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Title :

**Eco-friendly purification of contaminated water using
recycled materials**

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الملخص:

يسعى هذا المشروع إلى معالجة مياه الرافض المالحة المستخرجة بعد تصفية المياه الجوفية في محطات التحلية باستخدام النفايات المعدنية ، وهو توجه يحمل تأثيراً إيجابياً كبيراً على الصعيدين البيئي ، والاقتصادي ، بالإضافة للصحة العامة . تهدف هذه الدراسة إلى تثمين النفايات الصناعية وتحسين جودة الموارد المائية من خلال حلول مبتكرة تساهم بشكل مباشر في تحقيق الاستدامة البيئية والحد من التلوث .

تركز الدراسة على استخدام عينات من النفايات المعدنية الناتجة عن عمليات التعدين ، حيث يتم دمجها مع المياه المستهدفة . وبعد إتمام عملية الخلط والترسيب ، تُنقل عينات المياه إلى المختبرات المختصة لإجراء التحاليل الفيزيوكيميائية الدقيقة للتأكد من مدى استجابة المياه للمعالجة بهذه المخلفات الصناعية .

كشفت نتائج هذه الدراسة أن لها دوراً محورياً في عملية التحلية ، إذ تُساهم في تحسين عدد من المعايير الفيزيوكيميائية .

الكلمات المفتاحية: مياه الرافض المالحة ، النفايات المعدنية ، الامتزاز ، تحاليل فيزيوكيميائية .

Abstract:

This project aims to treat Reject Water at desalination plants using metal waste, an approach that has a significant positive impact on the environment, the economy, and public health. This study aims to recover industrial waste and improve water quality through innovative solutions that directly contribute to environmental sustainability and pollution reduction.

The study focuses on using samples of metal waste generated by mining operations, which are mixed with the target water . After mixing and sedimentation are complete, the water samples are sent to specialized laboratories for detailed physicochemical analysis to determine how the water responds to treatment with this industrial waste.

The results of this study revealed that these residues play a pivotal role in the desalination process, as they contribute to improving several of physicochemical parameters.

Keywords : Reject Water , Mineral waste, Adsorption, Physiochemical analyses

Résumé :

Ce projet vise à traiter les eaux de rejets des usines de dessalement à l'aide de déchets minéraux, une approche qui a un impact positif considérable sur les plans environnemental et économique, ainsi que sur la santé publique. Cette étude a pour objectif de valoriser les déchets industriels et d'améliorer la qualité des ressources en eau grâce à des solutions innovantes qui contribuent directement à la durabilité environnementale et à la réduction de la pollution.

L'étude se concentre sur l'utilisation d'échantillons de déchets métalliques issus des opérations minières, qui sont mélangés à l'eau à traiter. Une fois le processus de mélange et de sédimentation terminé, les échantillons d'eau sont acheminés vers des laboratoires spécialisés afin de procéder à des analyses physico-chimiques précises visant à vérifier la réponse de l'eau au traitement par ces déchets industriels.

Les résultats de cette étude révèlent que ces résidus jouent un rôle central dans le processus de dessalement, car ils contribuent à l'amélioration de plusieurs de paramètres physico-chimiques.

Mots clés : les eaux de rejets , Déchets Minéraux, Adsorption, Analyse physico-chimique.

DEDICATION

إهداء

الحمد لله الذي بنعمته تتم الصالحات، وبفضله وتوفيقه تذلل الصعوبات،
فله الحمد أولاً وآخراً على نعمه التي لا تُحصى، وعلى القوة التي منحني إياها لأُتمّ هذا
المسير.

ثم أهدي ثمرة هذا الجهد إلى كل الذين جعلوا من طريقي ممكناً؛ إلى عائلتي التي كانت لي
الوئد والملاذ، وإلى أصدقائي الذين تقاسمت معهم عناء السهر وحلاوة الحلم،
وإلى كل معلمٍ أضاء في عقلي فكرة، وكل عابرٍ منحني يوماً كلمة طيبة أو دعوة صادقة في
ظهر الغيب.

هذا العمل هو حصاد لكل يدٍ ربّنت على كتفي، ولكل قلبٍ آمن بي حين تعثرت، فإليكم
جميعاً، يا من كنتم جزءاً من الرحلة وشركاء في الوصول، أهدي هذا النجاح بكل حب
وامتنان.

Thanks, and Appreciation

شكر و تقدير

بسم الله الرحمن الرحيم

[يَرْفَعُ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ] { المجادلة: 11 }

الحمد لله رب العالمين، الذي أعاننا بفضلِهِ وتوفيقِهِ على إتمام هذا العمل العلمي، ونحمده سبحانه على ما مَنَّ به علينا من صبر ومثابرة لبلوغ ختام هذه الرحلة الدراسية.

ويطيب لي في هذا المقام أن أتقدم بخالص الشكر والامتنان إلى الوالدين الكريمين، تقديراً لدعمهما المستمر ومساندتهما التي كانت دافعاً أساسياً لمواصلة المسار العلمي وتحقيق هذا الإنجاز.

كما أتوجه ببالغ التقدير والامتنان إلى الاستاذة المشرفة الدكتورة "أمينة ثابت"، التي أشرفت على هذه المذكرة، فكانت لتوجيهاتها العلمية القيمة ونصائحها المنهجية الأثر الكبير في تقويم هذا العمل وإخراجه بصورته النهائية.

ويمتد الشكر إلى إدارة الكلية الموقرة لما وفرت من تسهيلات وظروف أكاديمية ملائمة، وإلى كافة الأساتذة الذين لم يخلوا علينا بعلمهم طوال سنوات الدراسة.

وفي الجانب التطبيقي، أتقدم بجزيل الشكر لرئيس مختبر (LBBCN) الدكتور "صلاح الدين لعويني" وكافة طاقم المختبر نظير إشرافه وتوجيهاته القيمة، كما يمتد الشكر والتقدير إلى كافة موظفي مختبر "مؤسسة الجزائرية للمياه" لما قدموه من دعم تقني وتسهيلات مخبرية وإشراف دقيق على البروتوكولات التجريبية، شاكرين للجميع تعاونهم المهني وجهودهم المبذولة في تيسير مراحل البحث.

كما أتقدم بعبارات التقدير للسادة أعضاء لجنة المناقشة لتفضلهم بقبول تقييم هذه المذكرة، ومراجعتها، وتقديم الملاحظات العلمية التي تساهم في إثراء هذا البحث.

وفي الختام، أتوجه بالشكر والتقدير لكل من ساهم من قريب أو بعيد في تقديم الدعم أو المساعدة لإتمام هذا العمل، سائلين الله عز وجل أن يوفق الجميع لما يحبه ويرضاه.

وآخر دعوانا أن الحمد لله رب العالمين.

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List of abbreviations

EC	Electrical conductivity
TU	Turbidity
mm	Micro meter
EEE	Electrical and electronic equipment
ml	milliliter
PH	hydrogen potential
TDS	Total dissolved solids
TH	water hardness
mg	milligram
WEEE	Waste electrical and electronic equipment
Cond	Conductivity
EDTA	Ethylenediaminetetraacetic Acid
NTU	Nephelometric Turbidity Unit
RO	Reverse Osmosis
TAC	Total Alkalinity
Sal	Salinity

General Introduction

No one doubts that Water is the source of life; without it, there would be no agriculture, industry, or stability. However, many people live in areas where this blessing is rare and struggle every day to achieve sufficient stability. In arid and semi-arid areas, disturbances increase every year. Population growth, city expansion, and farmland expansion occur while water resources remain limited; indeed, some water resources are steadily declining owing to severe degradation and increasing pollution.

El-Oued does not have the luxury of rivers and lakes. It relies almost entirely on groundwater stored in aquifers for hundreds of years. This water is pumped, treated, and then delivered to homes and farms. However, this water no longer comes out naturally. The geological authority in the vicinity issues special chemical permits, which require measures to ensure that the water is safe. Conventional treatment is costly, consumes a lot of energy, and occasionally leaves behind environmental impacts that cannot go unnoticed.

This is where the real story begins. Instead of relying on high-priced imported chemicals to treat water, we turned our attention to what changed people right what we, until recently, considered useless “waste.” Phosphate industry waste, once considered an environmental burden, houses this discovery, which opened the door to rethink how we deal with waste on the one hand and, alternatively, to upgrade the water to first class.

Our images in this take a look stem from a simple belief that a great solution is one that solves two problems at once. Use of phosphate waste routes:

- Safely dispose of industrial waste that was previously a burden on the environment.
- Providing a low-cost, locally sourced treatment material instead of relying on imports.
- To improve the quality of water used by the citizens of the surrounding area.

Water is polluted, and metal waste is piling up. Instead of tackling each problem separately, we decided to solve both at once.

We take the metal waste and use it to purify water of dangerous pollutants such as heavy metals.

Chapter I: Water Resources

1. Introduction

The greatest freshwater reserve on Earth is found in groundwater, which is a "hidden treasure" underneath you. It is found in the cracks and fissures of rock, sand, and clay in geological formations known as aquifers .

It is the world's most important source of water for drinking and irrigation, supports ecosystems as an essential component of the water cycle, and feeds all rivers during droughts. However, because it is so invisible, it is far too frequently vulnerable to pollution and overexploitation, making its sustainable management vital for the future.

2. Water Resources of the World

2.1. Definition of Water Resources:

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial, household, recreational, and environmental activities. Virtually all of these human uses require fresh water.

97% of the water on Earth is saltwater. However, only three percent is freshwater; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air.

Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. Water demand already exceeds supply in many parts of the world, where mitigation, and as the world population continues to rise, so too does water demand. Awareness of the global importance of preserving water for ecosystem services has only recently emerged, as during the 20th century more than half the world's wetlands were lost, along with their valuable environmental services for Water Education. The framework for allocating water resources to water users is known as water rights. [1]

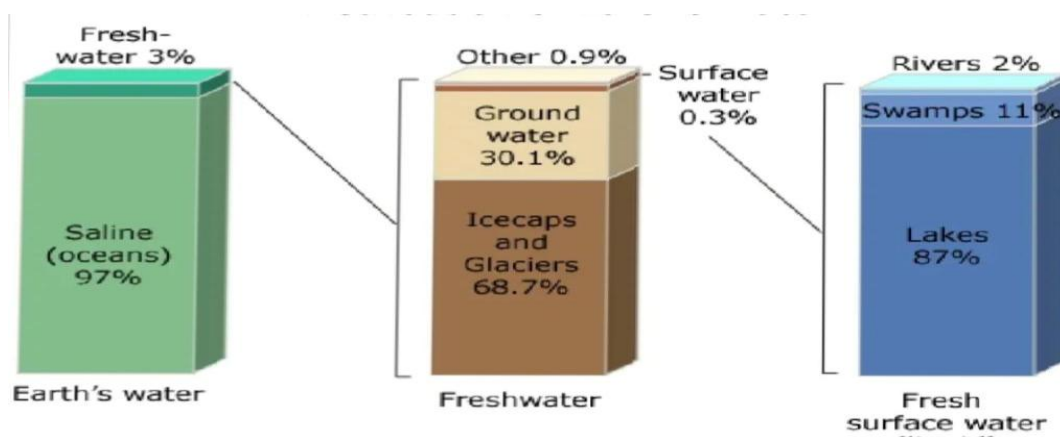


Figure 1: Distribution of Earth's water

2.2. Global Distribution water:

The large amount of freshwater contained in ice caps, glaciers, and deep in the ground is not accessible for use. Freshwater that can be used stems essentially from rainfall over land, generated through the hydrological cycle. Water is continuously recycled because of evaporation driven by solar energy. In this way, the hydrological cycle consumes more energy per day than that used by humankind over its entire history. [2]

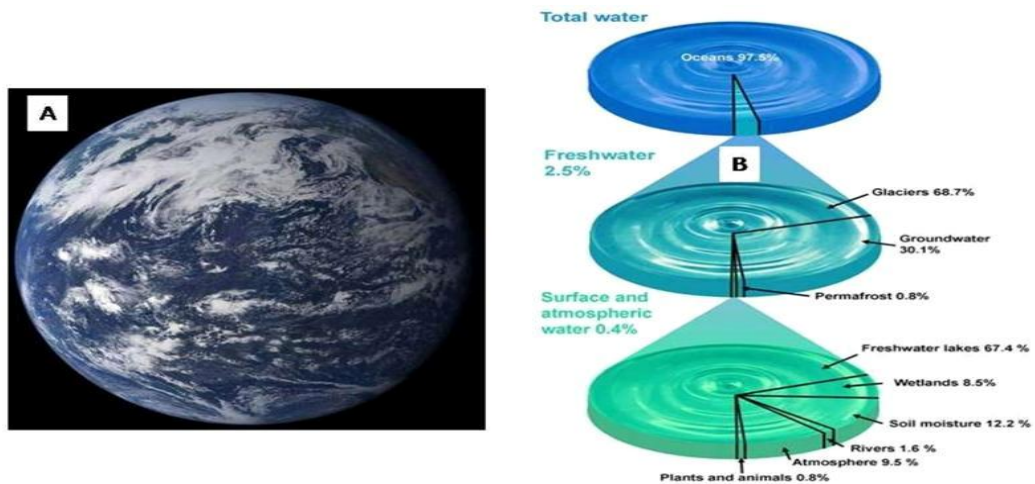


Figure 2: Distribution Earth's water: saltwater and freshwater

3. Types of water

3.1. Surface Water:

Surface water constitutes >70% of the earth formed by oceans, lakes and rivers. Rivers and other water streams carry different contaminants such as heavy metals, chemicals, organic and inorganic generated by urban/rural areas and industries into the bays and estuaries, ultimately reaching the ocean (Kennish, 1994, Simcock et al., 2016). Synthetic material, predominantly plastic bags, nets, and bottles carried away by the storm, pollute the ocean. Oil spills and leaks are also significant contributors to ocean pollution. [3]



Figure 3: Beni Haroun Dam, Mila Province, Algeria

3.2. Groundwater:

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rock called aquifers.

