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Recycling Wastewater Through Phytoremediation for Irrigating Green Spaces: Hydroponics as a Model

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Abstract:
This study aims to highlight the phytoremediation system for treating wastewater for irrigating green spaces. In light of water resource scarcity and the impacts of climate change, it has become imperative to sustainably exploit all available resources. This necessitates exploring alternative local water sources, including groundwater and treated wastewater, to meet future demands. The study focuses on reducing pollutant levels in wastewater to produce water suitable for irrigating green belts. Consequently, the study seeks to answer the following question: Does recycling wastewater through phytoremediation make it suitable for irrigating green spaces? The findings indicate that plants have varying capabilities in removing pollutants, with Nerium oleander (oleander) demonstrating a significant ability to eliminate pollutants, achieving a removal rate of up to 80%. In conclusion, the reduction of pollutants emphasizes the importance of reusing wastewater through phytoremediation.

Keywords: green space irrigation, wastewater, phytoremediation.

JEL Classification: P10; P18

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Introduction

The impact of climate change on water availability for meeting human needs has become increasingly evident, necessitating urgent efforts to combat climate change through improved management of the hydrological cycle and the adoption of innovative water management strategies. These strategies include modern methods such as fog harvesting, traditional approaches like wetland conservation, and advanced techniques such as resource-conservation agriculture, which have demonstrated significant efficacy. Moreover, wastewater treatment for irrigation presents an essential solution, as it helps preserve soil structure, organic matter, and moisture content, independent of rainfall variations.

Treated wastewater can partially address the gap between water supply and the increasing demand driven by global population growth. By 2025, urban dwellers are projected to constitute 54% of the global population, with domestic water usage accounting for approximately 11% of annual global consumption. More than 100 countries currently experience varying degrees of water scarcity, with nearly two-thirds of the global population anticipated to face moderate to severe water stress by 2025. Concurrently, substantial volumes of domestic and industrial wastewater are discharged, exerting significant pressure on the environment. Global wastewater discharges are estimated at 400 billion cubic meters annually, contaminating 5,500 billion cubic meters of water each year. Due to its considerable quantity and nutrient-rich composition (notably nitrogen and phosphorus), wastewater serves as a critical resource for irrigation, particularly in arid and semi-arid regions (Al-Rashidi et al., 2013).

Numerous countries are witnessing the expansion of hydroponic agriculture, particularly in regions characterized by water scarcity, infertile soils, or desert landscapes, where conventional cultivation depletes significant amounts of water and fertilizers. Many of these countries aim to achieve sustainability by optimizing green spaces. The project's conceptual framework is relatively innovative compared to existing global practices. Unlike conventional hydroponics, which utilizes a nutrient solution, this study uniquely employs treated wastewater. The project is inherently productive rather than consumptive, as it aims to facilitate a significant advancement in green space irrigation by providing an unrestricted surplus of water.

- **Problem Statement:**

Can wastewater recycling through phytoremediation render it suitable for irrigating green belts?

- **Sub-Questions:**

- What is wastewater, and what processes are involved in its treatment?
- What is meant by phytoremediation, and how is it applied?

- **Hypothesis:**

- Wastewater should not be viewed merely as an environmental issue requiring disposal. Instead, it should be recognized as a valuable resource, warranting strategic investment in its treatment and reuse.

- **Significance of the Study:**

- This study highlights the potential of phytoremediation to address traditional irrigation challenges, such as excessive water wastage.
- It underscores the importance of utilizing locally available resources to capitalize on wastewater generated from residential and community waste.

- **Objectives of the Study:**

- To identify and address the challenges posed by water scarcity in irrigating green belts and to examine scientific methods for wastewater treatment.
- To evaluate phytoremediation as an advanced, efficient, and sustainable approach for treating wastewater for use in irrigating green belts.
- To develop an economically viable and environmentally safe method for treating wastewater generated by population centers in the study area.

- **Methodology:**

This research adopts a descriptive methodological approach, relying on theoretical literature reviews and bibliographic surveys. The study is organized into the following sections:
- Definition and characterization of wastewater.
- Processes and methodologies for wastewater treatment.
- Application of phytoremediation techniques for wastewater treatment and its use in irrigating green belts.

1- Definition of Wastewater

Wastewater has various definitions, and only a few are outlined here for conciseness:

- Wastewater refers to water generated from areas comprising residential, commercial, and industrial establishments, as well as surface and groundwater, that flows or is discharged into a wastewater system. It consists of a mixture of water and contaminants, typically including dissolved and suspended substances resulting from human and animal waste, oils, fats, plant and animal residues, household chemicals, and soil particles (أحمد، 1990).

