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Evaluation of Treated Wastewater from Constructed Wetlands for Reuse in Agriculture

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ABSTRACT

This study was conducted to find out the mechanism of operation of the wetlands station at the University of Basrah, and to find out whether the water purified by the station had a positive impact on the environment surrounding humans, as well as whether it was possible to reuse the treated water for various human uses. The treatment of wastewater is essential to safeguarding the environment and the health of people and animals. Improper treatment of wastewater can lead to contamination of our water sources, harm to natural ecosystems, and grave illnesses. Over the course of a full year, from March 2018 to February 2019, samples were collected and tested for a number of parameters, including temperature, pH, electrical conductivity (EC), total suspended solids, chemical oxygen demand (COD), sulfate, ammonium, and nitrate. The findings demonstrated that the acceptable irrigation water specifications for Iraq were exceeded by high values of EC, COD, and total suspended solids at some months. Due to the high concentration of dissolved solids in sewage, EC values were high and exceeded the allowable limits for irrigation water used in Iraq. Additionally, in some months, COD is higher than what is allowed in Iraq. The results of the analyses proved that the treatment plant was working well and fulfilling the purpose for which it was established. It was able to get rid of water pollutants, producing treated water suitable for some human uses, such as agricultural irrigation. Thus, the station has achieved its two goals: the first is to prevent environmental pollution, and the second is the possibility of using treated water, which helps reduce the water crisis that the southern regions of Iraq are suffering from.

1. INTRODUCTION

Wastewater is the consumed water that a person spends to meet his daily needs for domestic, industrial, and commercial purposes. The amount of water is very large, and its quantities are increasing day after day to affect the environment directly as well as human and water security.

The potable water sector in Iraq, and particularly in Basrah city, faces numerous challenges. Resource depletion, rising pollution levels, and salinity issues are widespread in central and southern Iraq. These obstacles present opportunities for researchers to treat the wastewater and study the reuse of wastewater treatment with low costs.

The issue of wastewater reuse serves two aspects: The economic aspect and the environmental aspect. Firstly, in economic terms, we mean the ability to treat this water, cover the cost, and preserve the environment [1]. Secondly, the environmental and health impact, which is detriment, must be taken into consideration and must meet the regulatory conditions that remove as much as possible the specter of disease in the event of using this treated water [2-5].

The treatment of wastewater is a crucial step in addressing the issue of water scarcity. There are many approaches to treating wastewater, and one approach that has proven to be affordable and simple is the use of wetlands for treatment [6].

Constructed wetlands offer a low-cost, effective, secure, and environmentally friendly method of wastewater treatment, making them highly suitable techniques. Wetlands have many positive effects on the environment, including helping to preserve water quality, lessening the effects of drought and flooding, locking up carbon, and providing habitat for endangered species.

Despite the benefits of reusing treated wastewater for environmental purposes, irrigation with treated water results in increased salinity of the land, land sealing, and sodium buildup, all of which raise the risk of increased runoff and erosion. A specific worry regarding environmental issues is the issue of long-term sustainability.

Nowadays, one of the most popular techniques in use worldwide is the construction of wetlands. Numerous studies have noted that the substantial benefits of constructed wetlands have been thoroughly examined and extensively employed for the treatment of wastewater from a variety of sources, including household and commercial wastewater [7]. Wetlands were found to be among the most effective treatment technologies currently used in urban wastewater reuse for irrigation. They have advantages due to their low maintenance costs and energy requirements, as well as their ability to remove pollutants.

Voulvoulis [8] studied at the advantages and disadvantages of using recycled water as a backup supply of water when moving toward such an economy. The findings demonstrated that while a broader circular economy perspective could more effectively address many of the obstacles to water reuse, such as public perception, cost, and regulatory issues, caution must be taken to regulate and monitor the levels of contaminants in the recycled water according to its intended use. Variations were discovered in the global reuse programs and regulations that are currently in place, indicating the necessity of evaluating the advantages and disadvantages of each situation individually. Reuse and recycling are essential components of a circular economy strategy and provide a way to enhance water supply through improved wastewater management. In addition to guaranteeing the adequate and dependable operation of water reuse systems and appropriate regulatory enforcement, such a strategy should also ensure the safety of water reuse and, for that reason, apply water quality standards appropriate to the particular use.

Reusing water presented a number of issues and difficulties for both the environment and human health, as demonstrated by Helmecke et al. [9]. Chemical risks are included in this. Urban wastewater treatment plants typically release a variety of organic compounds into their effluent. Such chemicals that are left in the water after treatment could endanger public health, contaminate nearby land and water supplies, or even jeopardize sources of drinking water. To ensure that chemicals are not introduced into the food chain, it is necessary to regulate their potential to travel to and accumulate in the edible portions of fruits and vegetables after they are exposed to them in irrigated crops. Antibiotics carried by wastewater are beginning to cause environmental problems, which is starting to draw attention. For these reasons, stricter quality standards for agricultural irrigation are necessary to reduce chemical hazards. To achieve and guarantee safe irrigation, a combination of methods including chemical reduction at the source, technical and natural water treatment procedures, particularly to eliminate chemicals with persistent, bio-accumulative, and toxic or persistent, mobile, and toxic properties, good agricultural practices, and additional preventive measures will be required.

Tortajada [10] discussed about how recycled wastewater, sometimes referred to as reused water, has the potential to enhance sanitation and provide a sizable supply of safe drinking water in support of the Sustainable Development Goals.

All the papers [11-16] gave information on the importance of reuse in wastewater treatment.