Aquifers are typically composed of gravel, sand, sandstone, or fractured rock, such as limestone. Water can move through these materials because they have large, connected spaces that make them permeable. The speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well those spaces are connected. [4]

3.3. Seawater:

Seawater, water that makes up the oceans and seas, covering more than 70 percent of Earth's surface. Seawater is a complex mixture of 96.5 percent water, 2.5 percent salts, and smaller amounts of other substances, including dissolved inorganic and organic materials, particulates, and a few atmospheric gases .

Seawater constitutes a rich source of various commercially important chemical elements. Much of the world's magnesium is recovered from seawater, as are large quantities of bromine. In certain parts of the world, sodium chloride (table salt) is still obtained by evaporating seawater. In addition, seawater, when desalted, can provide a limitless supply of drinking water. Many large desalination plants have been built in arid coastal areas in the Middle East and elsewhere to alleviate freshwater shortages. [5]



Figure 4:mediterranean sea

3.4. Industrial Water:

Industrial wastewater is often used synonymously with industrial water, but this is not entirely correct. Industrial water is the generic term for water used in industrial production and processing. This includes, for example, water for cleaning surfaces, for preparing rinses, acid treatments, or active baths, and much more. Industrial water, once it has served its purpose in production, becomes polluted industrial wastewater.

The composition of industrial water is not regulated; it depends on the requirements of the respective production and can be deionized water (fully demineralized/distilled water) or, for example, completely normal municipal tap water. The composition of typical industrial wastewater types cannot be generalized either. The composition of industrial wastewater varies as much as the industries' production processes. [6]



Figure 5: Wastewater treatment and purification plant - Filfila Municipality - Skikda Province .

4. Groundwater

4.1. Underground Reservoirs:

Underground reservoirs are remarkable geological formations that serve a vital role in storing natural resources, particularly natural gas and water. These reservoirs have unique properties that allow them to effectively contain and manage various fluids. This article explores the structure, types, and applications of underground reservoirs, highlighting their significance in energy storage, water management, and environmental sustainability. [7]

4.1.1. Types of Underground Reservoirs:

Underground reservoirs can be broadly categorized into two types: volumetric reservoirs and water drive reservoirs.

✓ Volumetric Reservoirs:

Volumetric reservoirs are completely sealed by impermeable rock on all sides, functioning like pressure vessels. Their size and shape remain constant due to the geological characteristics that define them.

✓ Water Drive Reservoirs:

Water drive reservoirs, on the other hand, are sealed on the top and sides by impermeable rock but are underlain by water. These can be visualized as inverted buckets submerged in water. When gas is introduced, the water is displaced, causing the gas bubble to expand. This displacement occurs through two mechanisms:

- Gas Injection: In a sealed reservoir of constant volume, injecting gas increases pressure and compresses the water, requiring a substantial volume of water for a significant increase in the gas bubble.
- Water Displacement: The gas can push water out of the storage reservoir to another location. [8]

4.2. Characteristics of Groundwater:

The qualities of groundwater and surface water differ significantly. When compared together, groundwater is known to have the following qualities:

Groundwater has higher salinity : As groundwater flows farther and more slowly, it has longer contact with the rocks and soil so that the soluble minerals can be dissolved more easily. Thus, groundwater contains more salt than surface water.

Groundwater has higher density : With higher salinity, groundwater has higher density as a result.

Groundwater has smaller temperature differences: it exists and flows in the soil and beneath rocks and is less affected by changes in temperature, so the temperature difference throughout the year is also small. Thus, groundwater is cool in summer and warm in winter.

Groundwater is less susceptible to pollution. However, once polluted, it is more difficult to recover. [8]

4.3. Importance of Groundwater:

4.3.1. Groundwater and Humanity:

Very few individuals know that the water they consume actually originates underground. Groundwater supplies drinking water to about half of the global population, and almost half of all agricultural water sources are extracted from the ground. In addition, there are more than 2.5 billion people who have no other option than to extract groundwater.

Considering the growing number of people, which will increase from 8 billion at present to 11 billion in the next hundred years, there will definitely be an increasing demand for water and food production every single day. Thus, the efficient utilization of groundwater is absolutely critical; however, groundwater could be one of the solutions provided that it is managed efficiently and replenished effectively. [9]

4.3.2. Groundwater and the Earth:

While rivers and lakes are often considered to be the main source of water in the world, there is more to the story. Water stored under the ground constitutes 99% of the fresh water in the world and provides water for rivers and lakes as necessary. When there is too much water, it is absorbed by the groundwater.

However, this is not all that water underground does. It dictates which plant lives in certain regions. Plants that require little water live in higher altitudes far away from the water table. However, plants that need moisture live around the river and stream beds. For millennia, water underground has sculpted the land from the inside out, slowly eating away at limestone and creating caves and cavities within the earth. Where there is little life in deserts due to a drought, groundwater reaches the surface of the earth, creating oases of life in the middle of the desert. Groundwater is not just a water reserve, it is the hidden foundation upon which life exists. [10]

4.4. Risks associated with its exploitation:

The following points describe the dangers that come from using the resource. The overuse of groundwater resources leads to multiple environmental problems that result in aquifer depletion and water table decline and land subsidence and decreased water supply

to natural habitats. The process results in water quality degradation through saltwater intrusion and contamination while it creates financial challenges because of higher extraction expenses and well drying.

4.4.1. Key Environmental and Physical Risks:

Pumping groundwater faster than nature can replenish it comes at a terrible price. Groundwater reserves are shrinking, aquifers are shrinking, and what took thousands of years disappears in a few decades. As water is drawn from the bottom, the soil and rock above begin to compress and sink. This slow fall can blow up houses, damage roads and weaken foundations an affliction that hits cities especially hard.

Wells that groups have depended on for generations begin to dry up, nearby rivers, lakes and wetlands lose groundwater as even without this steady flow to feed them, aquatic ecosystems collapse and plant life and animals lose their habitat.

Within the coastal areas, the situation takes a visible turn. When large quantities of fresh water are removed, salt water is available to fill the void, polluting the aquifer and making its water undrinkable.

4.4.2. Water Quality and Health Risks:

A drop in the groundwater table doesn't just mean a lack of water; it also measures water exchange. When the water table falls, pollution from commercial agricultural feeds to harmful minerals such as arsenic and fluoride is clearly produced in the rocks and spewed. The biggest problem is that this contaminated water reaches humans without their knowledge. Its use often leads to long-term loss of fitness, which can also lead to most cancers.

4.4.3. Socioeconomic Risks:

Higher Economic Costs: Deeper drilling required by dropping water tables increases energy consumption and extraction costs.

Water Insecurity & Inequality: Scarcity threatens agricultural productivity and rural livelihoods, often leaving smaller farmers with less water than wealthier ones. [5]

5. Groundwater in El-Oued

The El Oued region in Algeria is one of the most important areas containing the largest national reserve of groundwater, on which it depends entirely for agriculture and date palm production. The region faces two challenges: the decline in the water table (its depth) due to excessive pumping for agriculture, versus the phenomenon of rising water (surface water) which threatens urban development. [11]

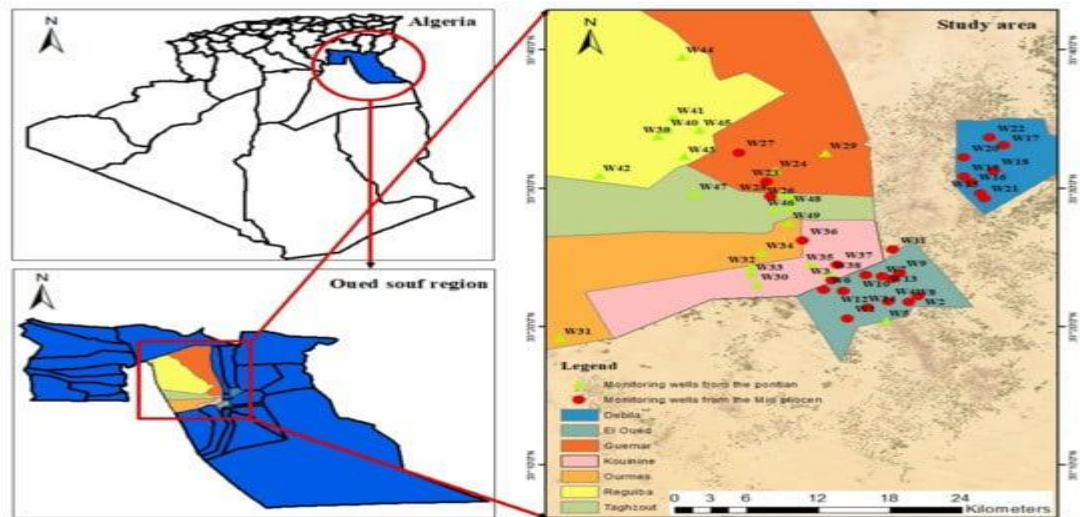


Figure 6: hydrogeological map of El oued region

5.1. Sources of Groundwater:

the sources of groundwater in Oued/El Oued:

Regional Aquifers: Phreatic Aquifer (Oued Souf): A shallow, unconfined aquifer highly utilized for agriculture, particularly in traditional "Ghout" cultivation, though prone to contamination from agricultural runoff.

Terminal Complex (CT): A major, confined aquifer system consisting of Miocene and Pliocene formations (sands, gravels, limestone) located at depths between 275 and 450 meters. It is heavily used but often exhibits high salinity and hardness.

Intercalary Complex (CI): A deeper aquifer used as a primary water source.

Recharge Sources: Due to the arid climate, these aquifers are fed by limited rainfall, which infiltrates the ground. Additional sources include lateral flow and, to a lesser extent, infiltration from ephemeral wadi runoffs.

Water Quality and Characteristics: The water, particularly from the Terminal Complex in regions like Oued Righ, is often highly mineralized, with a significant amount of dissolution of evaporitic and carbonate minerals.

Usage: Groundwater accounts for the vast majority of water use in the region for irrigation (potatoes, dates, vegetables) and drinking water .

The intensive, often excessive, pumping of these aquifers has led to management challenges, including water table fluctuations and quality degradation, necessitating monitoring of both the shallow and deeper layers. [12]

5.2. General Characteristics of Groundwater:

Composition: The geological nature of the soil determines the chemical composition of the groundwater. Water is constantly in contact with the ground, where it can stagnate or circulate, allowing equilibrium to develop between the soil's composition and the water's. For example, water that circulates in a sandy or granitic substratum is acidic and contains few minerals. Water that circulates through limestone contains bicarbonate ions and is alkaline. The following table compares the characteristics of surface water and groundwater based on the major analysis parameters.

Table 1: Comparison of Surface Water and Ground Water

Characteristic	Surface Water	Ground Water
Temperature	varies with season	relatively constant
Turbidity, SS	Level variable, sometimes high	Low or nil (except in karst soil)
Color	Due mainly to SS (clays, algae) except in very soft or acidic waters (humic acids)	Due above all to dissolved solids
Mineral content	Varies with soil, rainfall, effluents, etc.	Largely constant, generally appreciably higher than in surface water from the same area
Divalent Fe and Mn in solution	Usually none, except at the bottom of lakes and ponds in the process of eutrophication	Usually present
Aggressive CO₂	Usually none	Often present
Dissolved O₂	Often near saturation level, absent in very polluted water	Usually none
H₂S	Usually none	Often present
NH₄	Found only in polluted water	Often found
Nitrates	Level generally low	Level sometimes high
Silica	Usually moderate proportions	Level often high
Mineral and organic micro-pollutants	Can be present but liable to disappear rapidly once the source is removed	Usually none but any accidental pollution lasts a very long time
Living organisms	Bacteria, viruses, plankton	Iron bacteria frequently found
Chlorinated solvents	Rarely present	Often present
Eutrophic nature	Often. Increased by high temperatures	None

Some of the most typical characteristics of groundwater are weak turbidity, a constant temperature and chemical composition and almost overall absence of oxygen. Circulating groundwater can have extreme variation in the composition with the appearance of pollutants and various contaminants. Furthermore, groundwater is often very pure microbiologically. [12]

6. Conclusion

Finally, groundwater is much more than a temporary natural resource; it is the mile "savings account" of man, which nature throws into the depths of the earth to cope with the uncertainties of time. Our losing battle against water scarcity is being fought on the river banks not handiest seen yet could be decided through how we protect this hidden vein. Maintaining the sustainability of our water bodies requires a fundamental shift from the underdevelopment of "moderate use" to "conscious management" in all of it. Science, coverage, and public recognition must eliminate the shields that protect this essential artery from degradation and decay. If the earth preserves this treasure for thousands of years, it is our moral duty to ensure that the silent cycle of existence remains intact beneath you and passes it on to the next generation of destiny, naturally and abundantly.

