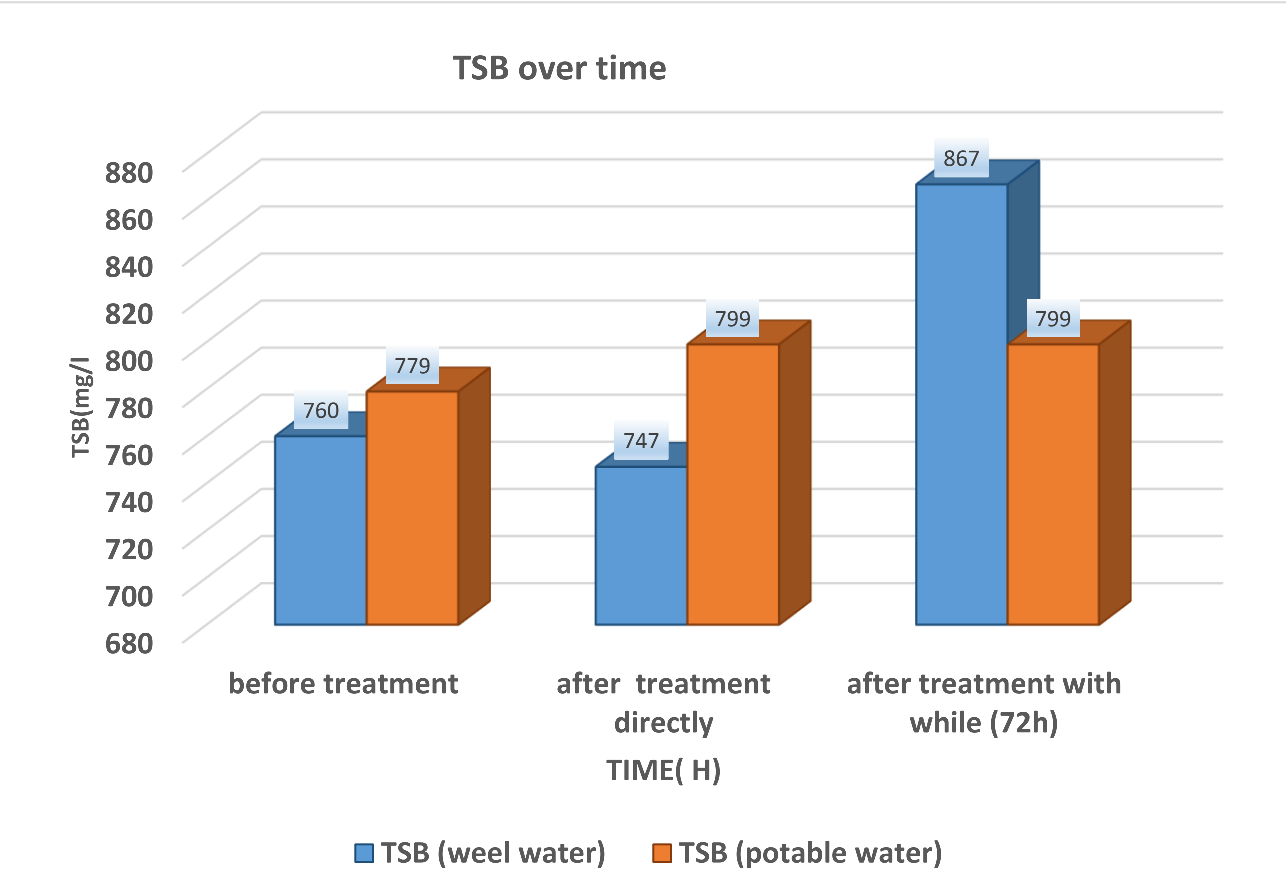


Figure 25 TSB results (test A)

As observed in the chart, there is a notable change in the Total Solid Bodies (TSB) following the electromagnetic treatment. Initially, the TSB value was approximately 760 mg/L. Immediately after the two-hour treatment, it decreased to 747 mg/L, indicating a direct effect of the applied electromagnetic field on the physicochemical properties of the water.

However, after 72 hours, the TSB increased significantly to 867 mg/L. This delayed rise may suggest either the onset of cumulative changes or a shift toward a new state of equilibrium in the water's structure and solute dynamics, potentially triggered by the temporary reorganization of hydrogen bonding and ionic distribution under the influence of the magnetic field.

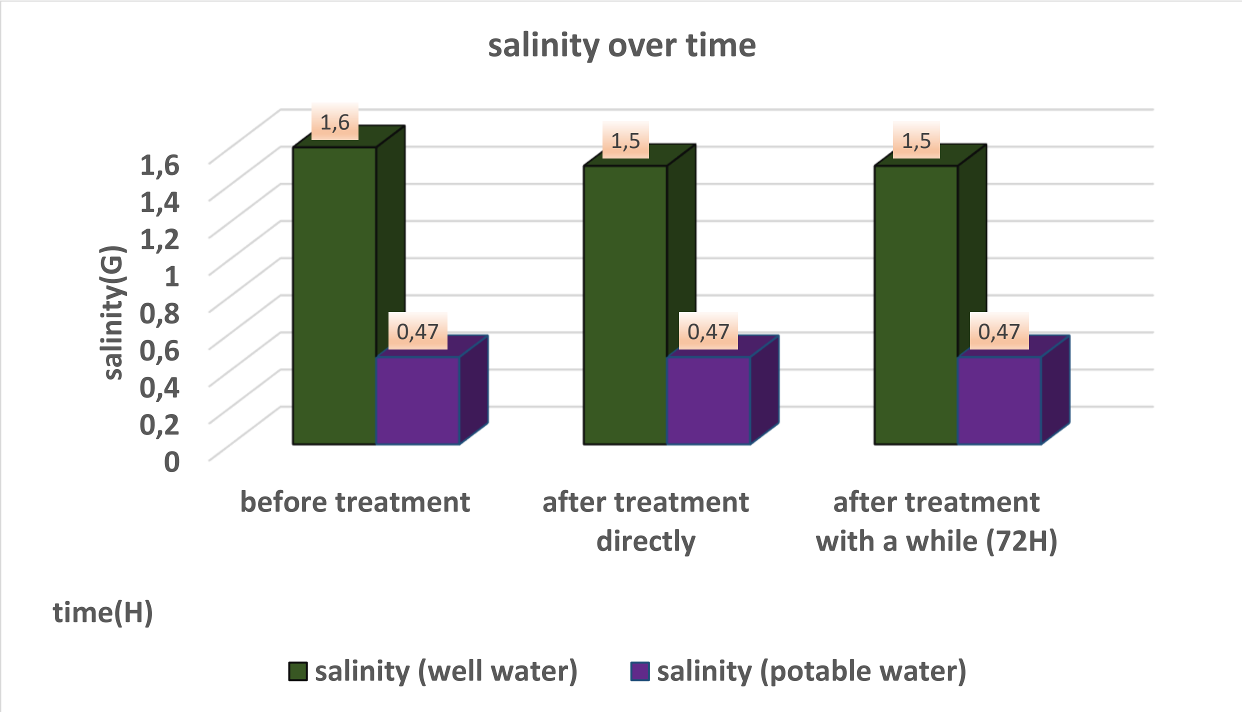


Figure 26 salinity results (test A)

It was observed that the salinity of the well water was initially 1.6 g/L before the start of the experiment. Immediately after the electromagnetic treatment, the salinity decreased slightly to 1.5 g/L, indicating a modest impact of the applied magnetic field on the concentration of dissolved salts.

After 72 hours, the salinity remained stable at 1.5 g/L, showing no further reduction. This suggests that the effect of the electromagnetic field on salinity may be limited to immediate post-treatment conditions, without inducing prolonged changes.

Despite the minor improvement, the salinity level remains relatively high compared to standards for potable water, indicating that additional treatment methods may be necessary for full compliance with drinking water quality requirements.

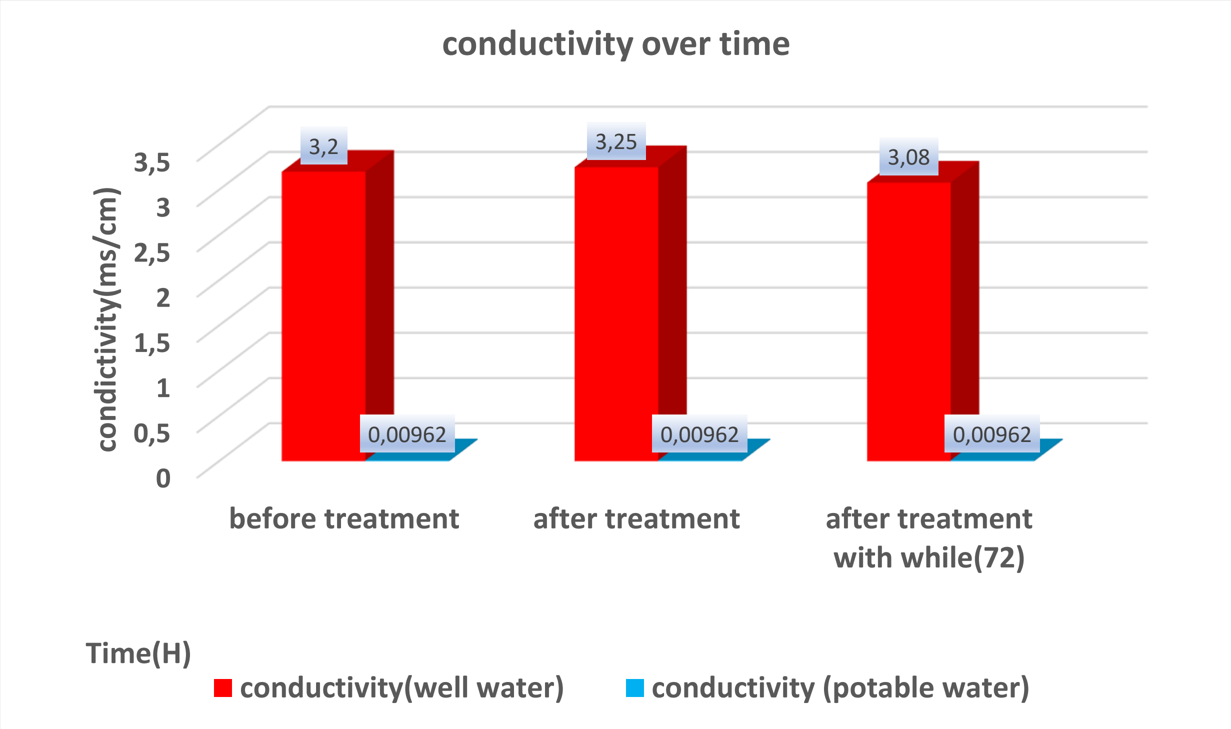


Figure 27 conductivity results (test A)

It was observed that the electrical conductivity of the water sample was initially 3.20 mS/cm. Following the electromagnetic treatment, it increased slightly to 3.25 mS/cm, indicating a temporary rise in ionic mobility or concentration—possibly due to realignment of ions and water molecules under the applied field.

