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Using A Subsurface Vertical Flow System to Remediate Municipal Wastewater

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Abstract: The goal of this study is to determine the efficacy of plants in the treatment of municipal wastewater (MWW) utilizing the aquatic plant common reed, also known as Phragmites australis. Two glass basins with dimensions of (60 cm x 26 cm) and a height of (60 cm x 26 cm) have been developed for this purpose (30 cm). In this investigation, two basins were employed: one served as a reference, while the other was used to conduct tests using synthetic and actual city wastewater. The plant treatment basins with a vertical subsurface flow (VSSF) system was used in this investigation because it provides greater ventilation. Furthermore, the retention duration is many hours due to water molecules penetrating the basin's layers of packing materials, which have a rather high hydraulic conductivity. Three layers of aggregates, sand, and agricultural sand were used to cover the basins' bases: the first layer was 3 cm of aggregates, the second was 3 cm of sand, and the final layer was 4 cm of agricultural sand. Before beginning the experiment, the plants were acclimated for two weeks. To imitate municipal wastewater, lab-created synthetic wastewater was employed. Samples were collected and tests were performed after four weeks of running the trials to determine certain significant pollution indicators and their elimination percentage. TDS= 20.6 %, TSS= 65 %, BOD5=75 percent, COD=64.1 %, and TH= 47.2 % were the findings. The capacity of Phragmites australis to function as a biofilter in the treatment process was demonstrated by its use in the phytoremediation of municipal wastewater.

Keywords: Municipal wastewater, phragmites australis, phytoremediation

1. Introduction

Most developing countries are currently confronted with a slew of environmental issues, particularly those relating to municipal wastewater treatment. Untreated wastewater disposal has an impact on surface water, which is prone to become endemic to bacteria and dangerous microbes. It has a foul odor and is not suitable for human consumption. (Danh et al. 2009). Because most third-world nations lack an integrated sewage network, wastewater is one of the most serious public health issues they face. Some wastewater includes a large number of aerobic and anaerobic bacteria as well as a large amount of organic substances. As a result, dumping sewage into rivers without treatment will pose a serious environmental threat. (Farid et al., 2014). More than 99 percent of wastewater is water, with the rest consisting of a mixture of soluble and colloidal molecules, organic and inorganic particles, including microorganisms, viruses, bacteria, and fungus. (Kumar & Chopra, 2018). Municipal wastewater is described as wastewater generated mostly by eating, dishwashing, scrubbing, toilets, showers, and sinks, as well as wastewater from municipal wastewater resources. Toilet drains, industrial waste, hospital waste, agricultural waste, human excretions, storm water flow, and any other dangerous,

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toxic, or biological waste are also included. (Ajibade et al., 2013). In the domestic municipality, municipal waste water has a wide range of dissolved and suspended pollutants, as well as a greater organic matter concentration. (Kumar & Chopra, 2017).

Treatment methods include the employment of complex procedures using high-cost chemicals that may harm the environment's equilibrium. Since of these factors, natural purification has become increasingly important, because if untreated wastewater is left untreated and aggregated in a certain location for an extended length of time, it may generate gases as a result of bacterial development, resulting in an unpleasant odor. Furthermore, it might include dangerous bacteria and poisonous chemicals. It lowers the dissolved oxygen level required by microorganisms to oxidize organic materials when released directly into water bodies. As a result, water is unfit for human consumption.

Untreated municipal wastewater is a major source of water quality degradation in many developing nations (Kumar & Chopra, 2016). In the context of the environment, bioremediation refers to the use of organisms with the potential to reduce pollution levels through biological-metabolic processes by the organism employed to reduce pollution based on the organism's capabilities. Phytoremediation is a type of bioremediation that relies on the capacity of particular plants to lower pollution levels in wastewater through certain metabolic processes (Li et al., 2013). Despite the fact that the notion of using plants with the ability to remove and extract pollutants has been known for a long time, it was only put into reality in 1983. Plants are being employed in a wider range of procedures to remediate polluted water and land, including any processes in which plants are used to contain, isolate, or remove contaminants. Some research compared different sets of tiles (Angassa et al., 2019).

The scarcity of water in Iraq's Tigris and Euphrates Rivers was caused by upstream nations building dams and reservoirs, which have a larger influence on the Tigris and Euphrates rivers' water imports. As a consequence of these nations' continued participation in different activities of water reservation and exploitation, the negative effects of shortage have risen. As a result of these activities, water revenues have decreased, resulting in diminishing agricultural land and increasing the pace of desertification, in addition to poor water quality and lack of fertility. In addition to the above, salt levels in those waterways have increased.