Chapter II: Water Pollution and Treatment Technologies

1. Water Pollution

1.1. Definition of Water Pollution:

Water pollution has been defined as any direct change in its physical, chemical or biological state that makes it unsuitable for consumption, whether in agriculture, industry or domestic use, according to the World Health Organization (1961). This is what Hopkins and Schulz (1954) stated, that polluted water is water whose quality decreases due to its mixing with sewage and various wastes that make it unfit for drinking or industrial and agricultural use. The concentration of pollutants in water also depends on the effect of its use for certain purposes, so it becomes fit for use. [13]

This was confirmed by Ulaniran (1995) by the presence of excessive amounts of hazards (pollutants) in the water that make it unsuitable for drinking, bathing, cooking or other uses. [14]

1.2. Sources of Pollution:

For the diversity of water pollutants, identify two sources that have point sources that are easy to identify and can be measured and controlled, such as wastewater. The second source is the non-point source, which is difficult to track due to the spread of its sites, and difficult to measure and control, such as urban and agricultural surface runoff. We mention the sources that cause pollution, including: [15]

1.2.1. Natural Sources and Runoff:

Rainwater is one of the natural sources of water pollution. Through it, pollutants and particles suspended in the air are dissolved in a phenomenon known as acid rain by dissolving acidic gases such as oxides of sulfur and nitrogen in rainwater. We also find that underground rocks and underwater volcanoes are a source of pollutants by transporting certain types of salts. Natural waste from leaves, branches and surrounding plants also helps enrich the water. [16]

1.2.2. Agricultural Activities:

With the increase in the global need for food, agriculture is witnessing a significant expansion, as it is known for its large consumption of groundwater and surface water resources. This resulted in excessive use of nitrogen and phosphate fertilizers and pesticides to support and increase crop productivity. The latter seeps in large quantities into the soil and pollutes groundwater, which poses a

threat to agricultural workers and affects crops and potable water. The environmental effects of pollution have extended to damage to food processing and aquaculture industries, an example of which is the phenomenon of eutrophication. [17]

1.2.3. Domestic Sewage:

Treated or untreated domestic and municipal wastewater's main problem is its transmission of intestinal diseases and organic pollution and its production of odors because it partly contains high concentrations of organic materials. When they behave in rivers, bacteria consume dissolved oxygen to break down organic matter, resulting in severe depletion of oxygen levels and the death of aquatic life. It also contains nutrients such as phosphates and nitrates, which often lead to the problem of eutrophication. Even after treatment, some of these problems are solved by discharging wastewater to treat lands and irrigate crops, but this results in severe health risks and land degradation if done without scientific considerations. [18]

1.2.4. Industrial Wastes:

Industrial activities dispose of wastewater in huge quantities that contain industrial waste that varies according to the nature of the activity from one industry to another, including toxic materials, heavy metals, and organic materials. Leaks through liquid waste find their way directly into water bodies and greatly affect the ecosystem. [19]

1.3. Types of Pollutants:

The multiplicity of complex elements in pollutants has led to their classification as follows: chemical, physical, and biological. This classification helps environmental engineers determine methods for treating each type: [20]

1.3.1. Chemical Pollutants:

Chemical pollutants constitute the most dangerous and prevalent category in the aquatic environment. They are further divided into two sub-categories based on their molecular structure:

- **Inorganic Pollutants:**

Heavy metals known for their chemical stability and slow decomposition, such as lead (Pb), mercury (Hg), and arsenic (As), their high levels in polluted water raise concern in the global community. Even their low levels accumulate in the food chain, causing toxic and chronic effects on living organisms. [21]

And agricultural fertilizers containing phosphates and nitrates, the use of very high levels to support agricultural production resulted in eutrophication of the medium. It is known that nitrates are a carcinogenic substance, which has led to an increase in the incidence of cancer. [22]

- **Organic Pollutants:**

Most organic pollutants share a carbon origin with other elements such as hydrogen, oxygen, and nitrogen, and they also have long bonds and are of living origin and are characterized by their resistance to photodegradation and biodegradation. Many of them are classified as carcinogens and mutagens. Most of these pollutants are products of industrial and petrochemical activities such as pesticides, fertilizers, hydrocarbons, phenols, plasticizers, biphenyls, detergents, oils and greases. [23]

1.3.2. Physical Pollutants:

Physical pollutants do not necessarily alter the chemical composition of water directly but rather affect its physical properties (color, taste, odor, temperature, and turbidity), negatively impacting aquatic life:

- **Suspended Solids:**

Impurities are pollutants that come from human activities such as wastewater, industry, or weathering of rocks and soil. We find organic materials from it, which are the result of the decomposition of plants and animals and are responsible for the brown color of water. There are also inorganic ones resulting from weathering of rocks such as clay, iron oxides, silica, etc. We have living organisms such as viruses, bacteria, and algae. The action of these impurities is to obstruct sunlight from reaching aquatic plants and inhibit photosynthesis. It results in reducing oxygen production by aquatic organisms. [24]

- **Thermal Pollution:**

With the increase in industrial processes and the emergence of power plants such as nuclear facilities. To produce huge amounts of heat, water resources were used for cooling. Pumping large amounts of hot water into bodies of water causes environmental disturbances that lead to an imbalance in the ecological balance by affecting aquatic life by reducing oxygen levels. As the planet's temperatures rise, the environmental situation worsens further. Studies suggest that thermal pollution affects humans indirectly. [25]

- **Radioactive Pollutants:**

Radioactive materials are available in nature through the decomposition of geological rock elements and soil formations or through human activities. They are relied upon to produce electricity from nuclear reactors or scientific research centers, as well as in medical applications. Unsafe disposal of these materials and their failure to contain them poses significant risks. Severe toxicity and prolonged persistence in aquatic environments affect human health and expose living organisms to major threats. [26]

1.3.3. **Biological Pollutants:**

Biological pollutants called pathogens. These pollutants consist of bacteria (salmonella) and viruses such as Hepatitis. We also have parasites and protozoa such as ameba. Most of it comes from one source, which is wastewater. [27]

2. **Groundwater Pollution**

The location of groundwater helps protect it from pollutants compared to surface water, as layers consisting of rocks and soil act as natural filters. But with the passage of time and the saturation of these layers with pollutants, groundwater becomes polluted, and here the site that was a means of protection becomes an obstacle to replacing it with fresh water and returning it to its original state. The place's lack of oxygen and sunlight helps pollutants survive for long periods, and as a result the water becomes unfit for agricultural or human use. [28]

2.1. Causes of Pollution:

Groundwater pollution has several sources. Excessive use of pesticides and fertilizers in agricultural activities makes the soil saturated with high concentrations of these chemicals that seep into the water layers over time [29]. Steady leaks from sewage points are the main carrier of pathogens such as bacteria and viruses, especially areas with fragile infrastructure and the unsafe disposal of industrial waste from solid and liquid waste, along with leaks from underground storage tanks of gas stations and factories that contain toxic heavy metals such as lead and nickel. Factors that directly contribute to ecosystem imbalance while threatening public health. [30]

2.2. Common Pollutants in Groundwater:

With the multiplicity of pollutants in groundwater, we notice the common presence of certain elements, including bacteria and viruses (pathogens). Heavy metals such as lead, arsenic, chromium and gasoline that come from industries. Finally, nitrates are more common in agricultural fertilizers. [27]

2.3. Effects of Pollution on Health and Environment:

Water pollution poses a threat to public health and destroys the ecosystem. On the environmental level, the leakage of waste and chemicals leads to soil poisoning and groundwater pollution. These pollutants also stimulate the growth of algae, which inhibits photosynthesis, which in turn reduces the percentage of dissolved oxygen, suffocates marine life, and disrupts the food chain. This is directly reflected in public health through the transmission of bacterial and viral diseases through contaminated water in food or potable water. Studies have shown that it is responsible for fatal diseases such as cholera, hepatitis, and some cancerous diseases. Water pollution is an increasing risk, especially in countries with fragile infrastructure and unsafe drainage systems. [31]

3. Water Treatment

Water treatment is defined as a sequence of physical, chemical, and biological processes aimed at improving water quality to make it suitable for a specific end-use (e.g., drinking, irrigation, or industrial application) or for safe discharge into the environment. [32]

3.1. Objectives of Water Treatment:

The goal of water treatment is to eliminate contaminants and reduce their concentrations to target levels (set by the World Health Organization or the US Environmental Protection Agency) or within local standards. The objectives can be summarized in the following factors:

- Public health safety: Removing pathogens (bacteria and viruses) is the overall goal to prevent the spread of waterborne diseases. [18]
- Removal of solids and turbidity: Removal of suspended solids and colloids that cause turbidity, that could harbor microbes and guard them from disinfection techniques.
- Removal of chemical pollution: lowering concentrations of poisonous materials consisting of heavy metals, nitrates and insecticides, in addition to removal of dissolved organic materials that purpose beside the point taste, scent and color.[32]
- Prevention of corrosion and scale: The purpose of the treatment is to adjust the pH and hardness of the water to protect pipe networks and industrial equipment against corrosion or scale, which is important in industrial applications. [33]

3.2. Principles of Treatment:

Water treatment engineering relies on integrating several "unit processes" and "unit processes" to achieve the desired quality. We classify these processes based on the removal mechanism:

- A. Physical principle:** It relies on physical forces to break down pollutants without changing their chemical form. The techniques include screening, sedimentation (using gravity to separate heavier solids) and filtration (passing water through a porous medium such as sand or membrane) .[18]
- B. Chemical Principle:** Involves chemicals to produce reactions that convert dissolved contaminants into insoluble, separable, or destructible substances. It relies on advanced technologies that include coagulation and flocculation (destabilizing colloids), oxidation and disinfection (using chlorine or ozone), and ion exchange and absorption (focusing on the removal of dissolved ions and trace contaminants).[32]

- C. Biological principle: It is mainly used in wastewater treatment, where microorganisms are used to decompose biodegradable organic matter into gases and biomass. [33]

4. Water Treatment Techniques

4.1. Physical Treatment:

In physical treatment, we use natural factors such as gravity and diffusion forces to separate pollutants without affecting their chemical composition. This stage is important for reducing the load on subsequent stages.

- **Sedimentation:**

Sedimentation is a critical step of water treatment, the primary goal is to scrape as many suspended solid particles from the water as possible. Efficiency is better when using a pre-coagulant method that combines high-quality particles to increase their weight until they end up in heavier groups.

The effectiveness of this method depends on several ingredients, mostly untreated water character and its turbidity, as well as meeting the coagulation stage by forming dense, fast-setting debris and ideally, more than 90% of suspended solids should be removed. It happens. Fast, larger installation and operation, higher sedimentation outcomes, producing cleaner water and reducing burden on subsequent remediation areas. [34]

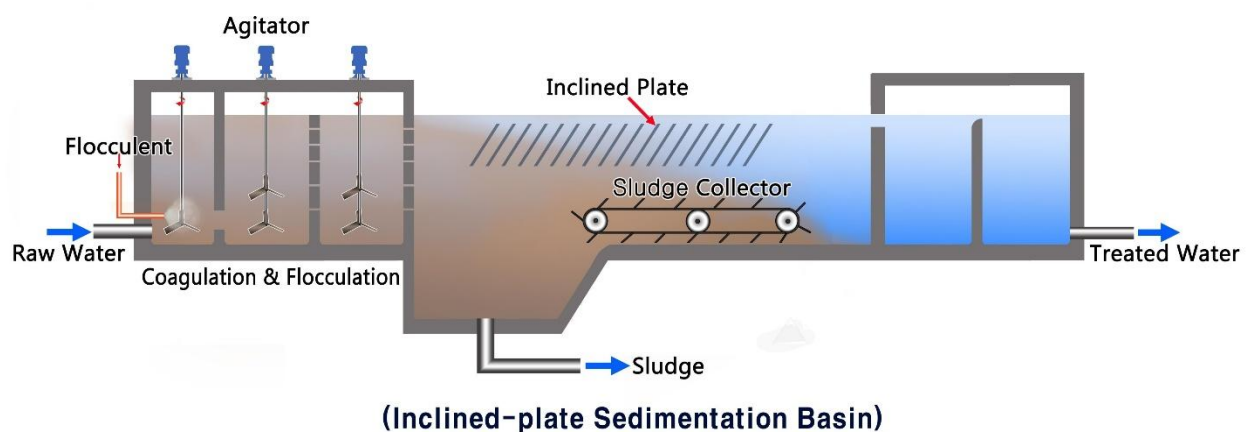


Figure 7: Sedimentation

- **Absorption:**

Absorption as the molecules or constituents of gasoline are dissolved in some other liquid and distributed easily, which distinguishes it from absorption, where contaminants accumulate most readily on the bottom of a solid without penetrating. In the water treatment plant life, these tips certainly become evident within the dissolution of air in water. Injection of ozone or chlorine into the water stream is the default in this system to disinfect any strong and remove natural contaminants. The same applies to aeration systems where oxygen is pumped into the water to stimulate vital chemical reactions. Three main factors govern the efficiency of this process: the proximity of the gas and liquid to the touch, the partial voltage of the fuel, and the temperature of the water and the more those factors are controlled, the better and extra effective the absorption results will be. [32]

4.2. Chemical treatment:

If the pollutants are completely dissolved or stable colloidal, chemical intervention is mandatory to remove these pollutants by adding special chemical materials.