However, after 72 hours, the conductivity decreased to 3.08 mS/cm, which may reflect a delayed structural reorganization or relaxation of the water back toward a more energetically stable state. Despite this slight reduction, the final conductivity remains significantly higher than that of potable water, which typically measures around 0.00962 mS/cm, suggesting that the treated well water still requires further purification to meet drinking water standards.

Table 6 Evolution of Salinity and Conductivity of Well Water After Electromagnetic Treatment (Test A)

I=1.6A V=16.5V N=152 T=2H	Before treatmen	After treatment directly	After 24 h	After 48h	After 72 h
Salinity	1.6g	1.6g	1.5g	1.5g	1.5g
Conductivity	3.20ms/cm	3.25ms/cm	3.20ms/cm	3,14ms/cm	3.08ms /cm

This table shows how salinity and conductivity of well water changed over 72 hours after a 2-hour electromagnetic treatment. Salinity slightly decreased and remained stable, while conductivity increased at first, then gradually decreased showing a delayed effect of the treatment on water structure.

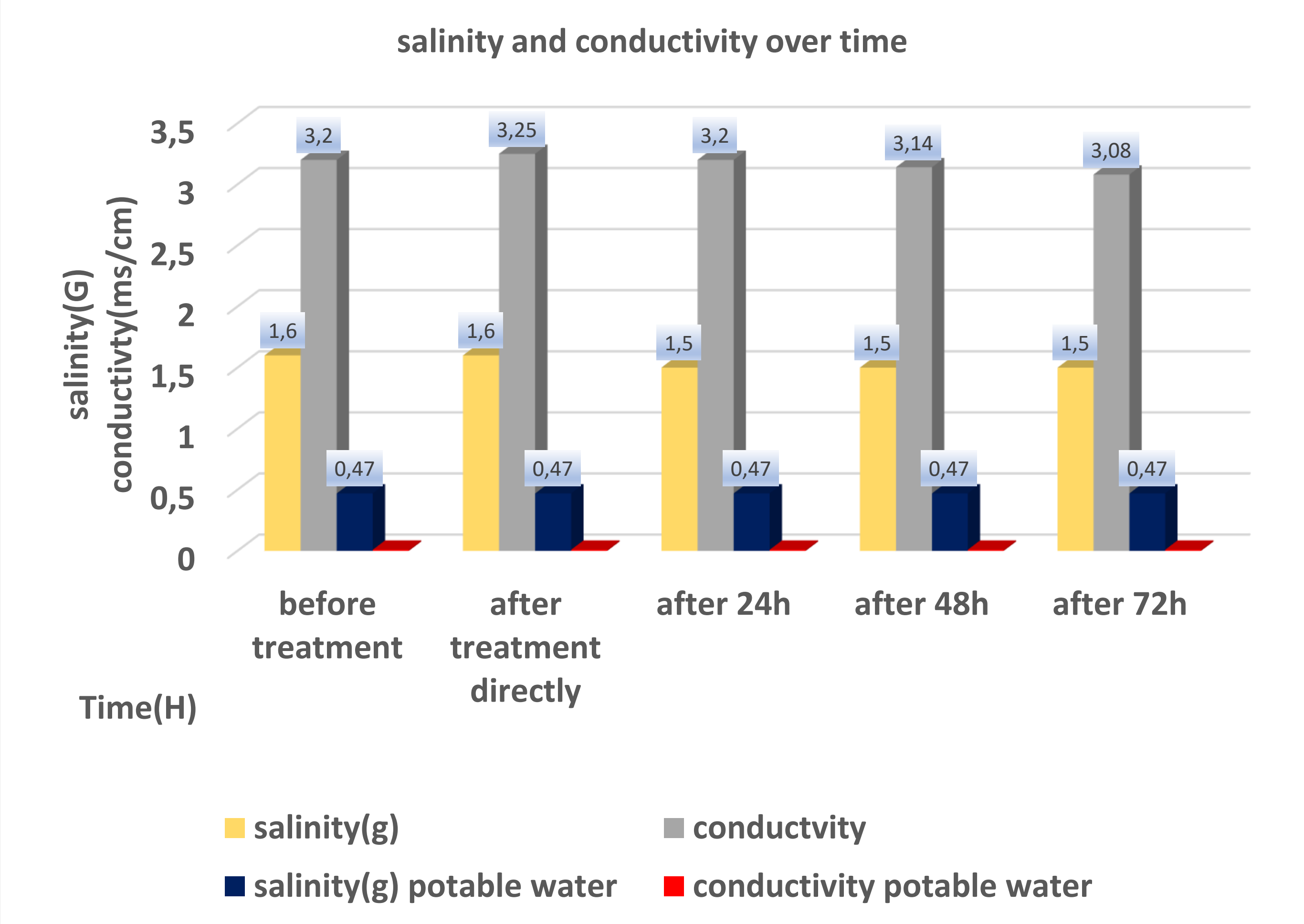


Figure 28 presents a comparison between the conductivity and salinity over time (test A)

This figure presents a comparison between the conductivity and salinity of well water. It is observed that both parameters vary over time following treatment, showing noticeable differences when compared to the standard values of drinking water.

4.6.2 Test B

In this initial test, 40 mL of well water (sourced from a depth of 120 meters in Ouled Sidi Brahim) was introduced into a glass pipe. The pipe was externally wrapped with a copper coil of 152 turns (N = 152) and 0.5 mm wire diameter to act as the electromagnetic inductor.

The coil was energized using a direct current (DC) power supply, with the following electrical parameters:

- Current (I) = 2 A
- Voltage (V) = 12.6 V
- Duration = 2 hours

After the 2-hours electromagnetic exposure, the treated water sample was analyzed using a conductivity meter to assess the changes in water quality

The results of this experiment are summarized below:

Figure 29 Test B (Before/After) treatment

Table 7 Variation of Physicochemical Parameters Before and After Electromagnetic Treatment (Test B)

I=2A V=12.5V N=152 T=2H	Before treatment	After treatment directly	After treatment with while (72h)
TSB	760mg/l	617mg/l	889mg/l
Salinity	1.6g	1.6g	1.5g
conductivity	3.20ms/cm	3.24ms/cm	3.03ms/cm

This table presents the measurements of Total Solid Bodies (TSB), salinity, and electrical conductivity of well water treated under a magnetic field generated by a copper coil (N = 152 turns) powered with direct current (I = 2 A, V = 12.6 V) for 2 hours. The data include values recorded before treatment, immediately after treatment, and 72 hours later, to observe any delayed effects of the electromagnetic field on water properties

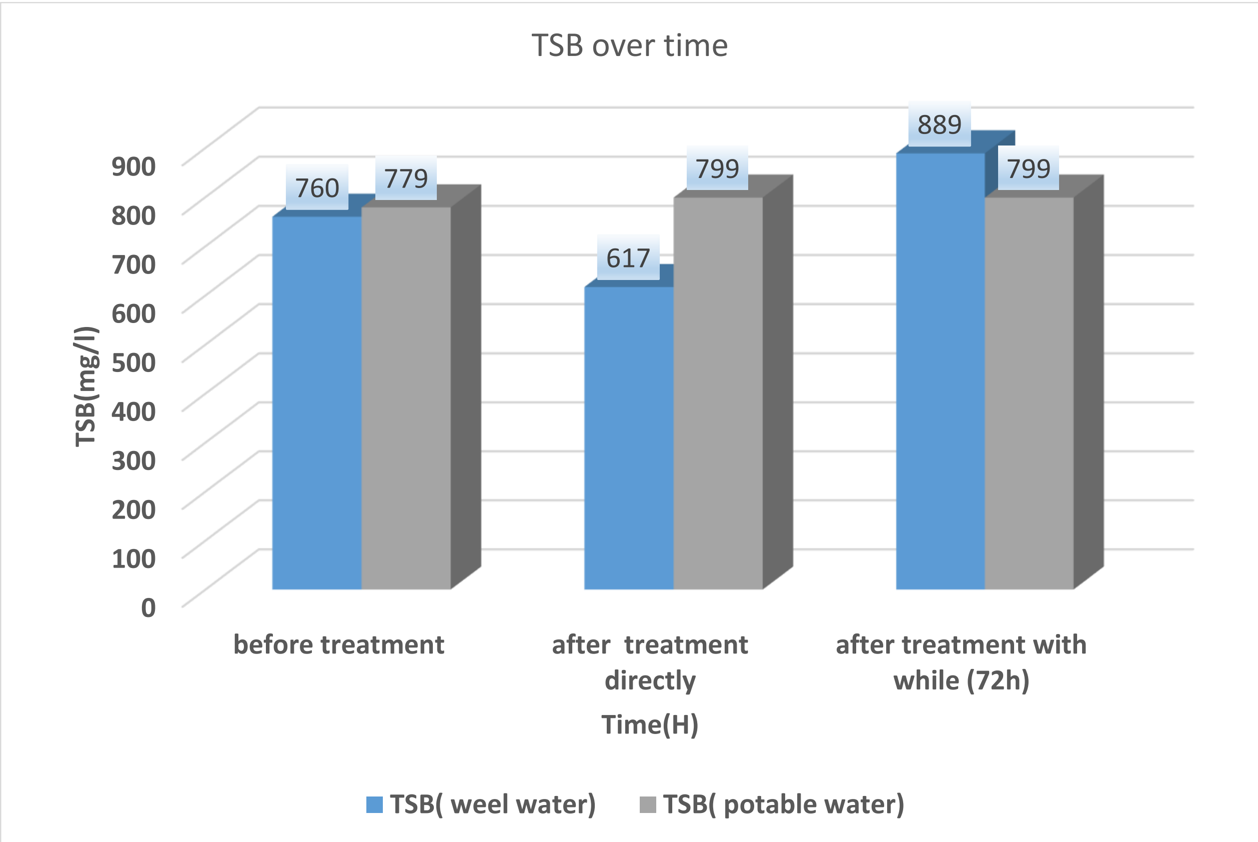


Figure 30 TSB results (test B)