- It is water resulting from diverse domestic uses and any discharge that flows into the city's sewage network.
- Wastewater denotes water previously used by humans in various applications and subsequently contaminated by substances altering its chemical composition or natural properties, rendering it unsuitable for humans, animals, plants, or marine organisms (Peng et al., 2002).
- It is also defined as polluted water containing foreign materials that deteriorate its chemical properties, making it unfit for human consumption. It may originate from industrial sources, with chemical, organic, or mineral compositions depending on the nature of the industrial activity (Satin & Selmi, 1995).
- According to the United Nations General Assembly (2009), wastewater encompasses the collection, transportation, treatment, disposal, reuse, and management of human fecal matter, domestic wastewater, and non-solid residues to promote public health.

Based on these definitions, wastewater can be understood as any liquid waste or byproduct resulting from the use of clean water, which becomes contaminated with various human and animal waste, oils, fats, and other harmful and toxic pollutants. Its impurity is evident through changes in its smell, color, and taste, collectively termed "turbidity." Furthermore, wastewater temperatures are generally higher than ambient atmospheric temperatures. Wastewater is composed of approximately 99% consumed freshwater and 1% harmful pollutants, which can be classified as follows:

- Physical Pollutants: Sand and dust;
- Chemical Pollutants: Gases, organic and inorganic substances;
- Biological Pollutants: Plant residues, carcasses of small animals such as rodents and cats, and microorganisms, including bacteria, viruses, protozoa, and eggs of roundworms.

The following illustration further elaborates on these components:

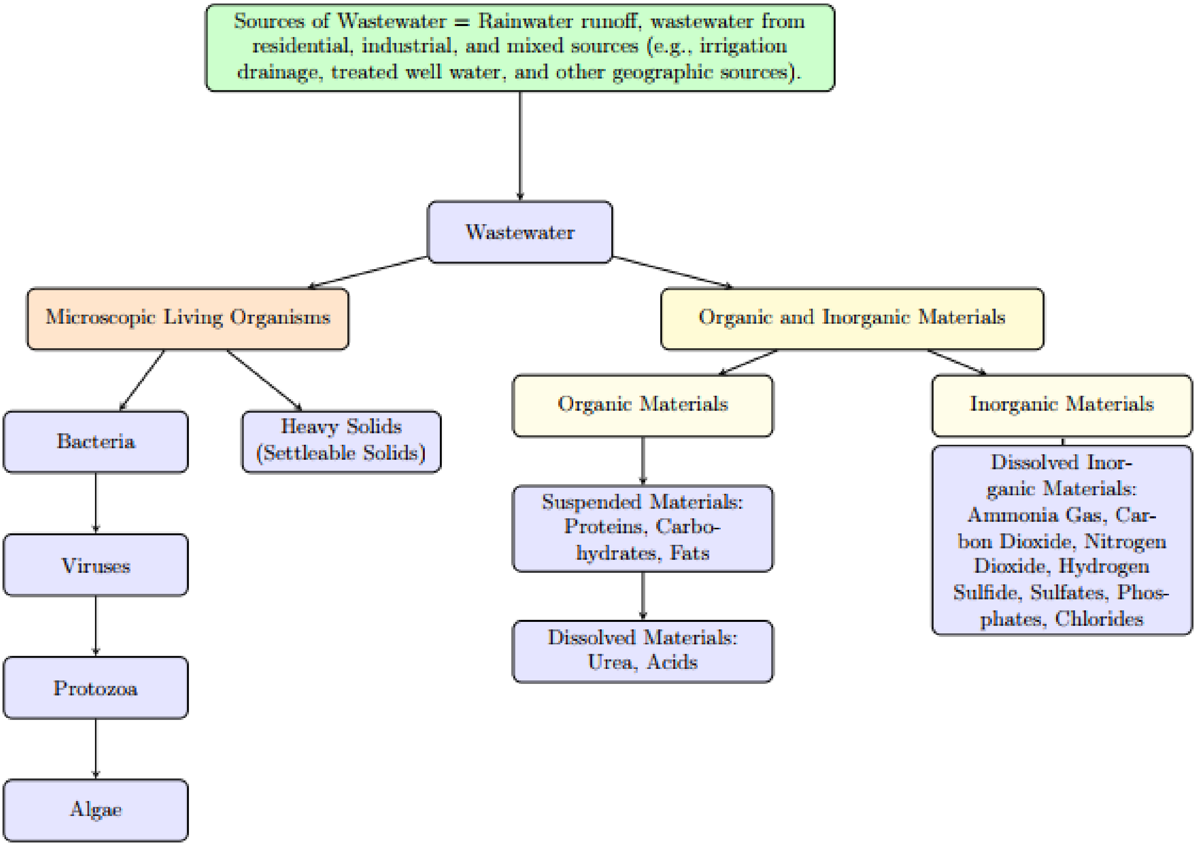


Figure (01): Sources and Components of Wastewater.