- **Coagulation:**

The coagulation process is a preliminary and crucial chemical step in the processing process, and is used to deal with colloidal particles and fine suspended materials that resist natural sedimentation processes due to their kinetic stability and electrical repulsion. This technique relies on injecting specific chemical reagents (coagulants), often aluminum or iron salts, to neutralize the negative surface charges that prevent these colloidal particles from assembling. Once these charges are neutralized and what is known as "destabilization" (Destabilization) occurs, dynamic conditions are created for the particles to gradually collide and clump to form larger, denser "flocs" (Flocs). This physical transformation radically increases the efficiency of removing these pollutants during subsequent physical separation stages, such as sedimentation and filtration. [32]

- **Ion Exchange:**

Ion exchange is a unique chemical technique based on the transformation principle, in which harmful ions dissolved in water change through different innocent ions that play the same charge as they pass through special stable materials known as resins. Nitrates and fluorides are The performance of this equipment is determined

by the adsorption capacity of the target ions through the resin and its general adsorption capacity, so that it is indeed a complete desire to achieve too high a purity level that meets the strictest environmental standards. [34]

4.3. Biological treatment:

We use living organisms to break down and analyze organic pollutants, which is an environmentally friendly and sustainable method inspired by natural purification cycles

- **Phytoremediation:**

At its core, plant prevention is a simple idea: using plant life to clean contaminated water. The “wetlands” system contains the following tips; These are engineered wetlands designed to mimic the natural wetland environment. Its kinetic mechanism is primarily based on the symbiotic relationship between plant roots and penetrating microorganisms that form together to disturb and obviously degrade pollutants and dissolved natural counts without the need for chemical agents within the water. [35]

- **Activated Sludge Process:**

This technology is more effective and responsive in removing contaminants than alternative methods. However, controlling their operating variables is complex, as the success of the process is linked to the characteristics of the water flow to be treated. Operational challenges increase particularly when the water contains high concentrations of nitrogen and phosphorus, or when sharp fluctuations in daily flow rates occur. [36]

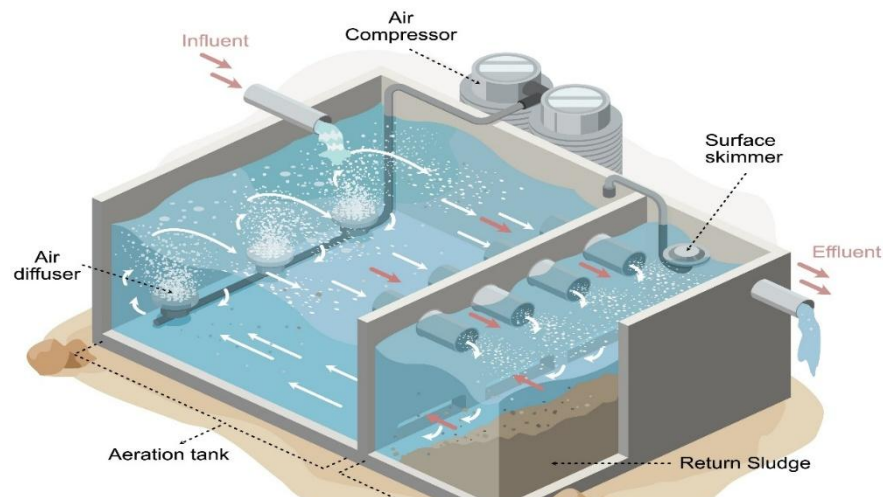


Figure 8: Aeration Basins

5. Groundwater Treatment

The water resources sector faces increasing challenges in restoring the quality of contaminated groundwater, especially as heavy metals and complex chemical compounds penetrate into deeper layers (Aquifers) and settle there for long periods of time. Purifying these sensitive resources requires careful engineering intervention that goes beyond traditional approaches that have proven technically and economically deficient in dealing with dissolved pollutants at low concentrations. In this context, adsorption technology emerges as a highly efficient strategic solution to accurately capture these impurities. To maximize the economic and environmental feasibility of this system, modern engineering research is moving toward replacing expensive commercial adsorbents with sustainable alternatives extracted from industrial and mineral waste. This dual approach achieves two parallel goals: purifying groundwater with high efficiency and at the lowest operational costs, and creating a safe outlet for valorizing solid waste such as phosphate accumulations within the framework of the circular economy. [37]

5.1. Specificity of Groundwater Treatment:

Groundwater is not always actually groundwater stored underground it is a whole different mile in nature and offers unique challenges. In a long adventure from rock and soil, spanning longer periods or centuries, vast amounts of salt and minerals dissolve into it and on the contrary it appears virtually free of suspended particles and microorganisms, because the clay acts as a powerful herbal cleanser. However, the enclosed underground environment lacks oxygen, creating special chemical conditions that cause substances containing iron, manganese and certain heavy metals to dissolve in the water. the slow movement of the groundwater, if industrial or mineral pollutants enter it, they are trapped in the aquifer for a very long time. All these characteristics make the treatment of groundwater a large specific number of calculations. Conventional techniques including sedimentation and coagulation designed to remove suspended impurities are inadequate here. The answer lies in superior technologies that target dissolved pollutants at once, including chemical oxidation, ion trafficking, and efficient adsorption. [29]

5.2. Limitations of Traditional Techniques:

Traditional water treatment technologies have been a big hit with groundwater, yet they quickly fall apart compared to groundwater, especially when contaminated with heavy metals or stubbornly dissolved chemicals .

Chemical precipitation is the primary method followed by engineers to separate heavy metals, yet it leaves behind vast amounts of toxic sludge Disposal of this sludge is no easy task, as it requires a complex additional measure and a stable, isolated garage. Furthermore, this method often fails to reduce metal concentrations to ideal levels, as required through stringent conditioning and environmental criteria Membrane filtration and reversible non-precipitation technologies are very powerful in trapping contaminants, but they face significant monetary constraints. They consume huge amounts of electricity and require lavish maintenance. Even worse, membranes continue to clog through groundwater salts and dissolved metals, reducing efficiency and shortening lifetime All of these limitations lead researchers and engineers to seek smarter options solutions that combine superior performance to stop dissolved contaminants with low-level occupational, non-harmful secondary They produce.[38]

5.3. Low-cost Treatment Techniques:

Faced with monetary and technical limitations imposed by traditional process technologies, researchers and engineers are all turning to more realistic cost-effective solutions This is where the term “cost-effective” no longer refers to just cost. Any fabric that is so abundantly natural or requires minimal guidance before use falls into this category.

In this context, the concept of circular economy has emerged as a clever, -fold answer. Instead of disposing of agricultural, commercial and mining wastes for exorbitant fees, they could be reused as potent materials for groundwater purification Thus, waste, which is an environmental burden, immediately becomes a promising financial alternative to replace expensive industrial products, including carbon emissions and major exports. unique physicochemical houses, with porous shapes and energetic sites on their surfaces, which give them very good abilities to remove dissolved pollutants and heavy metals from groundwater This further opened the door for adsorption manufacturing to grow to be a leading option in this field. [39]

5.4. Adsorption Treatment:

Adsorption is basically a delivery method where water-soluble contaminants flow to adhere to the surface of a porous strong fabric. This attachment is not accidental; Rather, it occurs in response to an imbalance within the bottom force of the solid film molecules, which encourages them to attract their surroundings, which will address their equilibrium. Adsorption occurs in two different ways: either through sensible, reversible physical forces with non-hazardous van der Waals forces, or through genuine chemical reactions that produce strong bonds that are hard to disrupt. Each system in groundwater treatment usually forms together captures heavy metals and complex organic compounds. As water flows over the absorbent, the machine gradually reaches an equilibrium state where the value of contaminant adsorption is equal to the value of desorption To describe this equilibrium mathematically and determine the maximum absorptivity of the fabric, engineers especially use freundlich Isotherm, mostly the model. [40]

5.5. Use of Natural and Recycled Materials:

Researchers and environmental engineers are turning to herbal materials and industrial waste as effective alternatives to drying equipment. These main materials include clays, herbal zeolites, and mining trade wastes, which derive their effectiveness from their complex chemical compositions, where dissolved pollutants are organic sites with high binding potential, especially with heavy metals. This waste, long a major environmental burden, was determined to have unique surface and mineral habitats activated phosphate and microporosity that allow water to interact strongly with contaminants It acts to stabilize heavy metals through more than one mechanism: surface adsorption, which ensures concentration and integration into groundwater range What makes this process accurate is that it immediately accomplishes two desires: treats contaminated groundwater at minimum viable cost, and reprocesses solid waste from environmental disturbance in a complex treatment plant It turns into a pathway. [41]

6. Phosphate Mining Waste as an Adsorbent

In addition to environmental issues, there is a greater interest in preserving natural resources. As such, the idea of reusing mining waste has become an area of considerable focus over the last two decades. In this regard, among many different industrial waste streams, phosphate mining waste is particularly significant. This is due to the large amount of phosphate that is currently mined globally and the large quantity of reject material

generated during each stage of the ore processing chain. Rather than simply being industrial by-product, these wastes are characterized by a number of physio-chemical properties that make them potential candidates for using as functional materials in a variety of engineering applications including, most specifically, adsorption-based processes used to clean-up the environment. [42]

6.1. Definition of mineral waste:

Mineral waste is what is left over after metals or precious metals have been extracted from ore. When the ore is processed to separate gold, silver, copper, or various metals, the material still has no direct economic value; That's called mineral waste. It is important to distinguish between those residues and what is known as “barren rock”, which refers to layers of rock and clay that are removed to access underground ore. This rock is not always resource rich in general and generally not in extractable quantities. Mineral wastes, however, vary in size, from solid clay-like substances to useless mineral-specific particles. Some are more dangerous than a number of these wastes can be highly toxic or even radioactive, making careful monitoring and management important to limit environmental damage. [43]

6.2. Geology of Djebel Onk:

The Jebel Onk phosphate deposits are located in the northern part of the Algerian Sahara, in the mountainous Némémcha region, in the eastern part of the country, approximately 20 km from the Algerian-Tunisian international border. The deposit is also within the Wilaya of Tebessa and is approximately 100 km from the provincial capital. Bir el Ater is the nearest town to the Jebel Onk phosphate deposits, and is connected to it by a highway. Phosphate from the Jebel Onk phosphate deposit is transported via a special rail line to the export port in Annaba (approx. 340 km from the deposit). Jebel el Onk is a limestone plateau or massif, about 20 km long, whose highest point (at the top of the massif) is the peak of Jebel Tarfaya, where the height reaches 1198 meters. The height varies up to approximately 635 meters at the base of the massif. The deposits are characterized by Thanetian structure, the base of which is characterized by the presence of significant phosphate layers, although strongly indurated. These are followed upwards by black marls and then by the main phosphatic formation, which extends to a thickness of about one hundred meters and consists of nine recognizable layers without any barren

intervals. The corridor is clayey in the lower part and becomes dolomitic towards the upper levels.

The ore body at Jebel Onk is of layered sedimentary character, and the mass has the form of an asymmetric anticline oriented in a north-northeast direction. The northern edge shows a slope angle of less than 15° , while the southern edge drops steeply and forms an almost vertical cliff in some places. The structure is affected by many faults and lateral displacements miner. [44]

6.3. Phosphate Ore Processing Methods:

The Djebel Onk processing plant is located in close proximity to the active quarries, approximately 2.5 km from the Kef Essenoun site and less than 1000 m from Djemi-Djema, a configuration that minimizes haulage costs and simplifies raw ore feeding logistics. The overall processing chain is designed to upgrade run-of-mine phosphate to commercial-grade product, and generates waste streams at each of its three main stages.

6.3.1. Mechanical Preparation:

The processing chain begins with the machining stage, whose number one purpose is to break the raw ore into small pieces and liberate the precious metal from the waste rock surrounding the phosphate ore.

The raw cloth comes out of the mine as lumps of size up to 1, two hundred mm and is crushed in series by two parallel lines the first using BABITLESS rotary cone crusher, and the second using HAZEMAG effect crusher, each with 1,000 tonnes hourly capacity. This is followed by the use of joint hammer generators through a secondary crushing stage, which similarly reduce the size to 20 mm. The shredded fabric then passes through vibratory screens that separate oversized debris, where screened fabric (15 mm) acts as a feed for dry and wet process pieces. The screened fabric returning from the screening channel, accounting for 8–10% of the produced principle levels.

6.3.2. Wet Processing:

The wet processing section treats approximately half of the screened material, with the goal of raising the tricalcium phosphate content to between 62 and 64%, while removing coarse inert particles and fine clay. The average mass yield is about 73%, meaning that 27% of the input material is rejected as waste.

significant proportion that translates, on an industrial scale, to approximately 530,000 tons of wet waste annually.

In this section, the material passes through three consecutive stages. It begins with mixing the ore with water to form a liquid slurry, then enters the clay removal stage, which includes curved screens with 1-mm openings, hydrocyclones, and a final screen with 0.5-mm openings. The effluent from the hydrocyclones a fine slurry containing clay, dolomite, and low-grade phosphate is directed to thickeners, from which it emerges as a sludge known as “Boi de Depurage”.

This sludge is characterized by the fineness of its particles, with approximately 34% of them smaller than 0.080 mm; it contains about 22.5% P_2O_5 , approximately 3.4% MgO, and about 36.5% $CaCO_3$. After drying, the de-sliming residues and coarse particles larger than 1 mm are stacked separately, awaiting reuse or long-term storage.