As observed in the chart, there is a noticeable change in the Total Solid Bodies (TSB) value. Initially, the TSB was approximately 760 mg/L, which is relatively close to the value for potable water. After the experiment, the TSB decreased significantly to 617 mg/L. This reduction may be attributed to the applied electromagnetic field causing a dispersal or partial breakdown of solid clusters, possibly leading to the dissolution of some suspended particles. After 72 hours, however, the TSB increased to 889 mg/L, suggesting that the water may retain and gradually respond to the treatment over time, potentially reaching a new state of equilibrium.

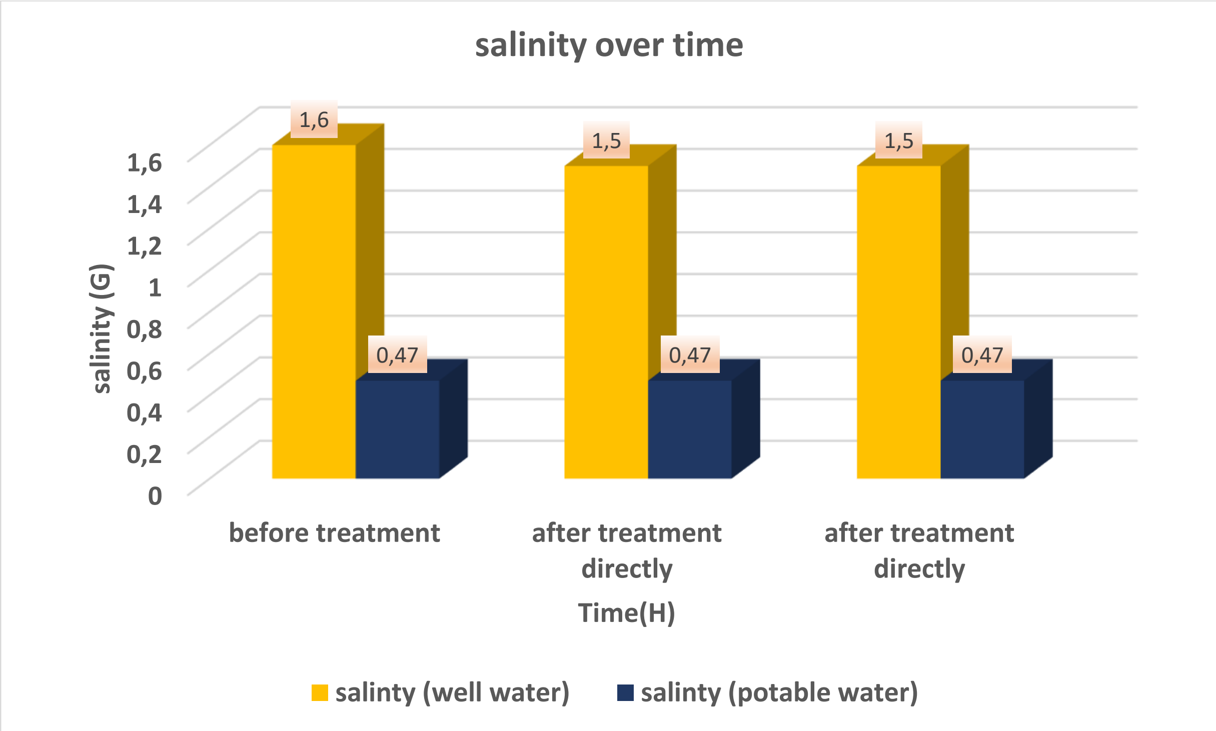


Figure 31 salinity results (test B)

It was observed that the salinity level was initially 1.6 g/L before the test began. Immediately after the application of the electromagnetic field, the salinity decreased slightly to 1.5 g/L. This value remained stable over the following 72 hours. When compared to the salinity of potable water, the value remains significantly high. These results suggest that the electromagnetic field may have an immediate but limited effect on salinity, with no further changes observed over time.

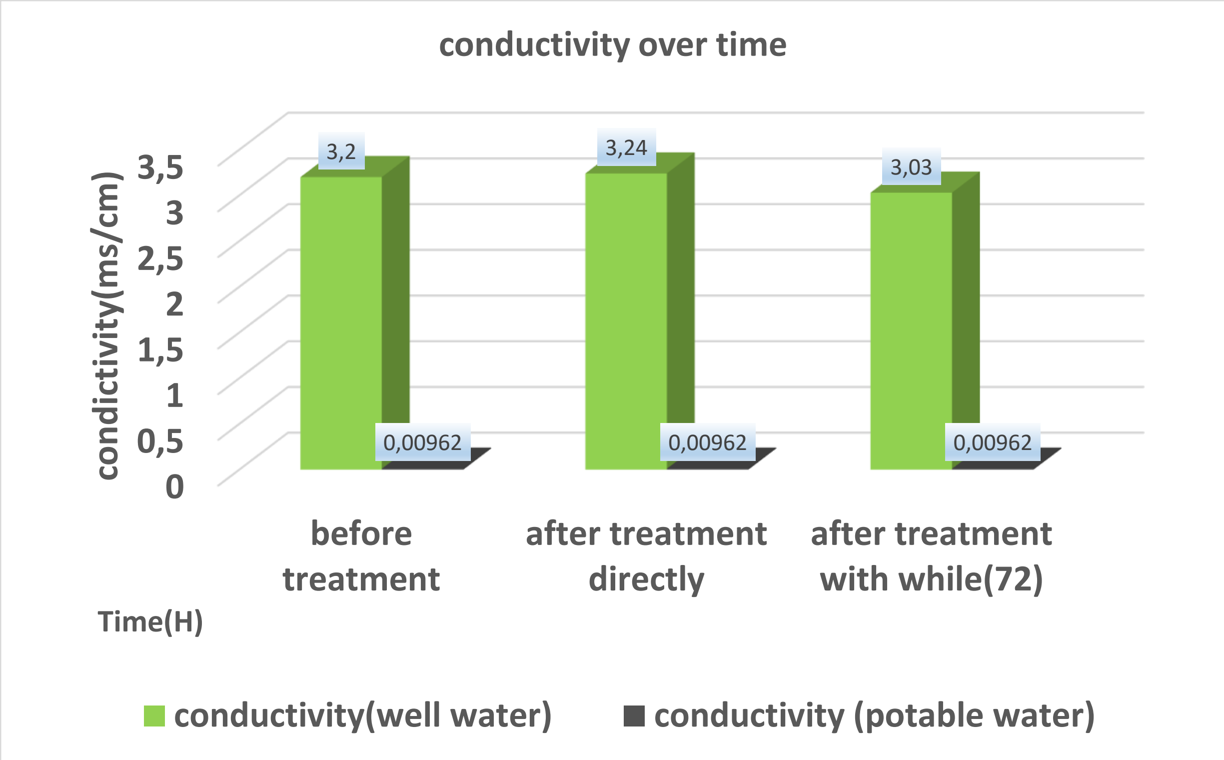


Figure 31 conductivity results (test B)

It was observed that the conductivity of the water was initially 3.20 mS/cm. At the end of the experiment, it increased slightly to 3.24 mS/cm, which may indicate a temporary enhancement in ion mobility due to the applied electromagnetic field. However, after 72 hours, the conductivity decreased to 3.03 mS/cm. This reduction could reflect a delayed reorganization or relaxation of the water's molecular structure toward a more stable state. Nevertheless, the conductivity remains significantly higher compared to that of potable water, which is approximately 0.00962 mS/cm.

Tableau 8 Evolution of Salinity and Conductivity of Well Water After Electromagnetic Treatment (Test B)

I=2A V=12.5V N=152 T=2H	Before treatmen	After treatment directly	After 24 h	After 48h	After 72 h
Salinity	1.6g	1.6g	1.5g	1.5g	1.5g
Conductivity	3.20ms/cm	3.24ms/cm	3.14ms/cm	3.10ms/cm	3.03ms /cm

This table shows how salinity and conductivity of well water changed over 72 hours after a 2-hour electromagnetic treatment. Salinity slightly decreased and remained stable, while conductivity increased at first, then gradually decreased showing a delayed effect of the treatment on water structure.