Source: Prepared by the researchers

Given that this water contains a substantial amount of harmful pollutants, which, if their concentration exceeds a certain threshold, can cause severe damage to both the environment and humans, it becomes imperative for civilized societies to protect their living environment by resorting to wastewater treatment. Wastewater serves as an additional water resource and allows for the conservation of freshwater for human consumption.

2- Definition of Wastewater Treatment

It is crucial to first define wastewater treatment, as its implementation determines whether treated water can be effectively reused. Wastewater treatment refers to the oxidation of organic substances present in the water and the separation of solid impurities, enabling the treated water to be discharged without harm to public health or reused after eliminating microbial contaminants (أحمد، 1990). Wastewater treatment involves a series of processes to progressively remove solid particles based on their size or density. These processes include screening or crushing large solids, utilizing chambers to remove coarse solids with high mass and sedimentation for suspended solids, chemical sedimentation to remove both settleable and non-settleable solids, biological oxidation, and final sedimentation to eliminate remaining suspended solids and oxidize dissolved organic matter (الجمعية العامة للأمم المتحدة المتحدة، 2009). The global need for wastewater treatment arises from several critical factors:

- Mitigating pollutant hazards: Wastewater contains contaminants that threaten human health and the environment where it is discharged.
- Reducing reliance on desalination: Treated wastewater provides an alternative and practical water source, reducing dependency on desalinated water.
- Enhancing strategic water storage: Treated wastewater can be artificially recharged into underground reservoirs, creating reserves for emergencies.
- Addressing increasing water demand: Wastewater is a continuously growing resource due to population growth and increasing per capita water consumption.
- Diversified applications: Treated wastewater can be used for numerous purposes that do not require high purification levels, depending on the intended use.

Treated wastewater is safe for human and agricultural applications as long as it poses no risks or harm to humans or the environment. Its uses include:

- Protecting public health and ecosystems from untreated wastewater hazards.
- Washing vehicles, streets, and public facilities, as well as cleaning rainwater drainage systems, sewage networks, and building exteriors.
- Irrigating forests and greenbelts to produce oxygen, timber, and reduce industrial pollution.
- Watering wild plants in remote areas and combating desertification.
- Utilizing treated water for firefighting and fire suppression.
- Using treated wastewater in construction projects, such as washing building materials.
- Disposing of treated wastewater through scientifically and environmentally safe methods to avoid environmental harm.

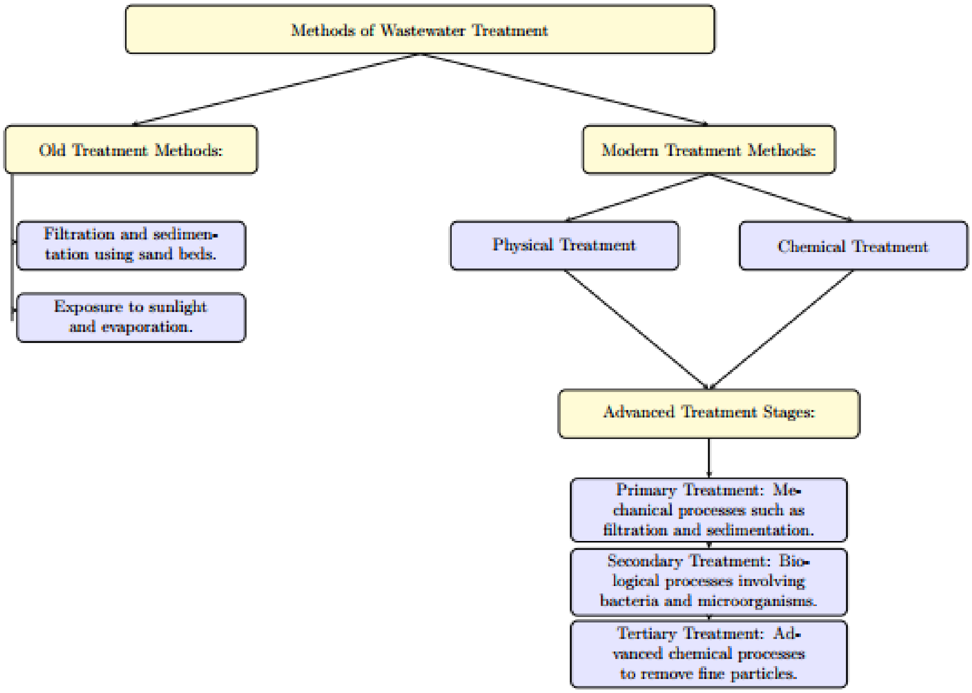
- Preventing soil pollution and reducing harmful salt concentrations to levels recommended by the World Health Organization (WHO), preserving soil fertility.
- Protecting groundwater resources from contamination and reducing nitrate and salt concentrations to WHO-permitted levels.
- Advantages and Disadvantages of Wastewater Treatment Systems