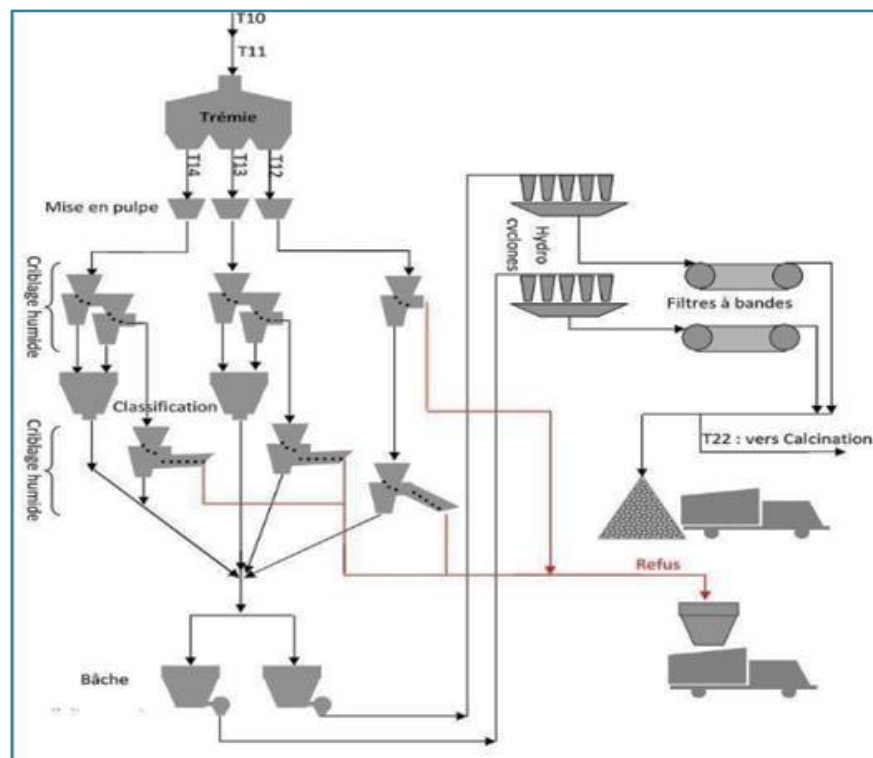


Figure 9:De-sludging technology diagram.

6.3.3. Dry Treatment:

The dust removal process is a fundamental step in the physical and mechanical processing of phosphate ore, as it aims to improve its quality to achieve a concentration ranging between 26.75% and 29% of phosphorus pentoxide P_2O_5 , and reducing the magnesium oxide MgO content to 12.6%. The

operational objective is to convert the raw ore (with a concentration of 54-56% DWT) into a high-quality commercial product (with a concentration of 62.5-63.5% DWT), with a particle size ranging from 90 to 800 microns.

The process involves five key stages to ensure the purification and classification of the ore:

- 1) **Fluidized-bed drying:** This stage involves drawing very fine particles through fluidizing gases. The process takes place inside two furnaces equipped with two systems (combustion and dilution) to ensure optimal drying and the separation of fine impurities.
- 2) **2 mm screening:** Screens with 2 mm openings are used to isolate and remove coarse materials (such as limestone). Particles smaller than 2 mm proceed to the grinding stage with a separation efficiency of up to 88%.
- 3) **Attrition milling:** “DRAGAN” mills equipped with rotating hammers and grinding chambers are used to liberate the outer phosphate particles, facilitating the final enrichment process via particle separation.
- 4) **Turbo-ventilated selection:** This stage relies on large fans to remove fine particles (less than 90 microns), thereby increasing the concentration of the final product.
- 5) **0.8 mm screening:** This operates on the same principle as the first screens, but focuses on isolating and removing phosphate granules larger than 0.8 mm to ensure the homogeneity of the final product.[44]

7. The Water Purification Plant 19 March in Oued Souf

The water treatment plant became fully operational on March 19, 2019, with a production capacity of 30,000 cubic meters per day, distributed through an integrated network of water towers, ensuring a regular and efficient supply of drinking water to all neighborhoods in the city. The Algerian company Chiali was responsible for the plant's design and operation, overseeing the entire operational process for two years following the handover phase to ensure optimal performance and strict adherence to approved technical standards and specifications. The plant features an integrated system of specialized facilities, including a laboratory for water analysis and quality testing, a comprehensive administrative unit, and a control room equipped with state of the art technology, as well as a multi-stage treatment system, enabling the achievement of the highest required levels of quality and purity.

The plant's optimal design achieved through the careful selection of filters, the adjustment of operating parameters, and the engineering of the desalination system has also contributed to significant economic savings, as the cost of producing one cubic meter of desalinated water has dropped from \$1 to \$0.59, a reduction of over 40%, reflecting a high level of economic and operational efficiency. The plant draws its raw water supply at a flow rate of 23,477 cubic meters per hour from three main wells: the March 19 Well, the Martyrs Well, and the Takart Road Well, to ensure a sustainable and continuous supply that meets production requirements in accordance with established plans and the city's actual needs.[45]



Figure 10: Photo of the entrance to the El-Oued desalination station.

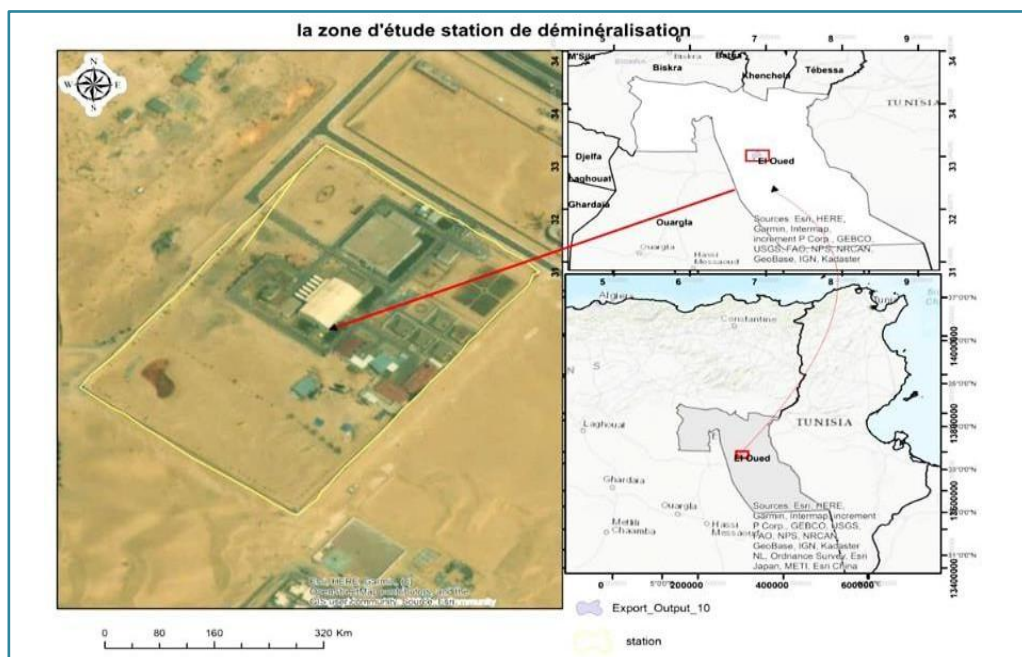


Figure 11: Satellite image the location of the station.

7.1. The treatment process :

The image shows the main elements of the water treatment chain.

- Inert water tank.
- Water tank osmosis.
- Supply and measurement of sodium hypochlorite.
- Sand filter feed pumps.
- Purified water tank.
- High pressure feed pump.
- Low pressure feed pump.
- Dechlorination of filtered water.
- Filtration Equipment.
- Reverse osmosis unit.
- Improving water quality through disinfection.
- Water preparation for sand filtration.

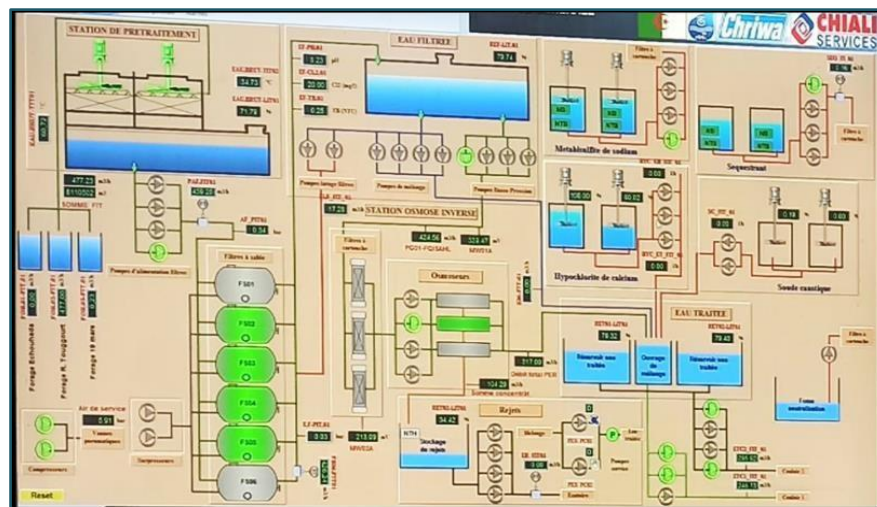


Figure 12: General diagram of reverse osmosis water purification.

7.2. Technical characteristics of the plant and produced water:

- Production capacity of 30,000 cubic metres per day.
- Storage capacity from 5,000 to 10,000 cubic metres.
- Reverse osmosis is a technique used to reverse the phenomenon of osmosis.
- By applying a modification, salts are transferred from the more concentrated medium to the less concentrated medium.
- The water pressure is higher than with reverse osmosis.
- The three hot water wells projected in Alpine are 60°C wells.

- The temperature of the produced water is less than 25°C.
- pH : 7.5-8.5
- Salinity : TDS : 300 mg/L, less than 600 mg/L. [45]

7.3. Physicochemical parameters required for analyses:

7.3.1. Physical parameters:

- Temperature:** The measure of water's thermal energy (°C). It directly affects chemical solubility, reaction rates, and determines whether an adsorption process is exothermic or endothermic.
- pH :** Measures how acidic or simple (alkaline) water is on a scale of zero to fourteen. pH is an important parameter in water treatment adsorption strategies because it dictates the chemical state of dissolved pollutants and the sediment velocity of the adsorbent fabric .
- Electrical Conductivity (EC):** The ability of water to conduct electricity, usually measured in $\mu\text{S}/\text{cm}$. It serves as a quick, biased indicator of the total concentration of dissolved ions (mineral salts) in a water sample.
- Total hardness (TH):** A degree of precise mineral content in water, often pressured by attention to calcium and magnesium ions High hardness indicates "hard water", which can result in scaling in commercial equipment and piping.
- Turbidity:** How much clear a liquid is. It represents cloudiness or the turbidity of the water as a result of a large number of isolated invisible debris (suspended solids). It is a leading indicator of filtration efficiency.
- Total Dissolved Solids (TDS):** The combined mass of all dissolved natural and inorganic substances (minerals, salts, and metals) in a given volume of water, usually measured in mg/L It is closely related to electrical conductivity.
- Salt (SAL):** The specific amount of all dissolved salts in water. Once TDS debt is all dissolved (which includes natural recall), the salinity is strictly about the salinity, which is a major factor in the favorable comparison of the groundwater.

7.3.2. chemical parameters:

a) Calcium (Ca^{2+}) Magnesium (Mg^{2+}) Ions :

The primary causes of water hardness, they form deposits in pipes and equipment and compete with heavy metals for exploitation sites, thus hindering treatment systems .

b) Bicarbonate Ions (HCO_3^-) :

A primary concern with water alkalinity, they act as herbal pH regulators and affect the efficiency of adsorbents and dissolution of metals.

c) Chloride Ions (Cl^-):

They increase water salinity and electrical conductivity and may be indicative of agricultural or sewage infections. They are not removed by normal drying but require osmosis in reverse.

d) Iron Ions (Fe^{2+}):

Not an uncommon mineral in groundwater, it dissolves invisibly in deeper layers yet oxidizes on exposure to air, forming rust scum, which increases its turbidity and its removal is the primary objective of water treatment.[46]

Chapter III: Results Analysis and Discussion

1. Reject Water

When treating treated water by Reverse Osmosis (RO), the process produces two distinct streams: clean, purified water and a highly concentrated leftover liquid commonly known as brine or reject water. This reject water contains all the salts, minerals, and impurities that were blocked by the RO membrane. As a result, its salinity and Total Dissolved Solids (TDS) are significantly higher than the original water source.

We take the sample on April 16, 2026 from the water desalination facility located in 19 march El-Oued for study and make the purposes of analysis.