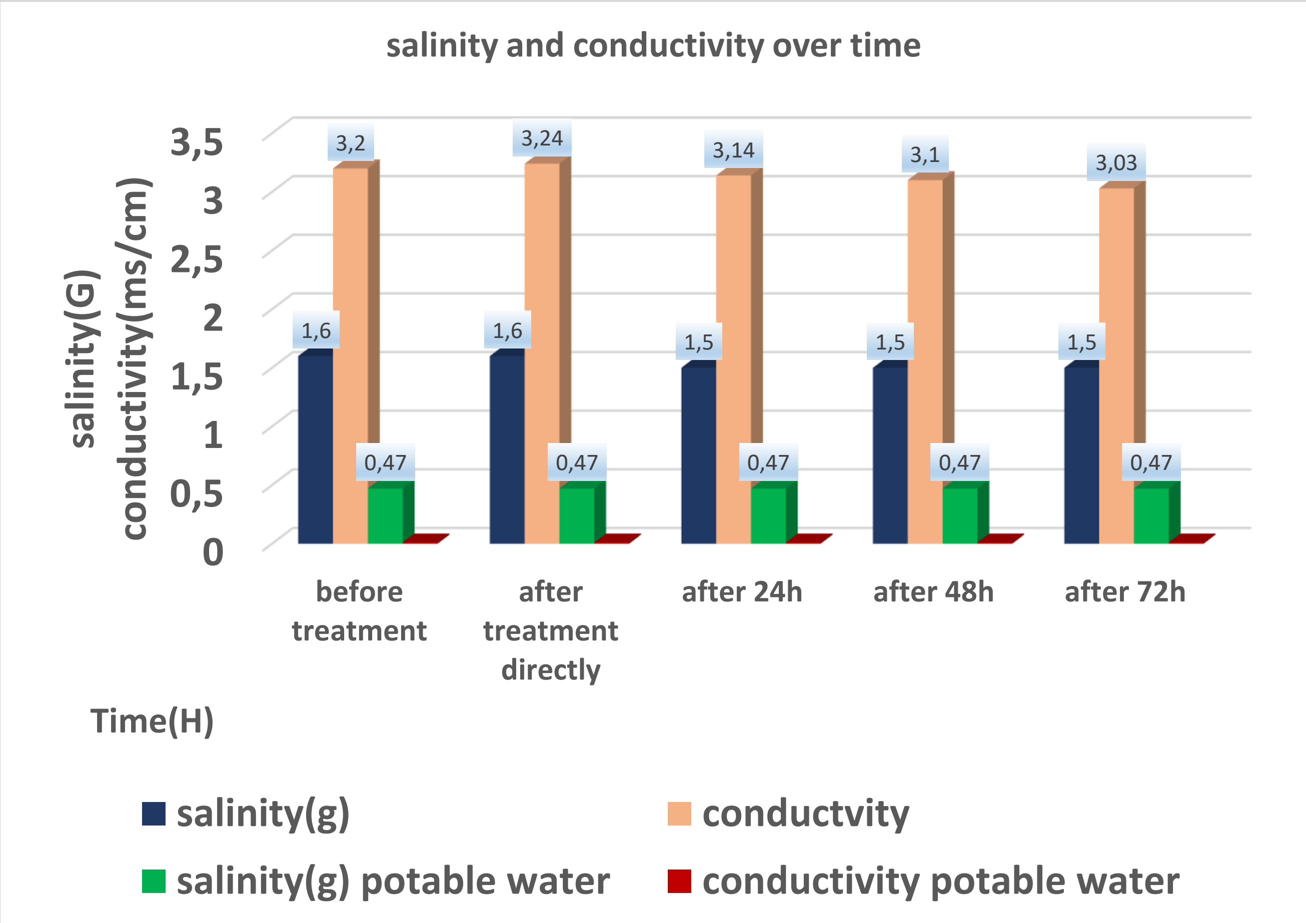


Figure 32 presents a comparison between the conductivity and salinity over time (test B)

This figure presents a comparison between the conductivity and salinity of well water. It is observed that both parameters vary over time following treatment, showing noticeable differences when compared to the standard values of drinking water.

4.6.3 Test C

In this initial test, 40 mL of well water (sourced from a depth of 120 meters in Ouled Sidi Brahim) was introduced into a glass pipe. The pipe was externally wrapped with a copper coil of 152 turns (N = 152) and 0.5 mm wire diameter to act as the electromagnetic inductor.
The coil was energized using a direct current (DC) power supply, with the following electrical parameters:

- Current (I) = 2.5 A
- Voltage (V) = 16 V
- Duration = 2 hours

After the 2-hours electromagnetic exposure, the treated water sample was analyzed using a conductivity meter to assess the changes in water quality The results of this experiment are summarized below:

Before	After

Figure 33 Test C (Before/After) treatment

Table 9 Variation of Physicochemical Parameters Before and After Electromagnetic Treatment (Test C)

I=2.5 A V=16V N=152 T=2H	Before treatment	After treatment directly	After treatment with while
TSB	760mg/l	780mg/l	720mg/l
Salinity	1.6g	1.5g	1.5g
condictivity	3.20ms/cm	3.24ms/cm	2.99ms/cm

This table presents the measurements of Total Solid Bodies (TSB), salinity, and electrical conductivity of well water treated under a magnetic field generated by a copper coil (N = 152 turns) powered with direct current (I = 2.5 A, V = 16 V) for 2 hours. The data include values recorded before treatment, immediately after treatment, and 72 hours later, to observe any delayed effects of the electromagnetic field on water properties

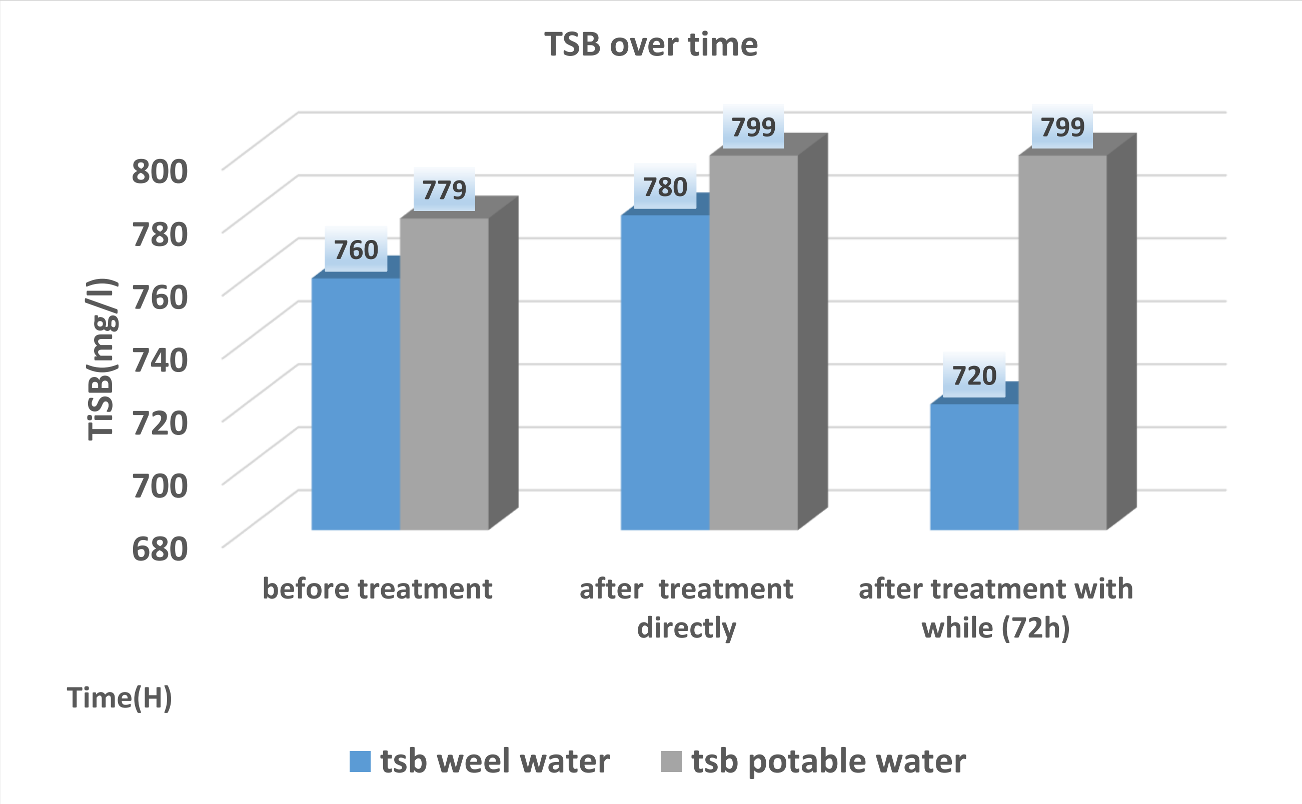


Figure 34 TSB results (test C)

A noticeable change was observed in the Total Solid Bodies (TSB) value throughout the experiment. Initially, the TSB measured approximately 760 mg/L, a value close to that of potable water. After the electromagnetic treatment, the TSB increased to 780 mg/L. This rise may be attributed to the applied field causing particle aggregation, mobilization, or temporary structural changes that made previously undetectable solids measurable. However, after 72 hours, the TSB value decreased to 720 mg/L, possibly indicating that the system had begun to stabilize, with some solids settling or reorganizing into less detectable forms.