Wastewater treatment systems offer several advantages:
- They are simple to construct, cost-efficient, and require limited equipment.
- Operational and maintenance costs are relatively low.

However, there are some disadvantages:
- These systems require large land areas, making them more suitable for regions with inexpensive land.
- Significant water losses can occur due to evaporation.

The following figure illustrates the various methods of wastewater treatment:

Figure (02): Methods of Wastewater Treatment.



Source: Prepared by the researchers

3- Hydroponics (Water Culture)

Hydroponics is a Greek term derived from two components: the first, "Hydro," meaning water, and the second, "Ponics," meaning work, resulting in the overall meaning: "Water Work" or "Water-based Farming" (أحمد،، 1995). It has several synonyms, including "water culture" and "soilless farming". However, the historical development of this agricultural practice has gone through several stages, which are outlined as follows:

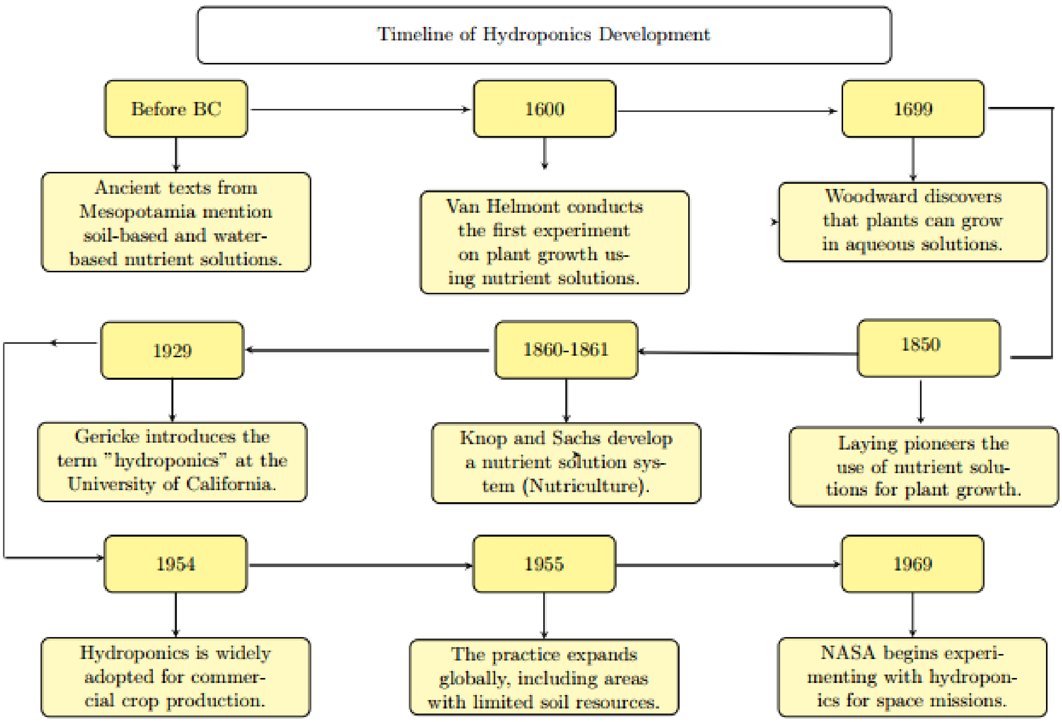


Figure (03): The Historical Development of Hydroponics.

Source: Prepared by the researchers

According to (Peng et al., 2002; Zorai et al., 2023), soilless agriculture refers to the cultivation of plants in agricultural media that do not include soil as one of their components, with the plants being nourished using specially formulated nutrient solutions containing the essential elements for plant growth. It entails growing plants in a medium other than soil that is suitable for their growth or directly in water (2018 ،محمود).