Phragmites australis is a well-known aquatic plant with all or part of its vegetative organs visible or rising above the water's surface (Dana, 2014). Stottmeister et al. (2003) Wetland plants were shown to be important in the adsorption, absorption, and dispersion of large rhizosphere purification surfaces to microbial colonization. It is generally known that wetlands plants can transport huge amounts of oxygen to their roots. The majority of the oxygen is used by breath within the plant or by plant-based carbon-supported microbes. A radial waste of oxygen plant is one that has surplus oxygen discharged (ROL) (Li et al., 2013). Root diameter variations have been linked to increased internal air space cross-cutting, resulting in increased oxygen transport in previous research (Bezbaruah and Zhang, 2004). Phragmites australis thrives in flooded areas and along river banks, adapting well to a variety of climatic situations. Because of its rapid growth rate and great capacity for creating huge amounts of biomass, P. australis is classified as an emergent plant utilized in the treatment of contaminated water (Angassa et al., 2019). The purpose of this study is to assess the efficacy of the municipal wastewater phytoremediation (MWW) process by employing Phragmites australis in the treatment of such wastewater to the point where it may be safely released to water systems.

2. Materials and Methods

2.1 Phragmites Australis Plants

The reed species *Phragmites australis*, a major aquatic plant on the banks of the Tigris River in Salah Al-Din Governorate, Iraq, was employed in this study. The plants were collected on the banks of the Tigris River at Tikrit University during the winter season, taking into account the convergent collection time. The plants were rinsed in water to remove suspended debris and clay from their roots, then placed in plastic bags until the planting technique in the proposed planting basins (fig. 1) was determined. 30 plants per square meter were extensively grown in the experimental ponds. This criterion was chosen based on the findings of a prior research (Reddy, 1983). Before beginning the tests, the plants were grown and acclimated for two weeks.

Fig. 1 - *Phragmites australis* aquatic plants on Tigris River banks

2.2 Wastewater Samples

Synthetic wastewater samples were utilized to acclimatize aquatic plants before sampling actual municipal wastewater from the AL-Dhibaei Municipal Wastewater Treatment Plant (WWTP) in Tikrit, Iraq. There are two types of wastewater utilized. Several mineral complexes (mineral components). As shown in Table 1, this mineral salt medium (MSM) contains a variety of organic and inorganic chemicals that reflect synthetic wastewater. Organic substances such as milk and peptone have been introduced to synthetic wastewater samples as a source of living mass.

Table 1 - Mineral Salt Medium (MSM)

Compound	Chemical formula	Added amount
a. Mineral compounds		
Potassium phosphate	K_2HPO_4	15
Calcium chloride	$CaCl_2$	20
Magnesium sulfate	$7H_2O.MgSO_4$	20
Zinc sulfate	$ZnSO_4$	1
Ferric chloride	$FeCl_3$	2
Sodium bicarbonate	$NaHCO_3$	50
Ammonium chloride	NH_4Cl	10
b. Organic compound		
Peptone	-	50

2.3 Experiments Basins

Experiments were carried out at Tikrit University's Department of Environmental Engineering laboratory. Glass basins with dimensions of (60 cm x 26 cm) and a height of (60 cm x 26 cm) (30 cm). As indicated in Fig.2, the basin base was covered in three layers: 3 cm aggregates in the first layer, 3 cm sand in the second layer, and 4 cm agro-sand in the third layer. The two basins were utilized in this work, one as a reference and the other to conduct synthetic and actual municipal wastewater bio-treatment studies. A vertical subsurface flow regime was used to deliver the wastewater samples, whether synthetic or genuine (VSSF). For three months, the studies were carried out in operating modes of the hydraulic loading rate (HLR = 0.015 m/d). The treated wastewater from each basin was collected through a pipe installed at the basin's end.