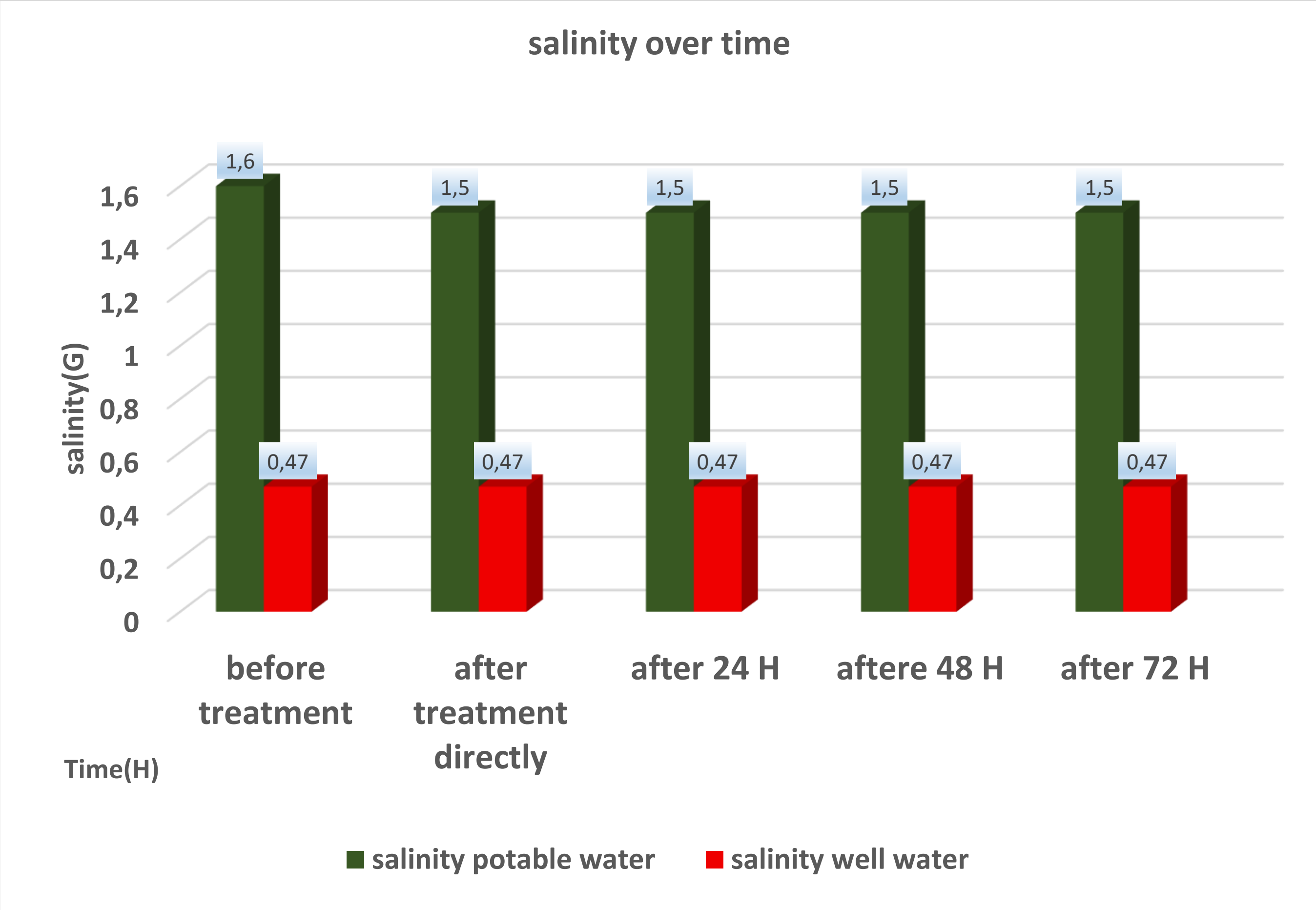


Figure 35 salinity results (test C)

It was observed that the salinity of the well water initially measured 1.6 g. Immediately after the application of the electromagnetic field, the value decreased to 1.5 g. After 72 hours, the salinity remained at this level. Although this represents a slight reduction, the salinity remains significantly higher compared to potable water standards. These results suggest that the electromagnetic field may induce a one-time effect on salinity, potentially by altering the solubility or distribution of dissolved salts during the treatment.

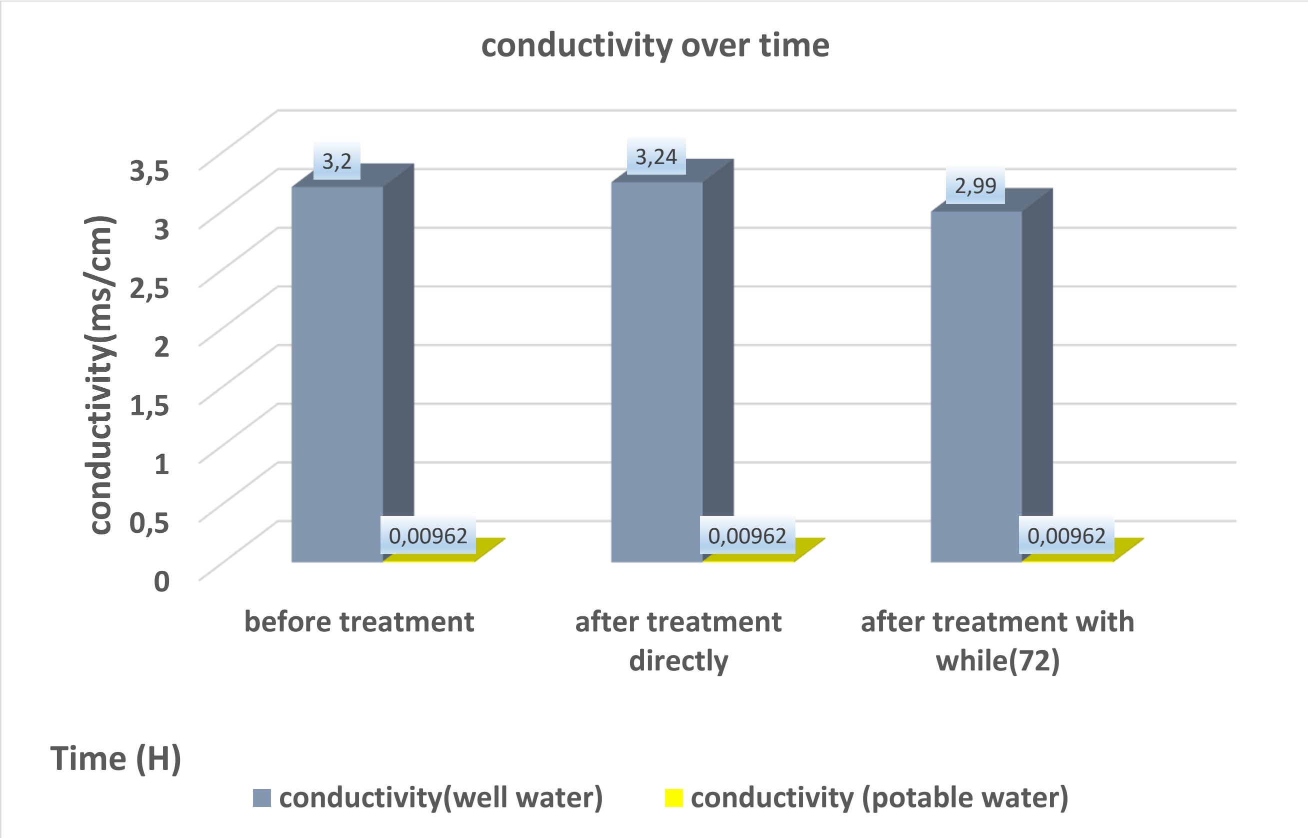


Figure 36 conductivity results (test C)

It was observed that the initial conductivity of the well water was 3.20 mS/cm. At the end of the electromagnetic treatment, this value increased slightly to 3.24 mS/cm, which may indicate a temporary enhancement in ion mobility as a result of the applied field. However, after 72 hours, the conductivity decreased to 2.99 mS/cm. This reduction could reflect a delayed reorganization or relaxation of the water's molecular structure toward a more stable state. Despite the decrease, the conductivity remains significantly higher than that of potable water, which is approximately 0.00962 mS/cm, indicating that the treated water still contains a high concentration of dissolved ions.

Table 10 Evolution of Salinity and Conductivity of Well Water After Electromagnetic Treatment (Test C)

I=2.5 A V=16V N=152 T=2H	Before treatment	After treatment directly	After 24 h	After 48h	After 72h
Salinity	1.6g	1.5g	1.5g	1.5g	1.5g
condictivity	3.20ms/cm	3.24ms/cm	3.14ms/cm	3.06ms/cm	2.99ms/cm

This table shows how salinity and conductivity of well water changed over 72 hours after a 2-hour electromagnetic treatment. Salinity slightly decreased and remained stable, while conductivity increased at first, then gradually decreased showing a delayed effect of the treatment on water structure.

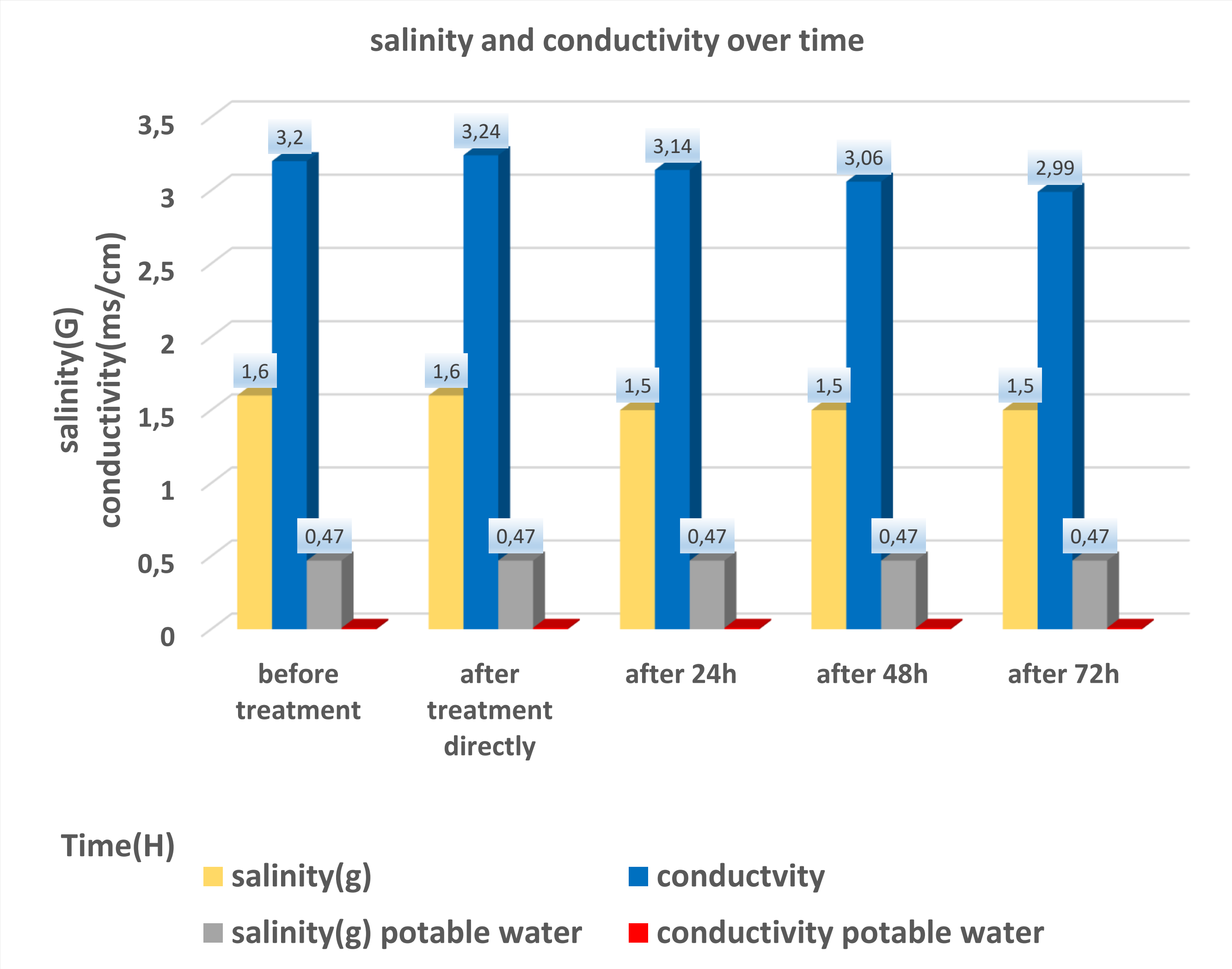


Figure 37 presents a comparison between the conductivity and salinity over time (test C)