Hydroponics refers to a set of systems for crop production that utilize only nutrient-rich mineral solutions instead of soil containing silt and clay. Researchers in plant physiology discovered during the 18th century that plants absorb essential mineral nutrients in the form of inorganic ions dissolved in water. Under natural conditions, soil serves as a reservoir for mineral nutrients, but it is not inherently essential for plant growth. Plant roots can absorb mineral nutrients present in soil only when water dissolves them. Consequently, soil becomes unnecessary for plant growth if these nutrients are artificially added to the water required by the plant. Terrestrial plants can be grown with their roots immersed only in a nutrient-rich mineral solution or in inert media such as perlite, vermiculite, or mineral wool. Notably, this configuration is known as phytoremediation.

3-1- Definition of Phytoremediation

Phytoremediation is a water treatment system that utilizes the filtration capacity of large and small plants. It can be regarded as an irrigation system that simultaneously treats wastewater by leveraging the filtration ability of plants with large or small leaves (Okba, 2024). This process has various names, including phytoremediation, natural filtration, aerated filtration, and vegetative filtration for large or small plants. All of these systems filter water with the aid of plants, functioning as biological converters that eliminate both biodegradable and non-biodegradable components, as well as nutrients, minerals, and pathogenic microorganisms (2017 ،الحمداني).

Phytoremediation treatment plants process pre-treated contaminated water through what is known as constructed wetlands or plant treatment ponds. In these ponds, plants, through their roots, stems, and leaves, provide an environment conducive to the growth of microorganisms that break down organic materials in pre-treated wastewater.

There are four types of systems or ponds used for wastewater treatment:

- Ponds planted with vegetation and characterized by free surface flow;
- Ponds planted with vegetation and characterized by horizontal surface flow;
- Ponds planted with vegetation and characterized by vertical flow;
- Ponds planted with vegetation and characterized by hybrid flow (horizontal + vertical), which is the subject of the applied study.

The idea of using plants for phytoremediation purposes first appeared in 1983. However, the concept dates back 300 years when certain plant species were utilized to treat contaminated water. For plants to be practically used

in removing metals from various ecosystems, they must have the ability to tolerate and accumulate metals in their tissues.
Several technologies are used in phytoremediation, as illustrated in Figure 4.

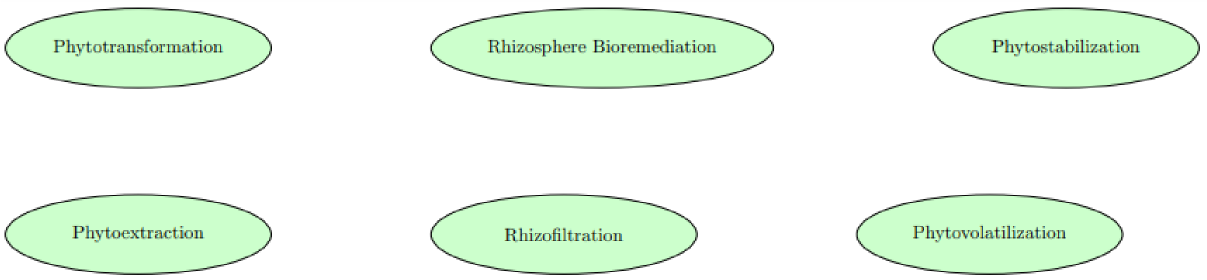


Figure (04): Phytoremediation Technologies.

Source: Prepared by the researchers, based on إبراهيم الحمداني، 2017، p 37.

Phytoremediation has several advantages, primarily reducing pollutant levels and pathogens. However, it also has disadvantages, which are outlined in the table below:

Table (01): Advantages and Disadvantages of Phytoremediation.

Advantages	Disadvantages
- Low construction costs and ease of implementation.	- Requires a large area for the treatment plant compared to traditional treatment plants.
- Can be used for secondary and tertiary treatments.	- Requires relatively large quantities of fill materials (gravel, sand, stones).
- Can be employed as an independent step for nitrogen and phosphorus removal.	- Decomposition of raw solids and biomass may cause clogging in parts of the filter medium, especially in sandy media, and improper treatment of primary sludge may lead to odor issues.
- Low operating and maintenance costs due to reliance on natural biological treatment.	- Replacing the filter medium can be costly if poor operation or design necessitates it.
- Minimal need for operational and maintenance energy, limited to essential needs.	- Basic supervision required for operation and maintenance does not eliminate the necessity of adhering to engineering guidelines and standards for plant design.

- No need for chemical usage or backup mechanical equipment.	- The executing entity must possess the necessary expertise to implement these systems properly.
- Does not require an expert operational team as with conventional treatment plants.	
- High tolerance for flow fluctuations, with excellent stability and reliability in performance.	
- Effective in eliminating harmful bacteria and parasitic worm eggs.	