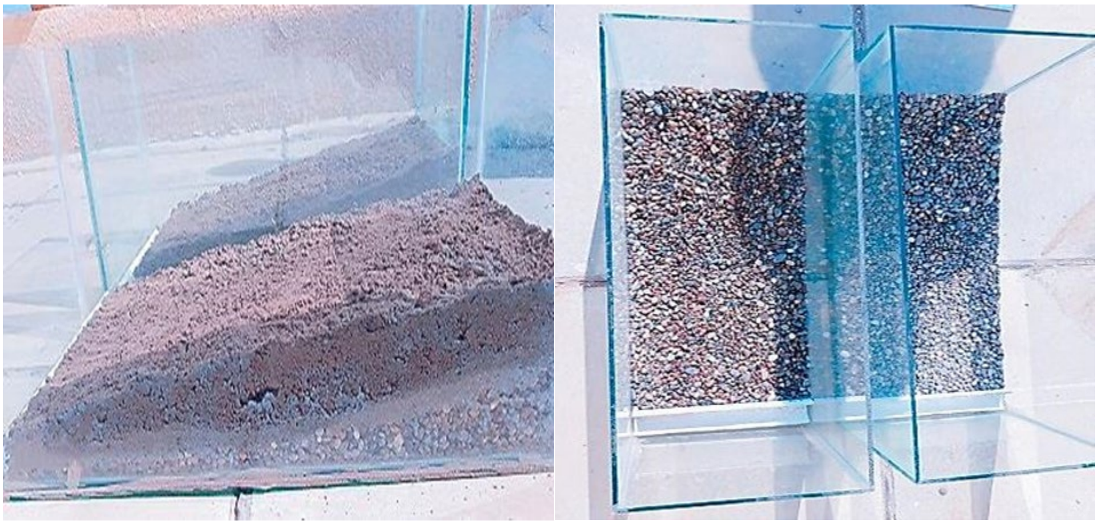

Fig. 2 - Glass basins used in the experiments

2.4 Vertical Subsurface Flow Regime

The effectiveness of a number of natural and built wetlands in Germany was investigated, and systems with a mixture of sand and gravel layers and vertical surface flow produced the greatest results (Hagendorf & Hahn, 1994 Vertical Subsurface Flow (VSSF) was chosen as the phytoremediation system's regime in this investigation because it provides greater ventilation. Furthermore, the retention duration is many hours due to water molecules penetrating the basin's layers of packing materials, which have a rather high hydraulic conductivity (Fig.3).

Fig. 3 - Experiment plants after cultivation into basins

2.5 Plant Growth

At the end of the experiment, the plant growth was measured by picking three out of ten plants in the same experimental unit at random using the technique described by (Hadad et al., 2006; Li et al., 2013). The root was then determined, as well as the fresh weight. Plant samples were dried at a constant weight at 70 degrees Celsius. The above-water biomass (total of shoots and leaves) and dry root biomass (g/m2) are provided in grams per square meter (g/m2). Eq.1 was used to calculate the relative growth rate (RGR), which was based on total dry biomass.

$$GR = \frac{\ln W_2 - \ln W_1}{T} \qquad (1)$$

Where:
RGR: relative growth rate of a plant, (g/d).
W_1 and W_2: the initial and final dry weights of used plants, respectively, of a whole plant sample, (g).
T: experiment time, (d).

2.6 Physical and Chemical Investigations

The studies were carried out using the analytical procedures outlined in Standard Methods. (APHA, 2005). The pH of the effluent was measured before and after phytoremediation trials using a pH meter (HANA, HI.8424). The turbidity of the water was measured using a turbidity meter (HANNA, HI 93703-11). TDS (total dissolved solids) were measured using a TDS meter (WA-2015). Titration techniques were used to determine total hardness (TH). The biochemical oxygen demand (BOD5) was determined using a 5-day incubation technique, whereas the chemical oxygen demand (COD) was assessed using the Open Reflux Method using potassium dichromate as an oxidant (Kumar & Chopra, 2017).

2.7 Calculating The Percentage of Removal

Following the implementation of phytoremediation trials, the % elimination of each pollutant indicator was calculated using the following equation: Eq.2:

$$R = \frac{C_1 - C_2}{C_1} \times 100 \qquad (2)$$

Where:
R: the percentage of pollutant removal (%).
C_1: Initial concertation of pollutant before phytoremediation experiments, (mg/L).
C_2: Final concertation of pollutant after phytoremediation experiments, (mg/L).