This figure presents a comparison between the conductivity and salinity of well water. It is observed that both parameters vary over time following treatment, showing noticeable differences when compared to the standard values of drinking water.

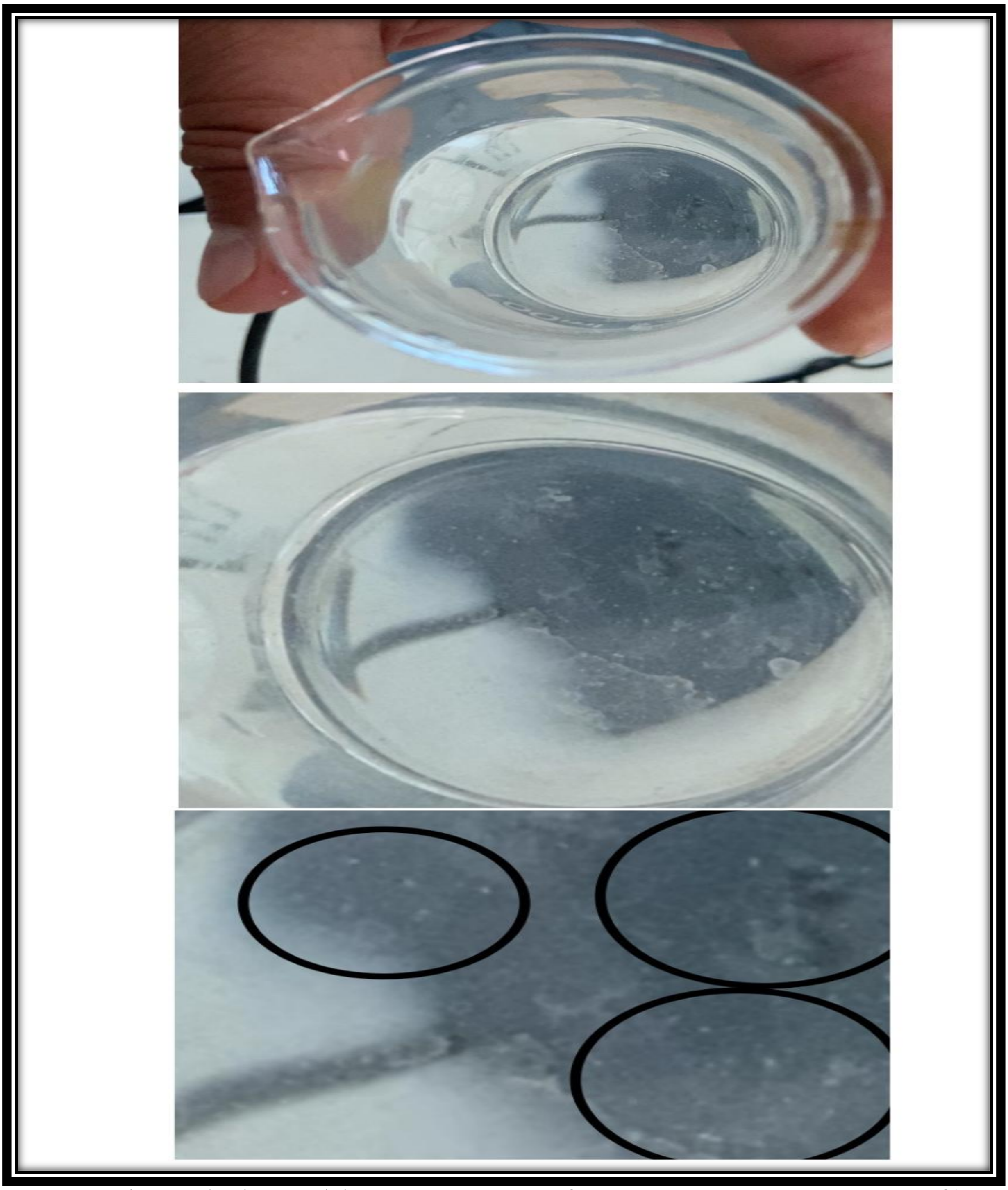


Figure 38 impurities that showen after the treatment ends (test C)

It was observed that both the conductivity and salinity of the well water changed over time when compared to the values typically found in potable water. Notably, for the first time in our project, visible impurities appeared immediately after the treatment process. The exact nature of these impurities remains undetermined due to the lack of advanced analytical equipment. Furthermore, it was discovered that magnetized water retains the influence of the magnetic field even after the experiment has concluded. For this reason, conductivity and salinity measurements were extended and recorded over a 72-hour period to assess the long-term effects.

4.6.4 Test D:

In this initial test, 40 mL of well water (sourced from a depth of 120 meters in Ouled Sidi Brahim) was introduced into a glass pipe. The pipe was externally wrapped with a copper coil of 152 turns (N = 152) and 0.5 mm wire diameter to act as the electromagnetic inductor.
The coil was energized using a direct current (DC) power supply, with the following electrical parameters:

- Current (I) = 3 A
- Voltage (V) = 18.1V
- Duration = 6 hours

After the 6-hours (we treated same water 3 times every treat with 2 hours)
The results of this experiment are summarized below:

Figure 39 Test D (Before/After) treatment

Table 11 Variation of Physicochemical Parameters Before and After

I=3A V=18.1v N=152 T=6H	Before treatment	After treatment directly	After treatment with while
TSB	760mg/l	817mg/l	915mg/l
Salinity	1.6g	1.5g	1.5g
condictivity	3.22ms/cm	3.24ms/cm	3.01ms/cm

Electromagnetic Treatment (Test D)

This table presents the measurements of Total Solid Bodies (TSB), salinity, and electrical conductivity of well water treated under a magnetic field generated by a copper coil (N = 152 turns) powered with direct current (I = 3 A, V = 18.1 V) for 6 hours. The data include values recorded before treatment, immediately after treatment, and 72 hours later, to observe any delayed effects of the electromagnetic field on water properties

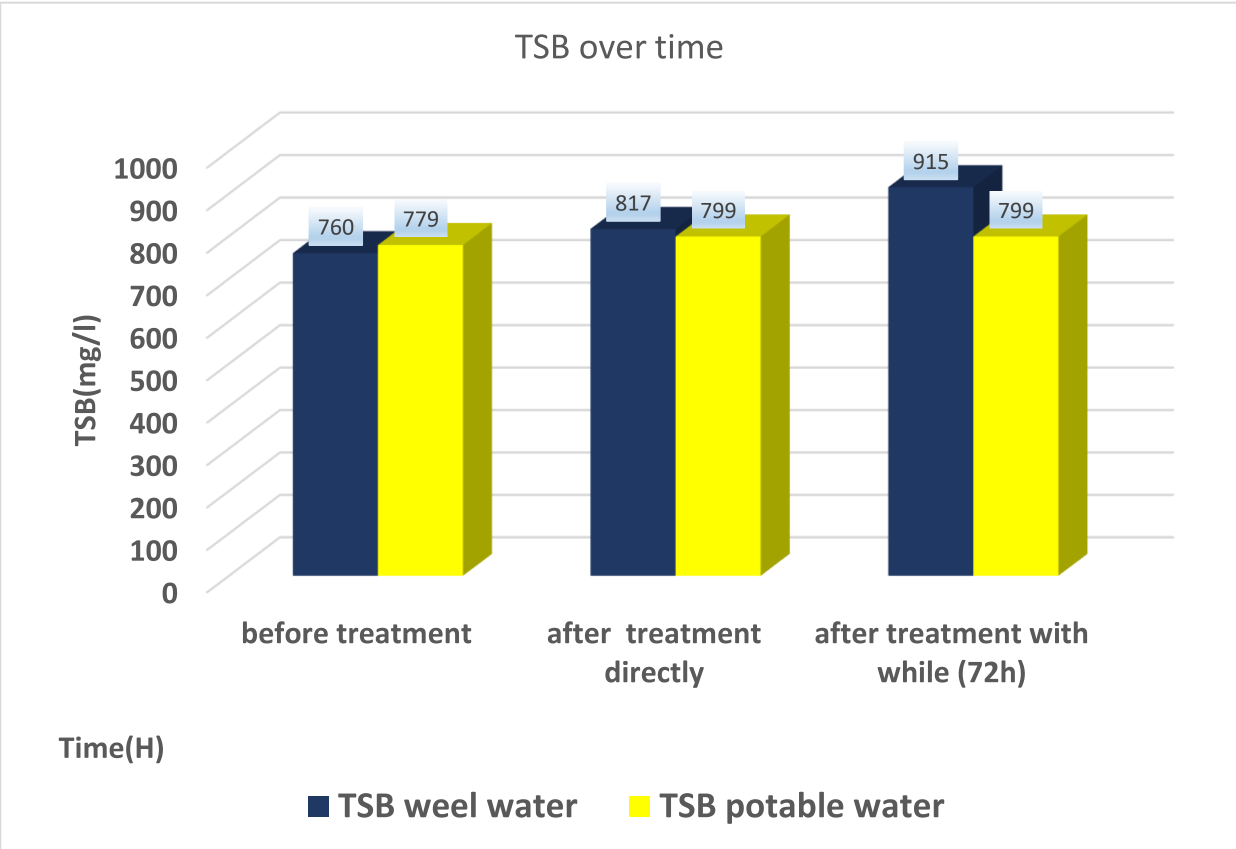


Figure 40 TSB results (test D)

As observed in the chart, there is a noticeable change in the Total Solid Bodies (TSB) value. Initially, the TSB was approximately 760 mg/L, which is relatively close to the value found in potable water. After the completion of the experiment, the TSB increased to 817 mg/L. Remarkably, after 72 hours, the value continued to rise, reaching 915 mg/L. This progressive and sustained increase suggests that the three consecutive 2-hour treatments induced cumulative effects on the water's composition. The continued rise in TSB even after 72 hours implies that the treatment not only had an immediate impact but may have triggered long-term structural or chemical changes in the water, indicating potential memory or delayed reorganization effects.