Source: Prepared by the researchers.

4- Plants Used in Treatment

Various types of plants are used in water treatment to address and mitigate water pollution (Zemri & Sari Hassoun, 2024). These plants are classified into groups such as floating plants with roots fixed in the soil, plants with submerged roots and exposed stems and leaves, plants completely submerged in water, reed plants with woody stems, reed plants with herbaceous stems, and floating plants with suspended roots, among others. However, we have selected some of these plants to highlight their importance.

4-1- Papyrus Plant (PAPYRUS)

Papyrus is a perennial aquatic plant that reproduces by seeds and can also propagate vegetatively. It is a fast-growing plant native to Central Africa and the Nile Valley (plants.ces.ncsu.edu, 2022). It has been introduced, often as an ornamental species, to other warm parts of the world. Botanists classify the papyrus plant as a genus within the sedge family, Cyperaceae. Most plants in this family grow in freshwater or slightly saline wetlands. Historically, papyrus plants grew in agricultural lands, along drains, swamps, rivers, and other similar environments.

It is known by several names, including papyrus reed, sedge papyrus, paper reed, Indian mat plant, or Nile grass.

A. Description of Papyrus Plant (www.missouribotanicalgarden.org, 2022)

- A soft perennial aquatic plant forming clusters of upright, round-stemmed stalks up to 30 cm in diameter.
- It consists of numerous slender stems, each bearing a small light-brown flower, with grass-like linear leaves and terminal clusters of small, greenish tapered flower spikes beneath clusters resembling leaves.
- The plant height ranges between 2.5–4 m and spreads horizontally 0.5–1 m, reaching its maximum dimensions within 2–5 years.

- It is also found in similar habitats in subtropical and tropical climates in the countries where it has been introduced.
- It tolerates annual rainfall between 100–4200 mm, optimal annual temperatures of 20–30°C, and soil pH levels of 6.0–8.5.

4-1-1- Uses of Papyrus Plant

- Traditional Uses: In its native environment, it has been used for thousands of years as food for humans and livestock, and as a source of herbal medicine (cabi, 2022).
- Cultural and Practical Applications: Perhaps most notably, it has been a source of material for making paper (papyrus), ropes, boats, mats, cushions, roofs, and floors. It was also used in making funeral wreaths, fans, sandals, and decorations for deities. Papyrus mats were used to build fences and huts, while its stems were used to seal joints in wooden boats. Its roots were cut into sections and used as beads.
- Modern Applications: Recently, papyrus has been considered a potential source of biofuel material. It is also recognized as an effective natural biofilter for water pollutants and has been acknowledged for its contributions to ecosystem functions and services.

Figure (04): Papyrus Plant.

Scientific Name : Cyperus papyrus	Scientific Classification
	Domain: Eucaryote Kingdom : Plantea Phylum : Phanerogams Subphylum : Angiosperms Class : Monocotyledon Order : Cyperales Family : Cyperaceae Genus : Papyrus Species : Cyperus

Source : www.floridata.com/Plants/Cyperaceae/Cyperus%20papyrus/511. Date de consulter: 14/01/2024.

4-1-2 Environmental Importance of the Papyrus Plant

- Wildlife Habitat: In its native tropical African environment, papyrus swamps serve as vital habitats for certain animals such as antelopes, African snakes, and the yellow papyrus warbler. These swamps also provide breeding and feeding grounds for various fish species and grazing areas for large herbivores.
- Nitrogen Fixation: Studies have shown that nitrogen fixation occurs in the healthy root systems of papyrus plants. Root-associated nitrogen fixation can supply up to 26% of the nitrogen requirements of papyrus plants. This fixation is attributed to the presence of diazotrophs in the root zone.
- Ecosystem Services: The plant contributes significantly to the regulation of water, carbon, and nitrogen cycles, as well as sediment and nutrient buffering capacities.
- Water Filtration: Papyrus plants are increasingly used as part of filtration systems to remove sediments, wastewater, and heavy metals from polluted water.
- Carbon Sequestration: The papyrus plant plays an important role in capturing and isolating substantial amounts of carbon dioxide from the atmosphere. It is estimated that up to 80 tons of carbon per hectare can be stored in the plant's above-ground and below-ground components. Under flooded conditions, up to 640 tons of carbon per hectare can be stored in peat and organic debris deposits (iucnredlist, 2022).