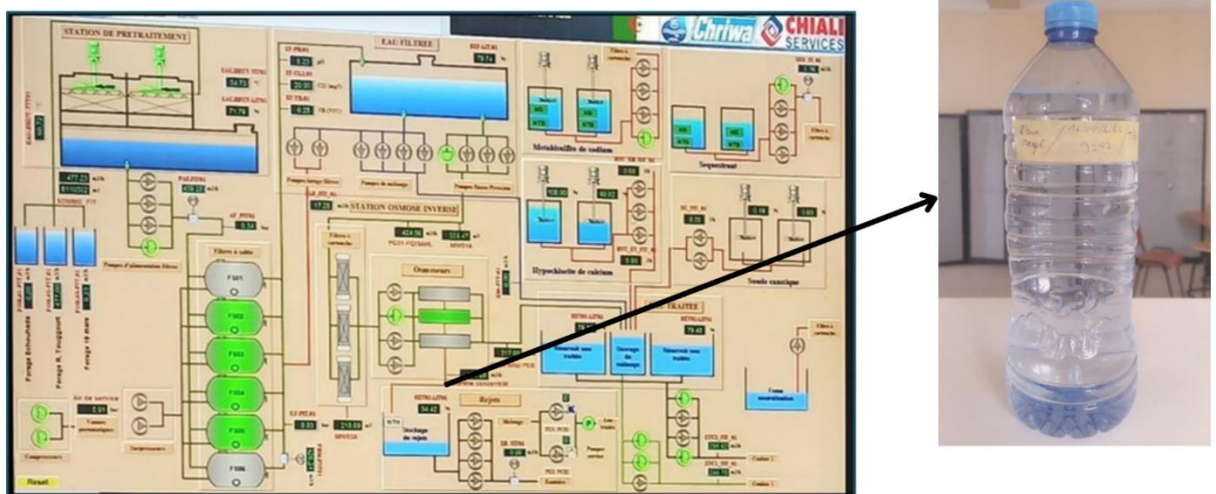


Figure 13: The sample (reject Water) to be analyzed.

2. Sample Preparation:

Metallic waste was first subjected to purification of its surfaces through washing in water and ethanol, three times. This purification was done to clean the metal surfaces from any dirt, solubles, and other organic compounds. After that, drying of the sample was conducted until the whole sample dried completely.

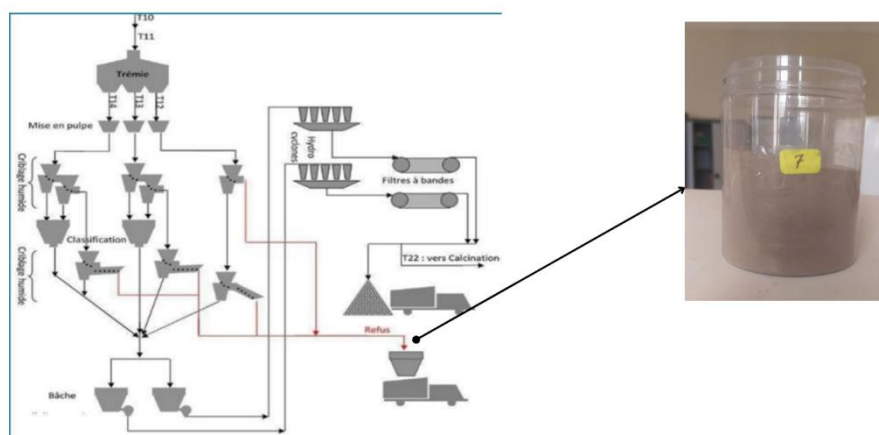


Figure 14: The sample of mineral waste

3. The Experience

- We prepare 1.5 L of reject Water
- Based on the previous study (Groundwater Treatment Using Mineral Waste-2025), we need 150 grams of the mineral waste sample per liter
- So, for each sample of reject water, we add 225 grams of metal waste and mix them



- We place the samples in a magnetic stirrer to homogenize the mixture
- Sample 1 is placed in the sun and stirred for 90 minutes
- Sample 2 will remain for 24 hours while being stirred
- After the specified time has elapsed, place the samples in a centrifuge
- Run the centrifuge for 3 minutes at 3,500 rpm



Figure 15:Centrifuge

- After centrifugation, two layers form: a sediment layer at the bottom containing the metal residues and a water layer
- After separating the water from the metal residues, filter the water through cotton



4. Physical-Chemical Analyses

We use a Multiparameter Water Quality Meter that measures °C (temperature), Cond (conductivity), pH, TDS, and Sal (salinity)

4.1. Measuring pH and Cond:

- First, we install the device's probes: the pH electrode
- and the conductivity cell, which measures Cond, TDS, and Sal
- The temperature sensor is built-in
- Next, we rinse the electrodes with distilled water and gently dry them with a soft paper towel to avoid damaging the sensors
- We immerse the electrodes in a neutral solution (pH=7) to set the zero point, then calibrate the device
- After that, we place the electrodes in the samples to be tested and read the measurements from the screen



Figure 16: A photo showing the measuring device with the readings

4.2. Measuring turbidity:

To measure turbidity, we use a turbidity meter

- First, the meter must be calibrated
- We turn on the meter, fill the test tube with distilled water, and zero the meter
- Next, we fill the test tube with the samples to be tested, place it in the meter, perform the calibration, and read the measurement from the screen



Figure 17: Turbidity Meter

4.3. Measuring Ammonia, Nitrite, Iron and Phosphate:

We use a UV-VIS spectrophotometer to measure ammonia, iron, nitrite, and phosphate.

To measure these elements, we need to prepare the following solutions:

- **Phosphate (PO_4^{2-}):** 50 ml (sample) + 1 ml (ascorbic acid) + 2 ml (R. mixture)
We let it sit for 15 minutes, then take a reading on the device.
- **Iron (Fe^{+2}):** 50 ml (sample) + 2 ml (acetate buffer) + 2 ml (phenanthroline) + 1 ml (hydroxylalanine)
Let it stand for 15 minutes, then take the measurement
- **Nitrite (NO_2^-):** 50 ml (sample) + 1 ml (R.mix)
Let it sit for 30 minutes, then read the result
- **Ammonia (NH_3):** 50 ml (sample) + 4 ml (R.1) + 4 ml (R.2)
Let it stand for one hour, then take the measurement



Figure 18: A photograph showing the solutions after preparation

- We prepare the device by filling the test chamber with distilled water and purging it
- Then we fill the test tubes with samples and take the measurement



Figure 19: UV-VIS spectrophotometer

5. Physical and Chemical Analyses Results

5.1. pH measurement:

The obtained results indicated the following:

Table 2: pH measurement results

	Reject Water	Sample 1	Sample 2
pH	8.13	7.98	7.4

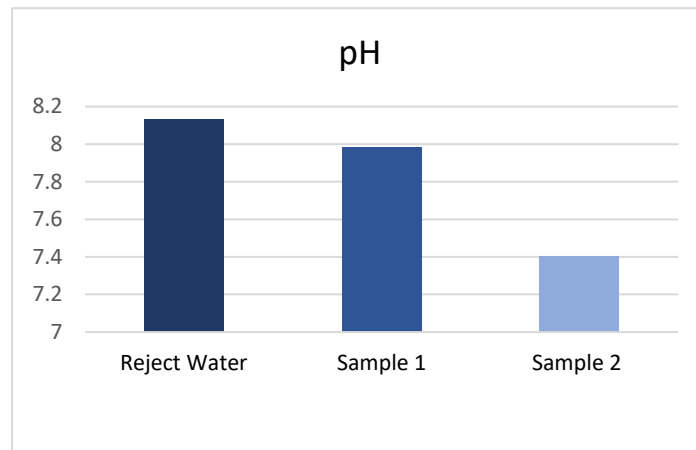


Figure 20: Bar charts representing pH value variations

☒ Discussion:

It decreased from 8.13 at the source to 7.98 (Sample 1) and then to 7.4 (Sample 2). This gradual and continuous decline toward neutrality reflects a continuous depletion of alkalinity in the water. Scientifically, this is attributed to the interaction of bicarbonate ions with cations to form precipitates, in addition to the possibility of ion exchange during which phosphate waste released protons (H^+) to compensate for the positive charges absorbed from the solution.

5.2. Turbidity measurement (TU):

The obtained results indicated the following:

Table 3: Turbidity results

	Reject Water	Sample 1	Sample 2
TU (NTU)	0.474	0.465	0.871

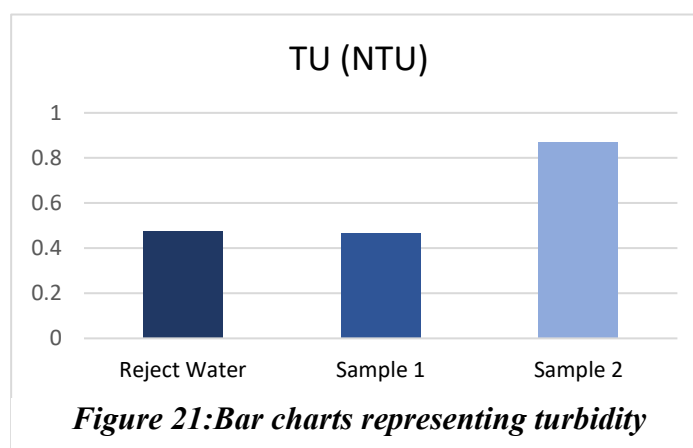


Figure 21: Bar charts representing turbidity

✖ Discussion:

It registered 0.474 NTU at the source, decreased slightly to 0.465 NTU (Sample 1), and then increased to 0.871 NTU (Sample 2). The initial stability indicates the integrity of the separation process after 90 minutes. The noticeable increase after 24 hours is a natural result of the mechanical effect of the prolonged mixing process (continuous agitation), which led to the erosion and fragmentation of very fine particles from the surface of the phosphate granules and their dispersion in the solution as suspended solids.

5.3. Electrical conductivity measurement:

The obtained conductivity (Cond) results:

Table 4:Electrical conductivity (EC)

	Reject Water	Sample 1	Sample 2
Cond($\mu\text{s}/\text{cm}$)	8800	8000	8100

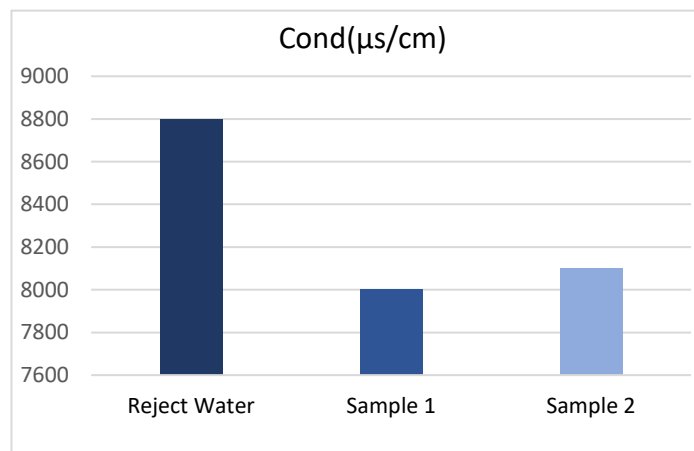


Figure 22:Column graphs showing changes in electrical conductivity values.

✖ Discussion:

It decreased from 8,800 to 8,000 $\mu\text{s}/\text{cm}$ (after 90 minutes), then rose slightly to 8,100 $\mu\text{s}/\text{cm}$ (after 24 hours). The initial decrease demonstrates the material's efficiency in rapidly capturing free ions. The slight increase in the second sample is explained by the phenomenon of "desorption"; the prolonged contact time and intense ionic competition in the solution led to the breaking of some weak bonds, causing a small fraction of the ions to be released back into the water.

5.4. Total Dissolved Solids (TDS) measurement:

The obtained TDS results indicated the following:

Table 5: Results of dissolved salts measurements TDS.

	Reject Water	Sample 1	Sample 2
TDS (mg/L)	5630	5120	5250

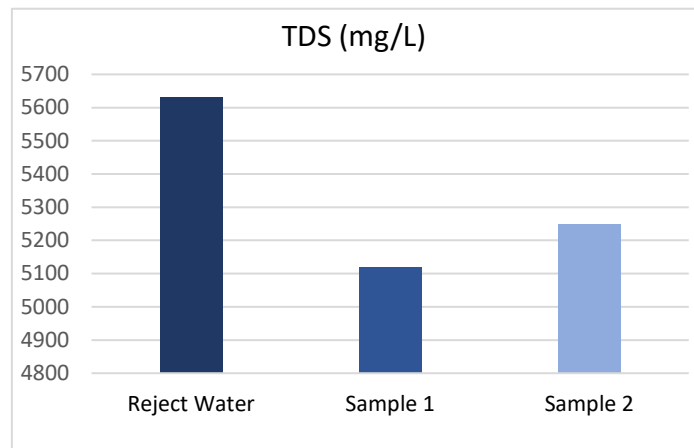


Figure 23: Bar charts representing variations in dissolved salts concentration TDS.

☒ Discussion:

It decreased from 5630 mg/L to 5120 mg/L, then rose to 5250 mg/L. This behavior is fully consistent with electrical conductivity. The delayed rise confirms that ionic repositioning and slight dissolution of some compounds from the solid structure of the sorbent occurred after it reached a state of rapid saturation.

5.5. Temperature measurement (°C):

The obtained temperature results indicated the following:

Table 6: Temperature analysis results °C.