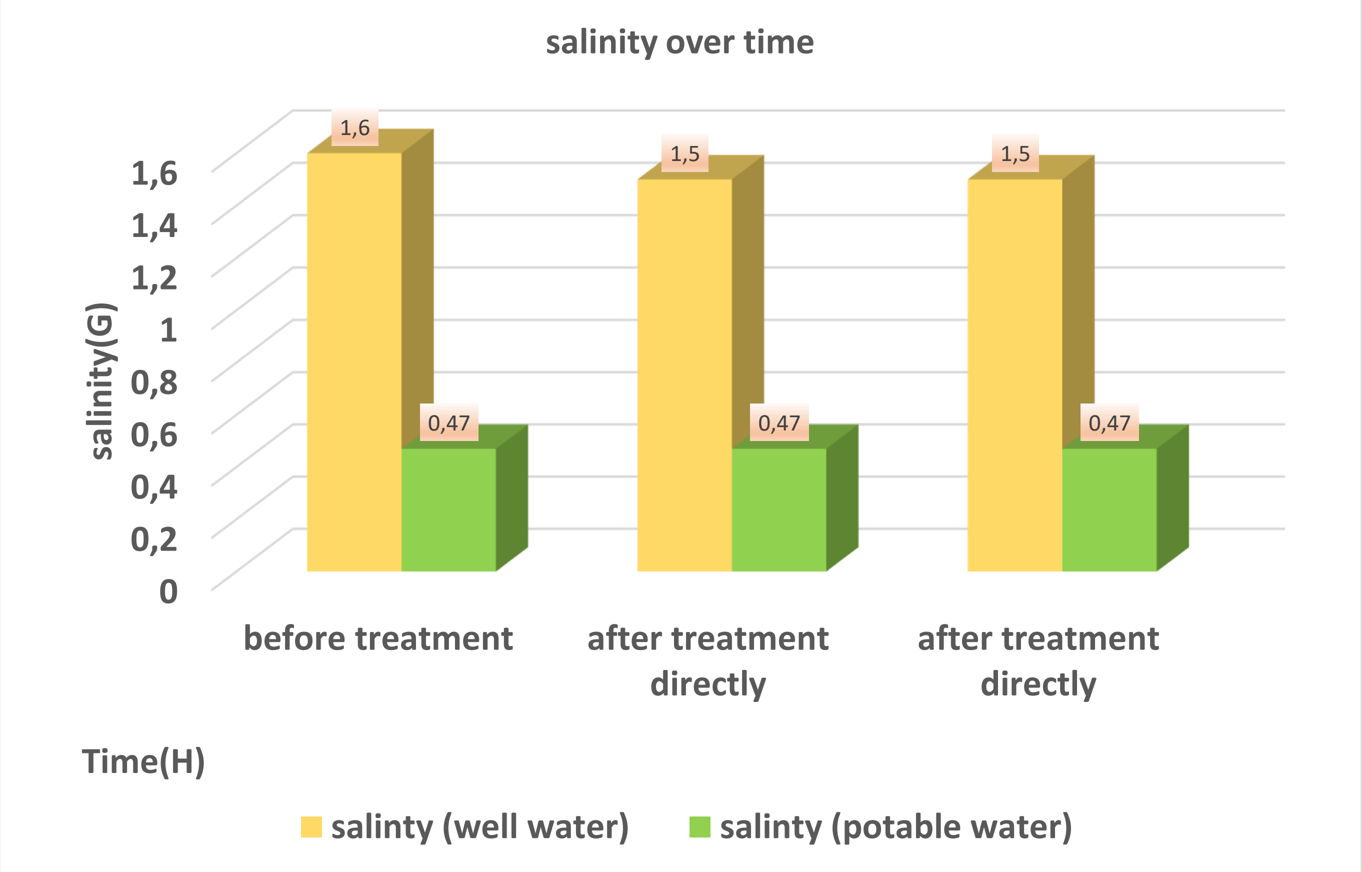


Figure 41 salinity results (test D)

It was observed that the salinity of the well water initially measured 1.6 g. Immediately after the application of the electromagnetic field, the value decreased to 1.5 g. After 72 hours, the salinity remained at this level. Although this represents a slight reduction, the salinity remains significantly higher compared to potable water standards. These results suggest that the electromagnetic field may induce a one-time effect on salinity, potentially by altering the solubility or distribution of dissolved salts during the treatment.

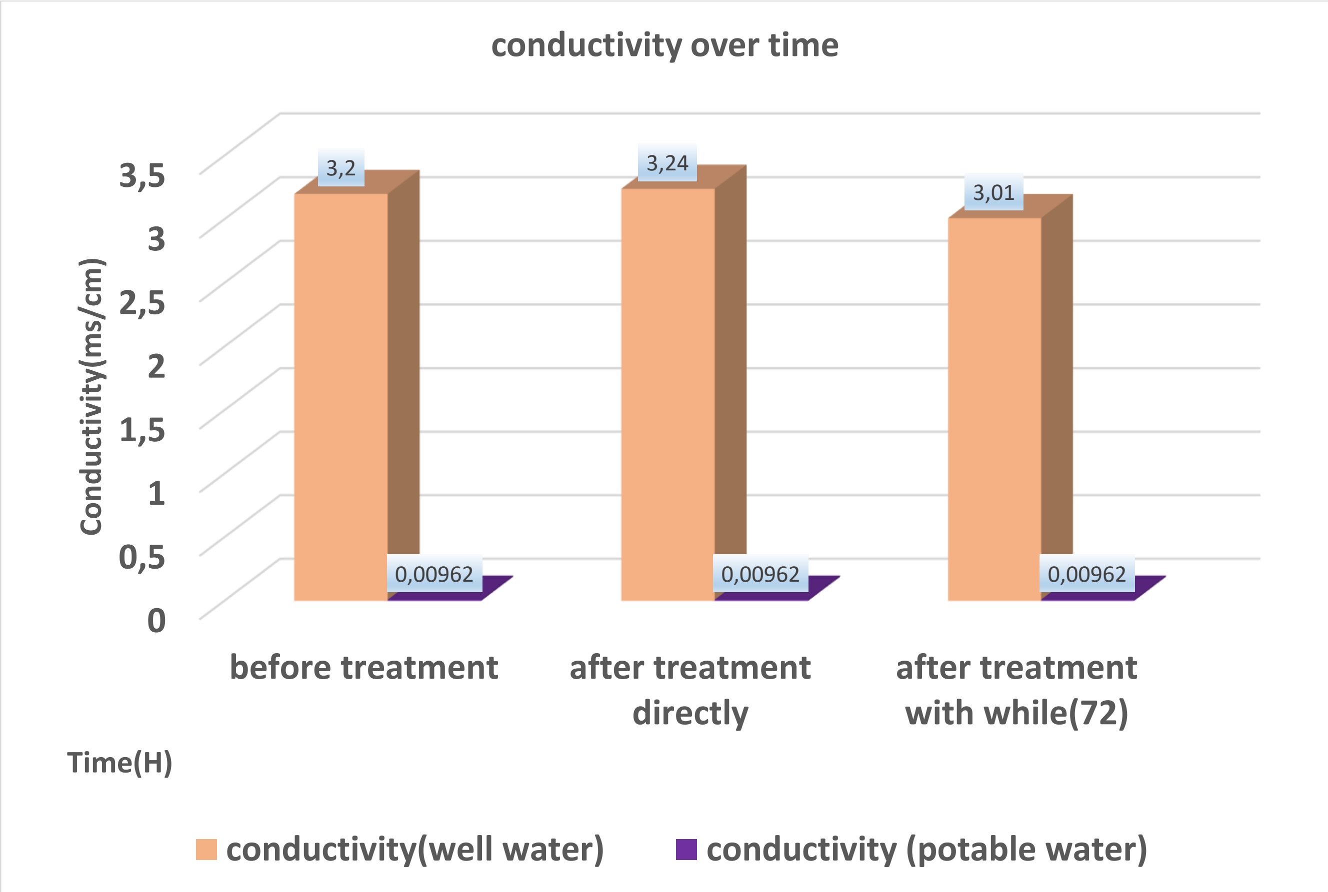


Figure 42 conductivity results (test D)

It was observed that the conductivity initially measured at 3.20 mS/cm increased slightly to 3.24 mS/cm immediately after the experiment. This increase may suggest a temporary enhancement in ion mobility due to the influence of the applied electromagnetic field. However, after 72 hours, the conductivity decreased to 2.99 mS/cm, which could indicate a delayed structural reorganization or relaxation of the water matrix toward a more stable configuration. Despite this reduction, the conductivity remains significantly higher than that of standard potable water, which is approximately 0.00962 mS/cm, highlighting the persistent impact of the treatment and the initial high impurity content.