4-2- Lemongrass Plant

Lemongrass is an aromatic, tropical herbaceous plant native to Southeast Asia. It is widespread in countries such as Thailand, Malaysia, and Indonesia, as well as in tropical regions such as parts of India. Currently, it is cultivated in Florida, California (USA), Central Africa, Brazil, and Guatemala. The plant is named for its sour taste, which is less intense than that of lemons. It is also known by other names, such as Makki Grass, West Indian Melissa, and Lemongrass Plant.

4-2-1- Description of Lemongrass

- Characteristics: Lemongrass is a perennial herbaceous plant belonging to the Poaceae family. It remains in the ground for up to 10 years. Its long, smooth leaves contain aromatic oil with a lemon-like fragrance. It is often grown as an ornamental plant in pots, parks, private gardens, or small farms.

- Soil Preference: The best soil for lemongrass is sandy, well-aerated, and well-drained, free from fungal infestations. The soil salinity should be low (around 1,000 ppm or less) and rich in organic matter to produce lush green leaves.

- Physical Characteristics: The plant grows to a height of 0.6 to 1.8 meters, with a horizontal spread of 0.8 to 1.3 meters. Its flowers are brown, small, and spike-like, and its fruits resemble barley or rice grains, measuring around 15 cm.

- Propagation: Lemongrass propagates through offsets (shoots) obtained by dividing the parent plant's vegetative mass. The offsets are planted in the soil at the start of spring until the end of April, which is the optimal planting period, though propagation can occur at other times of the year.

4-2-2- Uses of Lemongrass

- Geographic Spread: Lemongrass grows naturally in India, Madagascar, Sri Lanka, and tropical parts of Asia. It is one of the most essential herbs in Southeast Asian cuisine and is cultivated in many Arab countries.

- Essential Oil Extraction: The leaves and plant tips are used to extract aromatic oil, whose composition and properties vary depending on the plant type and variety. The distinctive taste and fragrance of the oil are due to its high citral content (70–80%), along with myrcene, limonene, geraniol, farnesol, and citronellol.

- Medicinal Properties: The oil is a natural antiseptic and antifungal agent, used to prevent the spread of infectious diseases.

- Insect Repellent: Lemongrass is effective in repelling and eliminating insects.

- Chemical Composition: The leaves and roots contain traces of hydrocyanic acid and a compound resembling insulin.

Figure (05) : Cymbopogon Citratas Plant.

Scientific Name : Cymbopogon Citratas	**Scientific Classification**
	English Name: Lemon Grass Family Poaceae: (Grass Family) Habitat: Tropical or Subtropical Regions Moisture: Very Humid, Semi-Humid, or Semi-Arid Propagation: Division, Seed Planting, and Seedling Transplantation Care : Moderate

Source:www.floridata.com/Plants/Cyperaceae/Cyperus%20papyrus/51
1. Date de consulter : 14/01/2024.

4-2-3- Economic Importance of Lemongrass

Lemongrass is considered one of the most economically significant herbs, attracting agricultural investors worldwide due to its numerous benefits. It provides a stable annual income and contributes to boosting the national income of the producing region. Lemongrass stems and leaves are marketed in vegetable markets for human consumption or used to prepare traditional medicines and remedies. The economic importance of lemongrass lies in its edibility and versatility. It is consumed in various ways, such as being cooked as a vegetable, added to soups, salads, and chicken dishes, or used as a spice from the base of its leaves. Lemongrass imparts a unique flavor to dishes, and its leaves are also added to meals to enhance their lemon flavor. Additionally, lemongrass leaves are used to prepare a tea with multiple benefits, including alleviating anxiety and stress. Its economic significance further increases with the extraction of its oil, which is used in the production of soft drinks. Lemongrass is also valued as a medicinal herb, known for helping to lower blood cholesterol levels, eliminating dandruff, and reducing high blood pressure.

4-3-Oleander Tree

The oleander family, in general, includes highly toxic and dangerous plants for both humans and animals. Despite their toxicity, many of these plants also have medicinal value. The family comprises about 1,300 species of herbs, shrubs, and trees belonging to approximately 300 genera, most of which are native to tropical and subtropical regions. The species Nerium oleander (britannica, 2022), commonly known as oleander or "donkey poison," is a popular ornamental plant in warm regions worldwide, including in Saudi Arabia, where it sometimes grows as a wild plant. The oleander tree has been known since the era of Greek civilization under three names: Rhododendron, Nerion, and Rhododaphne.

4-3-1- Description of the Oleander Tree

- Plant Characteristics: The plant typically produces a milky sap. Its flowers form in clusters or cymes, with sepals consisting of five lobed segments. The corolla comprises five united petals, twisted in the bud, and contains stamens fused into the corolla tube. The plant produces granular pollen grains.