3. Results and Discussion

3.1 Characteristics of Municipal Wastewater (MSW)

Table 2 shows the values of several physical and chemical parameters such as PH, TDS, EC, BOD5, COD, and TH in genuine municipal wastewater before and after phytoremediation studies using *P. australis.*

Table 2 - Values of pollutant indicators of municipal wastewater before and after phytoremediation using *P. australis*

Pollutant indicator value	Before phytoremediation	After phytoremediation (average value [1])	Removal percentage (%) [2]
pH	7.6	8.8	-
TDS ((mg/L)	2645	2100	20.6
TSS (mg/L)	500	175	65
BOD_5 (mg/L)	160	40	75
COD (mg/L)	390	140	64.1
TH (mg/L)	360	190	47.2

The use of *P. australis* in biotreatment experiments resulted in a slight increase in wastewater pH values, with the reading rising from 7.6 to 8.8 for the synthetic wastewater model in the first week, which can be explained by photosynthesis by the processing plants, which leads to the continued disintegration of carbonate and bicarbonate ions (Stottmeister et al., 2003), This, in turn, will raise the pH during the day and decrease it at night. Some plants have the ability to serve as a regulator by releasing or attracting positive or negative ions in order to attain environmental equilibrium (Al-Khafaji et al., 2016).

The results reveal that the common reed did not have a high efficiency in decreasing TDS (20.6%), which might be because the breakdown processes were high and beyond the plant's ability to reduce it for a short period. These findings are similar to those of earlier research by Kazem and Al-Hatimi (2017). The data also show that P. australis was reasonably successful in eliminating total suspended solids (TSS) during the course of the trial. TSS levels fell from 500 mg/L to 175 mg/L. This considerable reduction is owing to the aquatic plant's high capacity for TSS filtering and sedimentation. *P. australis* acted as a biofilter, collecting suspended particles and absorbing them with water, or pushing them to the bottom, filtering the water and enhancing its clarity. These findings backed up the claims made by academics like Akbar et al. in 2014. The entire suspended material was eliminated by more than 90% in their research. In their study of utilizing P. australis in the treatment of wetland, Kadlec & Reddy, 2001, calculated that TSS reduction was 70%.

TSS estimate is a critical criterion for evaluating the performance of wastewater treatment methods like sedimentation basins.

BOD5 removal was assessed to be 75 percent, which is one of the most significant indications in assessing the degree of pollution of water with organic compounds, as well as an indicator of the efficacy of the treatment procedure used at WWTPs. This decrease indicates significant aerobic decomposition of organic matter while also confirming the self-purification process in the treatment basins via the Rhizoremediation process carried out by P. australis plants by providing oxygen around the root zone, thus creating sufficient aerobic conditions in the rheumatic region, which in turn boosts the microorganisms in that region, Physical activities such as sedimentation and biological processes such as microbial degradation enhance the microorganisms in that location, allowing them to eliminate organic contaminants from wastewater. A lot of researchers have raised this concern (Akbar et al 2014, and Manios et al., 2003). The chemical oxygen demand (COD) was an excellent indication of wastewater pollution, particularly industrial effluent. The plants' relative growth rate (RGR), which varied substantially depending on the amount of sewage present, grew faster in diluted and synthetic samples.

4. Conclusions

Phragmites australis, often known as common reed in English, was chosen for this study because of its various benefits, including its ability to produce oxygen gas at a rate of 5-12 mg of O2/m^2.d. Because of the high rate of oxygen generation, this plant demands a lot of nutrients, which improves its ability to extract nutrients from wastewater as well as its antibacterial capability.

The pH of the wastewater was slightly increased by P. australis. This is because the processing plants' photosynthesis will continue to disintegrate carbonate and bicarbonate ions to create hydroxyl ions and carbon dioxide gas, increasing the pH value during the day and decreasing the pH value at night. Due to the phenomena of evapotranspiration and its association with increasing the mass of plants in the study basin, the value of the produced model (reading zero) in the electrical conductivity EC decreased somewhat. In addition to the role of aquatic plants in the phytoremediation process, which involves the breakdown of metal complexes through decomposition and the release of specific metals in the form of dissolved ions with electrical conductivity, which raises electrical conductivity values.

The results showed that P. australis was not very efficient at decreasing TDS, which might be attributed to high breakdown processes that were beyond the plant's capacity to reduce it in a short period of time. During the trials, the reed plant was successful in eliminating total suspended solids (TSS). Phragmites australis functions as a biofilter by attracting suspended material, absorbing it with water, or pushing it to the bottom, thereby filtering and improving the clarity of the water. In terms of the change in BOD5, which is one of the most significant indicators in evaluating the degree of organic matter pollution of water as well as an indicator of the efficacy of the treatment procedure utilized, it was decreased by 75%.

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