Tableau 12 Evolution of Salinity and Conductivity of Well Water After Electromagnetic Treatment (Test D)

I=3A V=18.1 v N=152 T=6H	Before treatment	After treatment directly	After 24h	After 48h	After 72h
Salinity	1.6g	1.5g	1.5g	1.5g	1.5g
conductivity	3.22ms/cm	3.24ms/cm	3.16ms/cm	3.07ms/cm	3.01ms/cm

This table shows how salinity and conductivity of well water changed over 72 hours after a 6-hour electromagnetic treatment. Salinity slightly decreased and remained stable, while conductivity increased at first, then gradually decreased showing a delayed effect of the treatment on water structure.

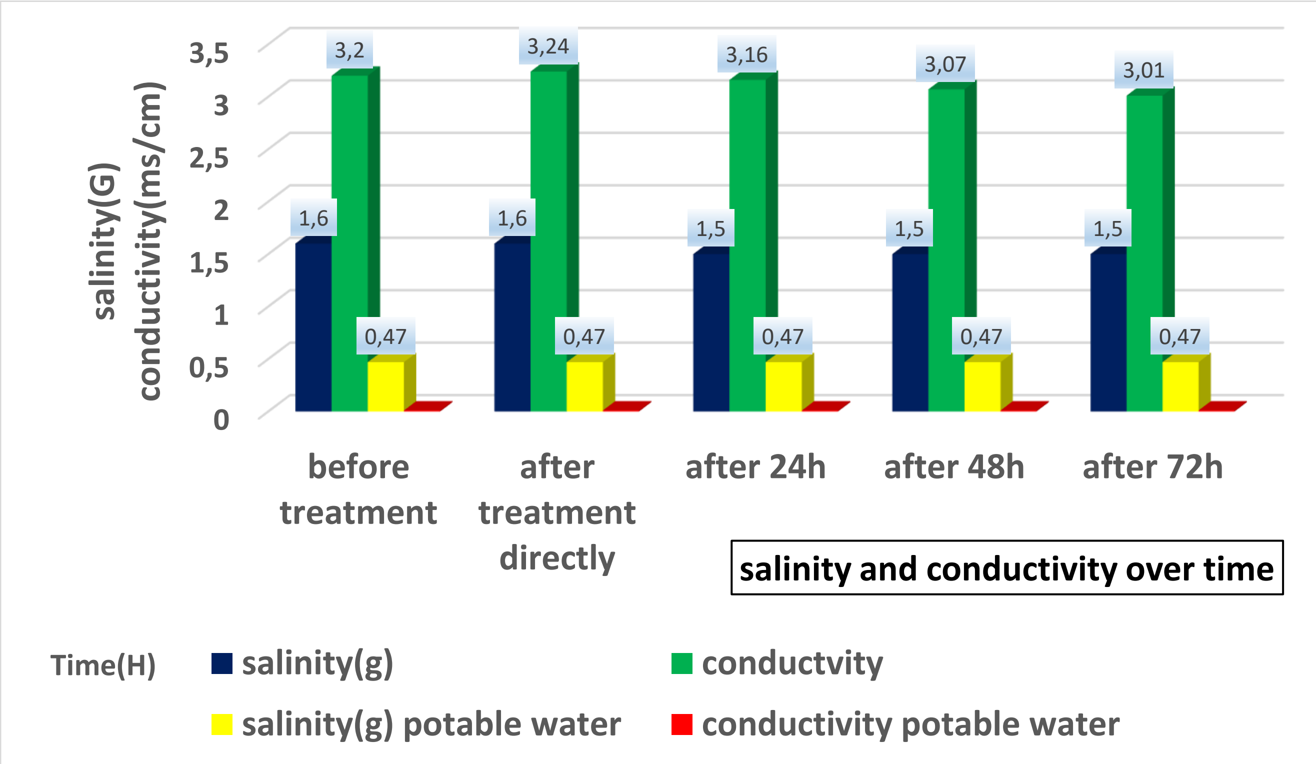


Figure 43 presents a comparison between the conductivity and salinity over time (test D)

This figure presents a comparison between the conductivity and salinity of well water. It is observed that both parameters vary over time following treatment, showing noticeable differences when compared to the standard values of drinking water.

Figure 45

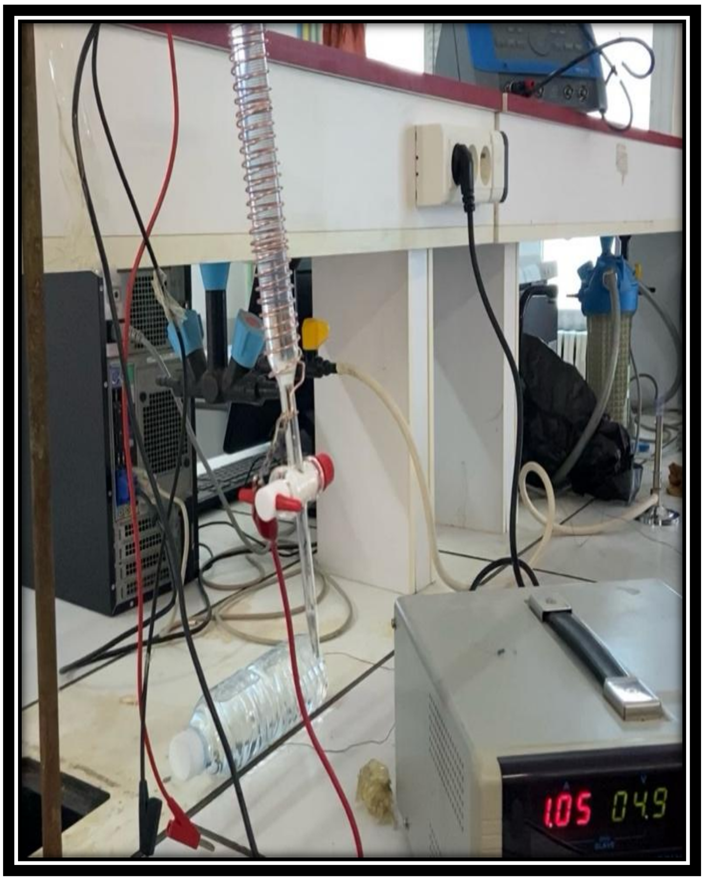


Figure 44

Before achieving conclusive results, we encountered several technical difficulties throughout the experimental process:

- Initially, we employed a frequency generator (Figure 44), but observed no noticeable effect on the water samples. Despite increasing the frequency to the maximum limit the device could handle, the output current intensity remained nearly zero.
- In response, we reduced the number of coil turns to accommodate the low current, yet this modification also yielded no measurable results.
- Subsequently, we attempted to use a DC generator with a thicker copper coil (Figure 45) to increase the current. However, we again found that the output current was negligible and no changes were recorded in water parameters.
- In another attempt to enhance current flow, we added resistors in series, which increased current intensity but lowered the voltage. Through further circuit modifications (branch configuration), we were finally able to generate a suitable current and voltage for effective testing.
- However, we faced another challenge: the standard resistors could not withstand the current, leading to equipment limitations. To solve this, we introduced power resistors, which provided stability and allowed us to carry out the experiments successfully.
- Due to time constraints, we were unable to test the AC generator, and therefore, all results presented are based solely on the application of DC electromagnetic fields

- Effective results were only observed when the system operated above 1.5 A and 12 V, below which no significant changes were detected.

After overcoming these challenges, we confirmed that electromagnetic fields can indeed have measurable and diverse effects on water properties:

- The field significantly influences electrical conductivity, total solid bodies (TSB), and even salinity, as demonstrated in the previous experiments and bar charts.
- One of the most remarkable findings was the persistence of magnetic influence: water did not revert to its original state immediately after the field was removed. Instead, the effects gradually diminished over a period of 72 hours or more.

This observation suggests the existence of a memory-like or delayed structural response in water when exposed to magnetic fields—an area that warrants further scientific investigation and opens new avenues for research in electromagnetic water treatment and molecular restructuring.

4.7 Conclusion

In conclusion, both the theoretical and experimental components of this work have demonstrated that the use of electromagnetic fields for water treatment represents a promising and innovative alternative to traditional methods, which often rely on chemicals or complex physical infrastructure. The analyses conducted on drikable water and well water samples revealed notable changes in several physicochemical parameters, such as electrical conductivity, salinity, and TSB, indicating a tangible effect of electromagnetic treatment.

The added value of this study lies in its proposal of a simple, low-cost, and chemical-free solution for improving water quality—particularly relevant in regions facing water scarcity or lacking advanced infrastructure.

Adding to the list that the obtained results do not show a major impact considering that the trated water is still not suitable for human use under such conditions but the results are under study ,this results offers a big hope for humanity in our bigest problem in the near future which is the global water crisis.

Moreover, the observation of lasting effects up to 72 hours after treatment opens the door to further research into the long-term and cumulative impacts of this technique.

Based on the findings, this approach can be considered a promising first step toward the development of non-conventional, sustainable water treatment technologies, with the potential for integration into existing systems following more in-depth studies on its effectiveness and safety.

4.8 General Conclusion

At the end of this work, we have explored the topic of water treatment through an approach that combines both theoretical and practical aspects, with the aim of investigating the potential use of electromagnetic fields as a non-conventional alternative to classical methods for improving water quality. In the first chapter, we introduced water as a vital resource, presenting its types, sources, and natural cycle, in order to establish a foundational understanding of its importance and characteristics. The second chapter focused on the issue of water pollution, outlining its main causes and examining the most widely used traditional treatment methods, along with their advantages and limitations. In the third chapter, we examined the influence of electromagnetic fields on water, by reviewing related scientific studies and explaining the underlying physical principles. Finally, in the fourth chapter, we conducted an experimental study in which sample of well water were exposed to an electromagnetic field, while monitoring changes in key physicochemical parameters such as conductivity, salinity, and TSB.

Through this study, we aimed to provide an initial perspective on the feasibility of this alternative treatment technique, while emphasizing the need for further research and experimentation in this promising field, particularly in light of the environmental and resource-related challenges facing the world today.

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