	Reject Water	Sample 1	Sample 2
Temperature(°C)	23	23	23

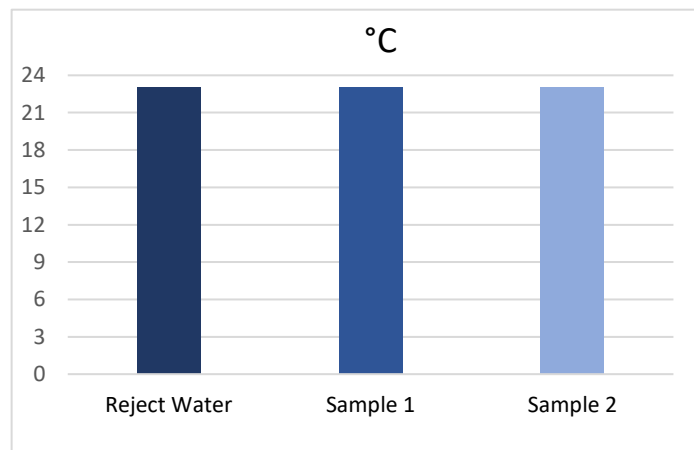


Figure 24:temperature value variations °C

✖ Discussion:

The temperature remained constant at 23 °C in the reject water after 90 minutes (Sample 1) and after 24 hours (Sample 2). This complete stability indicates that the adsorption process took place under isothermal conditions. The absence of any temperature fluctuation confirms that the chemical reactions between the absorbent material and the solution were neither exothermic nor endothermic to a degree that would affect the overall system, and that the mixing system was ideal and did not generate additional mechanical heat.

5.6. Salinity measurement:

The obtained results indicated the following:

Table 7:Salinity analysis results

	Reject Water	Sample 1	Sample 2
Sal (ppt)	4.8	4.4	4.5

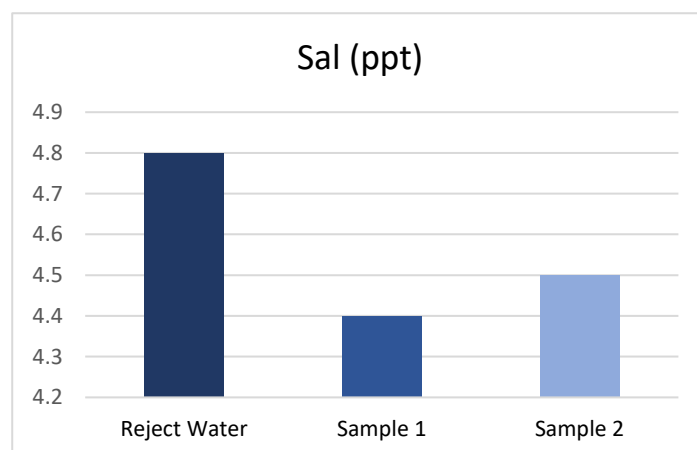


Figure 25:Salinity value

✖ Discussion:

It fell from 4.8 ppt to 4.4 ppt (Sample 1), then rose slightly to 4.5 ppt (Sample 2). Salinity behavior is closely related to dissolved solids. These values reflect the absorbent material's ability to cause a real and rapid reduction in the total salinity of the water, with subsequent marginal changes that do not affect the overall treatment efficiency.

5.7. Phosphate measurement (PO_4^{-2}):

The obtained results indicated the following:

Table 8: Phosphate analysis results

	Reject Water	Sample 1	Sample 2
PO_4^{-2} (mg/L)	5.172	9.048	1.546

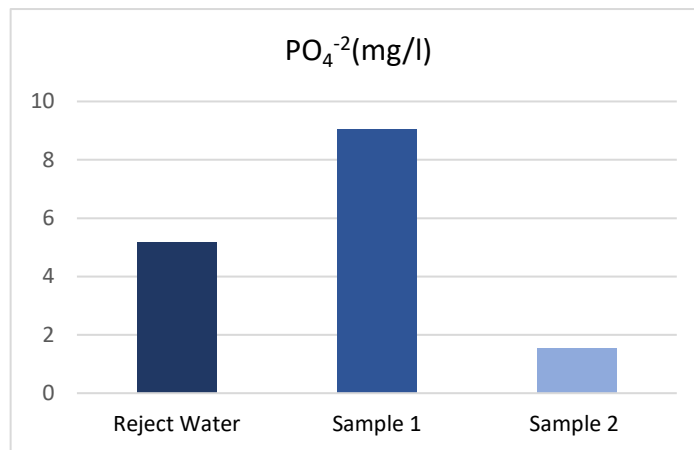


Figure 26: Phosphate value variations

✖ Discussion:

It jumped from 5.172 mg/L to 9.048 mg/L (Sample 1), then dropped sharply to 1.546 mg/L (Sample 2). This represents a dual chemical dynamic. The initial increase is due to the dissolution of the native phosphate present in the pores of the raw material (since it was not chemically treated). The sharp decrease after 24 hours indicates the occurrence of slow “co-precipitation” reactions, in which the dissolved phosphate associated with cations (such as calcium or magnesium) and formed solid complexes that settled out of solution.

5.8. Nitrite (NO_2^-) measurement :

The obtained results indicated the following:

Table 9: Nitrite analysis results

	Reject Water	Sample 1	Sample 2
Nitrite (NO_2^-)(mg/L)	0.03	0.04	0.05

☒ Discussion:

The levels rose slightly and gradually from 0.03 mg/L to 0.04 mg/L and then to 0.05 mg/L. These very low values reflect the slow decomposition of some trace nitrogen impurities remaining in the phosphate waste. These changes are considered to be within acceptable limits and do not adversely affect the success of the treatment.

5.9. Iron (Fe^{2+}) measurement:

The obtained results indicated the following:

Table 10: Iron analysis results

	Reject Water	Sample 1	Sample 2
Iron (Fe^{2+}) (mg/L)	0.11	0.14	0.09

☒ Discussion:

It was 0.11 mg/L at the source, rose to 0.14 mg/L (Sample 1), and then fell to 0.09 mg/L (Sample 2). These micro-dynamic changes represent a simple process: an initial release of iron from sorbent waste, followed by precipitation or re-adsorption as the nature of the solution changed (decrease in pH and phosphate activity), which created conditions suitable for the re-release of iron.

5.10. Ammonia (NH_3) measurement:

The obtained results indicated the following:

Table 11: Ammonia analysis results

	Reject Water	Sample 1	Sample 2
Amonia (NH_3)(mg/l)	0.082	0.917	1.808

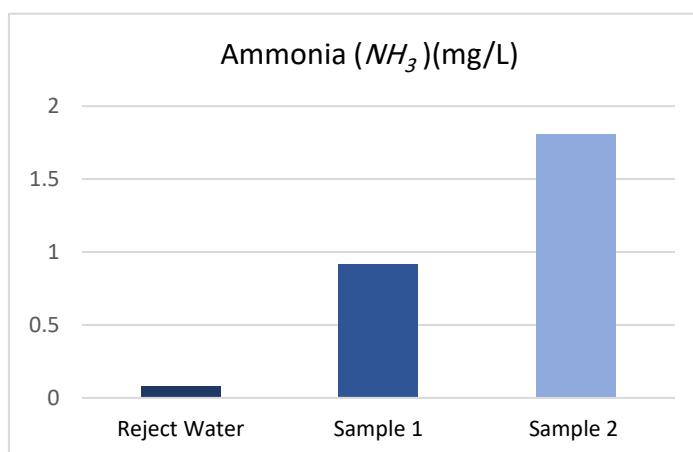


Figure 27:Ammonia value variations

☒ Discussion:

It rose steadily from 0.082 mg/L to 0.917 mg/L (Sample 1) and reached 1.808 mg/L (Sample 2). This behavior confirms that washing with distilled water and ethanol was not sufficient to remove all organic matter or nitrogen compounds naturally present in the metal waste, leading to their continuous release into the water as the contact time increased.

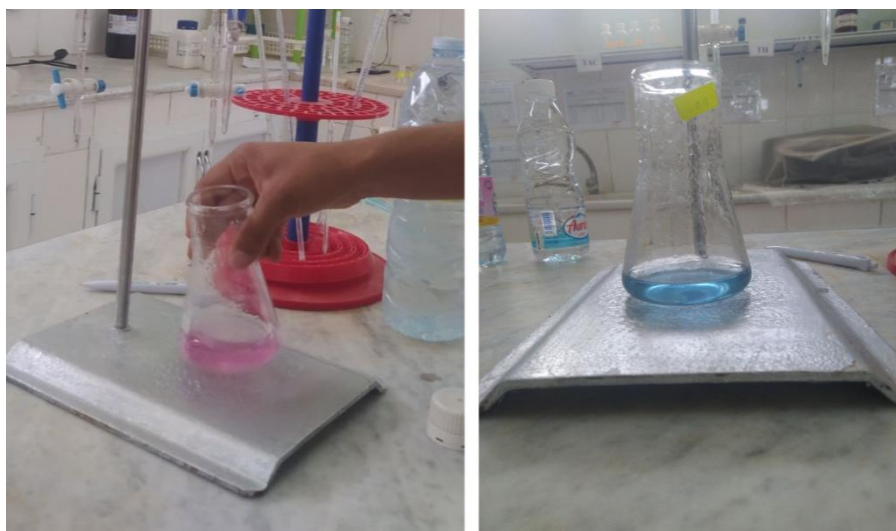
6. Titration:

After measuring the conductivity and pH, a colorimetric titration is carried out to determine the concentrations of Ca^{2+} , TH, TAC^- , CL^- .

6.1. Measuring the concentration of calcium electrolytes (Ca^{2+}):

To determine the concentration of Ca^{2+} in the samples, we prepare the following solution:

- 10 mL (Sample) + 40 mL (distilled water)
- Add 2 ml of (NaOH)
- HSN (colored)
- Titrate with EDTA ($C_{10}H_{16}N_2O_8$) until a blue color appears. Record the equivalence volume of EDTA

**Before calibration****After calibration***Figure 28: The method of detection of (Ca^{2+})*

We can calculate the Ca^{2+} concentration according to the following relationship:

$$C_{Ca^{2+}} = V_{EDTA} \times 40.08 \text{ (mg/l)}$$

6.2. Titration of Total Water Hardness:

To determine the titer, proceed as follows:

- 10 mL (Sample) + 40 mL (distilled water)
- Add 4ml (Ammonia Buffer)
- NET (colored)
- Titrate with EDTA to the equivalence point and record the result

**Before calibration****After calibration***Figure 29: The method of detection of TH*

We can calculate the TH concentration according to the following relationship:

$$TH = V_{EDTA} \times 100 \text{ (mg/L)}$$

6.3. Magnesium (Mg^{2+}):

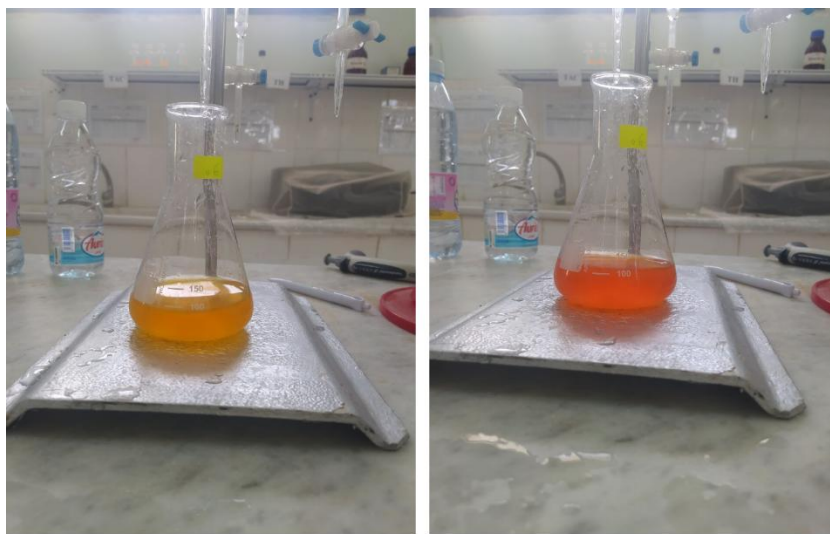
By measuring the concentration of calcium ions (Ca^{2+}) and the total hardness (TH), we can determine the concentration of magnesium ions (Mg^{2+}) using the following equation:

$$[Mg^{2+}] = ([TH] - [Ca^{2+}])(24.305) \text{ (mg/l)}$$

6.4. Titration (TAC^{-}):

To determine the titer, proceed as follows:

- 100 ml (Sample)
- 3 drops of (methyl orange)
- Titrate with H_2SO_4 to the equivalence point and record the result



Before calibration

After calibration

Figure 30: The method of detection of (TAC^{-})

6.5. Carbonic acid (H_2CO_3):

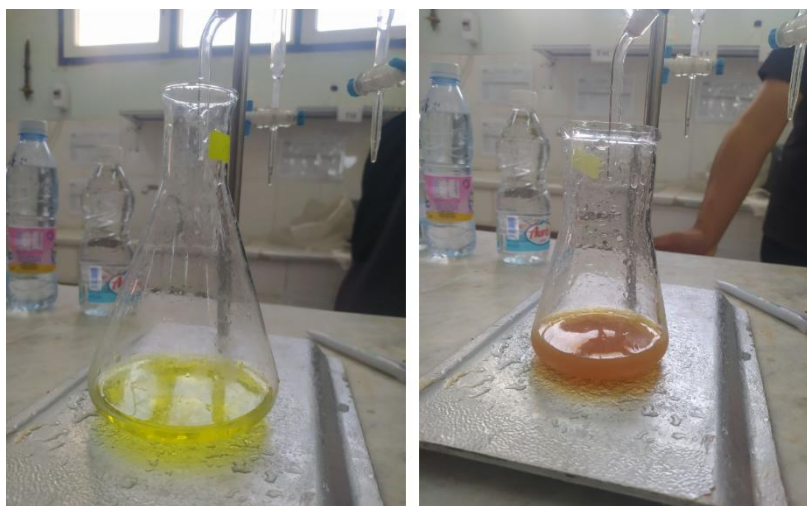
Using TAC, carbonic acid is calculated using the following equation:

$$[H_2CO_3] = [TAC^{-}] \times (12.2) \text{ (mg/l)}$$

6.6. Measuring the concentration of chlorine electrolytes (Cl^-):

To determine the titer, proceed as follows:

- 5ml (sample) + 45ml (distilled water)
- Add 1ml (K_2CrO_4)
- Titrate with $AgNO_3$ to the equivalence point and record the result



Before calibration

After calibration

Figure 31: The method of detection of (Cl^-)

We can calculate the Cl^- concentration according to the following relationship:

$$[Cl^-] = \frac{V_{AgNO_3}(10) - (0.5)}{50} \times (0.02)(35453) \text{ (mg/l)}$$

7. The following tables show the results obtained after calibration:

1) Calcium (Ca^{2+}) results:

Table 12: Analysis results of the metal (Ca^{2+})

	Reject Water	Sample 1	Sample 2
Calcium Vtitr (Ca^{2+}) (mL)	981.96	761.52	761.52

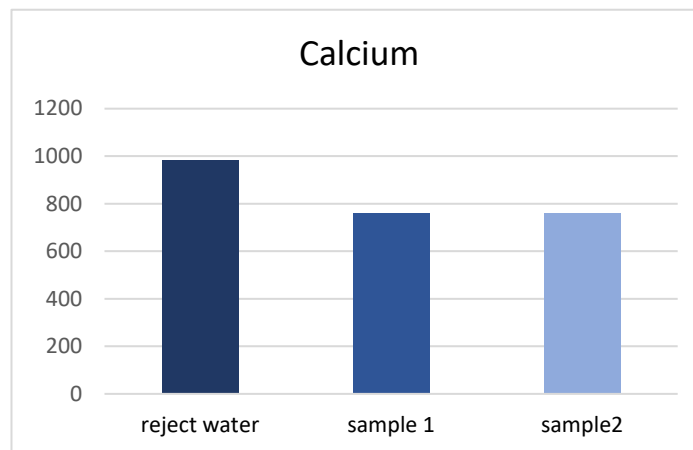


Figure 32: Calcium value variations

☒ Discussion:

It decreased significantly from 981.96 mL to 761.52 mL in Sample 1 and stabilized completely at 761.52 mL in Sample 2. This complete stabilization demonstrates the high and strong chemical affinity between the phosphate surface and calcium ions. The substance reached a state of rapid saturation with calcium and maintained strong bonds that did not break even with continued mixing.

2) TH results:

Table 13: Analysis results of TH

	Reject Water	Sample 1	Sample 2
TH (mg\LCaCO ₃)	3500	3200	3000

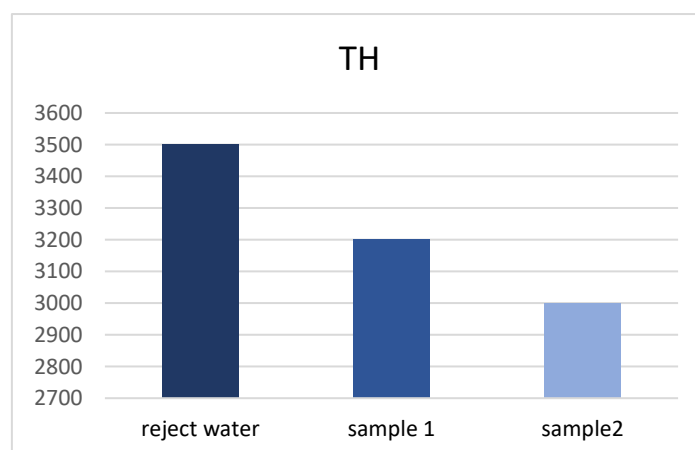


Figure 33: TH value variations

☒ Discussion:

It decreased steadily from 3,500 mg/L to 3,200 mg/L (Sample 1) and then to 3,000 mg/L (Sample 2). Hardness is the combined indicator of calcium and magnesium activity. This continuous and significant reduction confirms the effectiveness of phosphate waste in reducing water hardness by combining the efficiency of direct calcium adsorption with delayed secondary precipitation processes.

3) Magnesium (Mg^{2+}) results:

Table 14: Analysis results of the metal (Mg^{2+})

	Reject Water	Sample 1	Sample 2
Magnesium Vttr (Mg^{2+}) (mL)	255.202	315.965	267.355

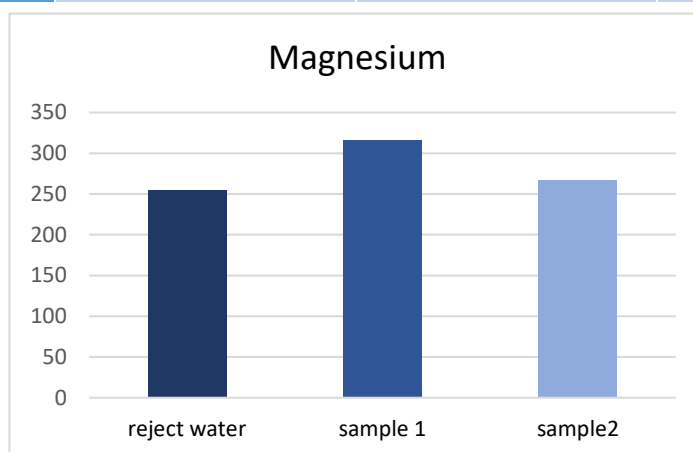


Figure 34: Magnesium value variations

☒ Discussion:

It rose from 255.202 mL to 315.965 mL (Sample 1), then decreased to 267.355 mL (Sample 2). The initial increase is attributed to the rapid dissolution of magnesium salts present as impurities in the absorbent material. The subsequent decrease is the result of their reabsorption through adsorption mechanisms or their participation in precipitation reactions with phosphate and bicarbonate over time.

4) Carbonic Acid (H_2CO_3) results

Table 15: Analysis results of the metal (H_2CO_3)

	Reject Water	Sample 1	Sample 2
Carbonic acid Vttr (H_2CO_3)(mL)	652.7	366	317.2

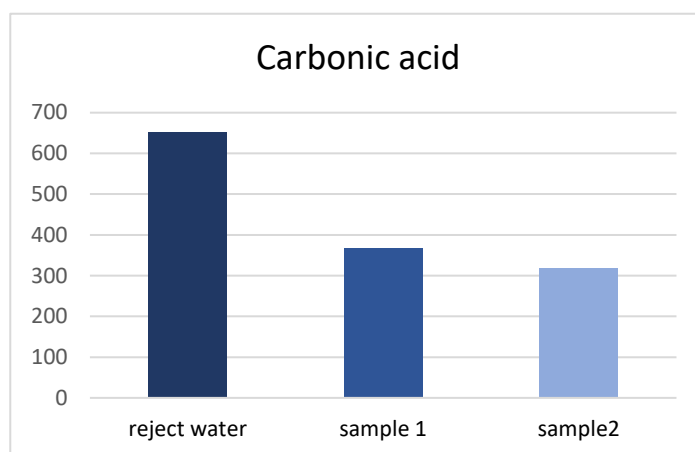


Figure 35: Carbonic acid value variations

☒ **Discussion:**

It decreased significantly and steadily from 652.7 mL to 366 mL (Sample 1) and then to 317.2 mL (Sample 2). The continuous consumption of bicarbonate reflects its role as a buffer in the solution and confirms its direct involvement in reactions to form solid carbonates with positive cations, which is the most accurate chemical explanation for the continuous decrease in pH that we recorded.

5) Chlorine (CL^-) results:

Table 16: Analysis results of the metal (CL^-)

	Reject Water	Sample 1	Sample 2
Chlorine Vtitr (CL^-) (mL)	1907.371	1411.029	1978.277

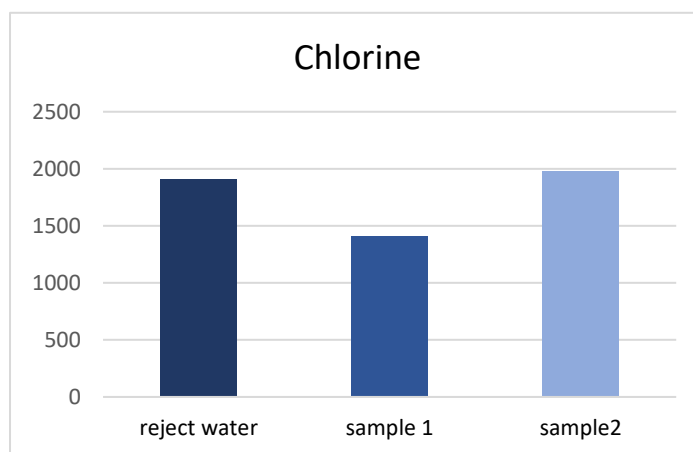


Figure 36: Chlorine value variations

☒ Discussion:

It decreased from 1,907.371 mL to 1,411.029 mL (Sample 1), then increased to 1,978.277 mL (Sample 2). The adsorbent achieved excellent chlorine removal initially due to rapid physical adsorption. The increase after 24 hours is explained by the phenomenon of “desorption”; intense ionic competition in the wastewater medium displaced the weak chlorine bonds in favor of other ions, thereby returning the chlorine to the solution.

Table 17: Table of results of physical-chemical analyses

	Reject Water	Sample 1	Sample 2
Temperature(°C)	23	23	23
pH	8.13	7.98	7.4
Cond(μs/cm)	8800	8000	8100
TU (NTU)	0.474	0.465	0.871
TDS (mg/L)	5630	5120	5250
Sal (ppt)	4.8	4.4	4.5
PO_4^{-2} (mg/L)	5.172	9.048	1.546
Nitrite(NO_2^-)(mg/L)	0.03	0.04	0.05
Ammonia(NH_3)(mg/L)	0.082	0.917	1.808
Calcium Vtitr (Ca^{2+}) (mL)	981.96	761.52	761.52
Magnesium Vtitr (Mg^{2+}) (mL)	255.202	315.965	267.355
Chlorine Vtitr (Cl^-) (mL)	1907.371	1411.029	1978.277
Iron (Fe^{2+}) (mg/L)	0.11	0.14	0.09
TH (mg/L $CaCO_3$)	3500	3200	3000
Carbonic acid Vtitr (H_2CO_3) (mL)	652.7	366	317.2

CONCLUSION

The results from this experiment have shown the promising potentiality and initial feasibility of using phosphatic industrial waste as an inexpensive absorbent for RO Reject Water treatment at the “19 March” desalination station. By measuring and analyzing several physical and chemical properties, the following scientific conclusions were made:

- ❖ **Chemical and Kinetic Stability:** The sample demonstrated a very good ability to reduce the total metal concentration and achieve complete stability, as the electrical conductivity was found to be identical (8,000 $\mu\text{S}/\text{cm}$) in both experiments, in contrast to the reference sample, which measured 8,800 $\mu\text{S}/\text{cm}$. These results were accompanied by complete thermal stability at 23°C, thanks to rapid attainment of a dynamic equilibrium state unaffected by external factors.
- ❖ **Hardness Removal Efficiency:** The material achieved significant success in reducing total hardness (TH) from 3500 mg/L to 3000 mg/L within 24 hours. This is primarily due to the high affinity between the substance and calcium ions, which stabilized at 761.52 mL in both samples, confirming the strength and stability of the bonds formed.
- ❖ **Chemical reaction dynamics:** This experiment indicated that there were many complex chemical reactions which resulted in a slow reduction in the pH value to 7.4 due to the usage of bicarbonate. Moreover, phosphate and magnesium co-precipitated with each other as the experiments progressed, whereas chloride ions were extracted because of the ionic competition in the saline environment.
- ❖ **Optimal operation time:** It has been observed that the most appropriate operational time to attain an optimal equilibrium between efficiency and avoiding any side effects, such as increasing the turbidity level to 0.871 NTU or increasing the ammonia level as a result of decomposition of some constituents in the raw materials during increasing contact time, is 90 minutes.

Based on these results, we recommend subjecting phosphate waste to chemical or thermal activation processes to enhance its sorption capacity and stabilize its structural components. The study also suggests expanding the research to determine the optimal dosages, thereby contributing to the transformation of this industrial waste into a sustainable resource for water treatment in accordance with the principles of the circular economy.

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Annexes:

❖ The materials and solutions used:



R.1



R.2



R.melange



R.mix



Ascorbic Acid



Hydroxylamine



Phenanthroline



Acetate Buffer



$AgNO_3$



EDTA



HSN



NET



$H_2OS_4^-$



K_2CrO_4



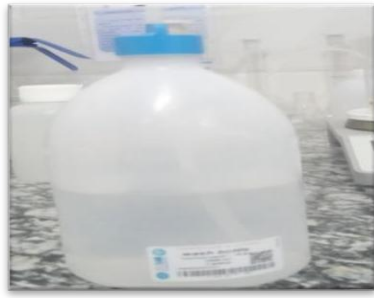
NaOH



Methyl Orange



Ammonia Buffer



Distilled Water

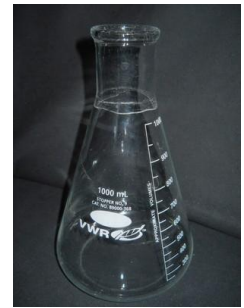
❖ Used Tools and Glassware:



Magnetic Stirrer Bar



100ml glass beaker



Conical Flask 1000ml



Magnetic mixture



Channel Pipette 5ml



Funnel



100 ml Graduated Cylinder