- Reproductive Structures: The ovary is composed of two carpels, resulting in a follicular fruit or a drupe with a single stone, or occasionally a berry-like fruit.

- **Leaf Structure:** The leaves are toothed, rough, and rigid, usually opposite but more commonly arranged in whorls of three, rarely four.

- Flowers: The flowers are attractive, red in color, and have a pleasant fragrance (شيطروب et al., 2022). They grow in terminal clusters. However, all parts of the plant are extremely toxic as they contain cardiotoxic compounds. For this reason, planting oleanders in populated areas or areas accessible to children has been prohibited in Saudi Arabia.

- Soil and Climate Tolerance: The plant thrives in high-salinity soils (up to 5,000 ppm) and can withstand frost temperatures as low as -6°C.

- Planting Locations: Oleander is planted in homes, public spaces, street landscaping, line plantations, soil cover, hill afforestation, hanging gardens, parks, floral hedges, small valley farms, urban areas, and wadis.

- Growth and Physical Attributes: The plant grows relatively quickly, reaching a height of 2–3 meters and a spread of 2–6 meters.

- Flowers and Fruits: The flowers are pale pink, and the blooming season extends from May to the end of September. The fruit is pod-shaped, measuring 12–18 cm, and is highly toxic.

Figure 6 : Oleander Tree

Scientific Name : Oleander Nerium	**Scientific Classification**
	Family Name: Apocynaceae Habitat: Mediterranean or semi-Mediterranean regions Humidity: Very humid, semi-humid, or semi-arid Propagation: Cuttings, seed planting, or transplanting seedlings Care Level: Low Vegetative Growth Period: Perennial

Source : www.floridata.com/Plants/Cyperaceae/Cyperus%20papyrus/511. Date de consulter : 14/**01/2024**

4-3-2- Environmental Importance of the Oleander Tree

Some invertebrates are unaffected by the toxins of the oleander tree and feed on its leaves. Specifically, the larvae of the Wasp Moth feed on oleander leaves, consuming only the pulp surrounding the leaf veins while avoiding the fibers. Similarly, the larvae of the Common Crow Butterfly and the Oleander Hawk Moth also feed on oleander leaves, retaining or modifying the toxins to make themselves unpalatable to potential predators like birds (Amiri et al., 2022). Oleander flowers require insect visits for seed production and appear to rely on a deceptive mechanism for pollination. Their conspicuous corolla serves as a strong visual signal to attract pollinators from a distance. However, the flowers lack nectar and provide no reward to their visitors. Consequently, they receive very few visits, similar to many other non-rewarding flower species.

Conclusion

This study revealed the following insights:

- Phytoremediation can be one of the most successful sustainable agricultural practices. Wastewater should not be viewed as a problem to be eliminated but as a valuable water resource that can be utilized and recycled.
- The oleander plant demonstrated a high capacity to remove pollutants, achieving an efficiency of 80%. The reduction in pollutants underscores the importance of reusing wastewater through phytoremediation.
- Treated wastewater is a reliable water resource that can support irrigation of green belts.
- Using treated wastewater can enhance the tourism sector by irrigating forests, gardens, squares, green spaces, ornamental plants, lakes, fountains, and artificial waterfalls, as well as maintaining bird sanctuaries and ornamental fish ponds—serving as an alternative to freshwater.
- Treating wastewater helps protect the environment from pollution, reduces pressure on freshwater resources, minimizes reliance on desalination or groundwater extraction, and combats desertification by planting forests and timber trees that reduce carbon dioxide emissions. Treated wastewater can also be used for cleaning streets, building exteriors, drainage systems, firefighting, and construction.
- The goal of wastewater treatment is to address water shortages for irrigating green spaces, making this project a viable solution to mitigate water scarcity.
- Implementing wastewater recycling strategies through phytoremediation represents a profitable environmental investment aligned with sustainable green development, achieving self-sufficiency in irrigation water.

Recommendations

- Support applied research and leverage it to promote the reuse of wastewater, given its significant role in water security.
- Develop and improve wastewater treatment technologies to reduce costs and rely on local resources.
- Encourage the use of treated wastewater for irrigating green spaces, thereby reducing reliance on freshwater consumption.
- Create opportunities for infrastructure investment, particularly in wastewater treatment plants and ponds, to enhance service efficiency.

- Prohibit the use of untreated wastewater due to its impurities, as it contains significant contaminants, including human waste, harmful microbes, toxins, and pathogens that pose risks to human health.
- Adopt exceptional ideas and implement scientific research findings in hydroponic agriculture specifically and sustainable green development more broadly.

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