The problem of the study is that water security is in grave danger, and this is due to population growth on the one hand and misuse of water on the other, in addition to the phenomenon of global warming.

This study aims to:

1. To evaluate the method of treating wastewater using wetlands.
2. Examination of treated wastewater according to Iraqi standards.
3. Determine the quality for reuse of this treated water.

2. METHODOLOGY

Basrah University, which is situated at latitude 30°33'20.531"N and longitude 47°44'54.283"E, is home to the built wetland station. In Figure 1, it is situated in close proximity to the traditional wastewater treatment system. Water could therefore be transferred from the primary septic tank to the newly built wetland station [17, 18]. Basin in Figure 2 was constructed out of fiberglass and stood on a concrete base, measuring 300 cm in length, 120 cm in width, and 100 cm in height. Located beneath the storage tank, it can be supplied by gravity. Sand and gravel were dried after being cleaned with tap water. The media of the basin was filled with washed and dried gravel and sand to a depth of 60 cm; this was placed from coarser to finer [18]. The aquatic merge plant included in this system is called Typha Domingo's [19]. Water that has been retained beneath the bed's surface moves horizontally from influent to effluent as it passes through the wetland.

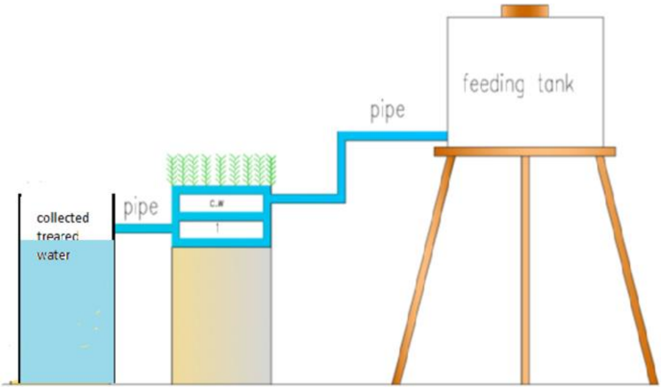

Figure 1. Built systems for wetland stations

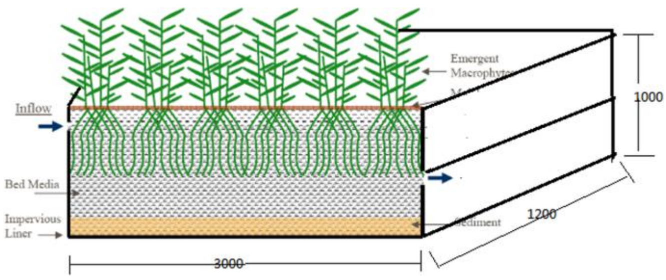

Figure 2. Wetland basin constructed

3. MANNER OF OPERATION

A two-inch submersible pump is used to raise the primary wastewater treatment into the storage tanks, where it is then applied to artificial wetlands. A 2500 Liter storage tank is placed atop a tall iron stand and covered in wood plates and an iron plate for roofing. Following a 24-hour stay in a sedimentation basin as a secondary treatment step, water enters the wetland cells**.** Wetland cells are intended to serve as a tertiary treatment stage, holding water for six days. With a controlled level outlet, the water's depth is kept constant at 0.6 meters.

4. COLLECT STUDY SAMPLES

A laboratory study was conducted on samples of water entering the wetland station and treated water leaving the wetland station. In accordance with physical and chemical analyses, water samples were drawn from the treated wetlands twice a week. After the wetland has been treated, samples are collected from the inlet and outlet to evaluate the water's quality. Ninety-two samples were examined, 36 of the samples had their temperature, pH, and EC measured in the field, the remaining 56 samples had their COD, total suspended solids, sulfate, ammonium, and dissolved oxygen (DO) measured in the laboratory.

5. TESTS NESSCARY FOR THE STUDY

The following elements have been studied and are considered important in the reuse of treated wastewater. The standard procedures were followed when conducting the tests [20].

5.1 PH

The goal of conducting this test is to determine the pH of the water sample sent to the laboratory, as the expression pH expresses the intensity of acidity or alkalinity of the reaction of water in a solution as a function of the hydrogen ion concentration. The effect of this number on the increase in the rates of dissolved substances in natural water may be attributed to the increase in the intensity of acidity with a decrease in the pH.

5.2 EC

This test aims to measure the EC of the water sample under analysis and experiment, that is, the ability of the sample to conduct electrical current under the influence of an external electrical current. In water, this ability is related to the amount of ion concentration in the water, or, in other words, to the total concentration of dissolved materials in the water. As these materials increase, the conductivity increases. Here, the water being tested has a high EC, as many dissolved materials abound in the wastewater. Increasing the EC of the water sample means the possibility of increasing pollution.

5.3 Total suspended solids

That is, the insoluble ones, which are also components of wastewater and are directly proportional to the degree of water loss. What applies to the total dissolved substances applies to them, as determining the total suspended substances, which are the substances remaining on the filter in the filtration process for the sample under study, which, along with the volatile and dissolved substances, are an indicator of the amount of organic substances present in the original water from which the study sample was taken, and knowing the concentration of suspended substances. In liquid waste, it is of high importance.

5.4 COD

COD is An indicator of how much oxygen is consumed. An indicator of the quality of the water, a COD is used to quantify the amount of organic pollutants present in a body of water.

5.5 DO

Measurements of DO are crucial for determining the quality of water. For breathing, all aquatic animals require DO. When large algal blooms or other excess organic materials are broken down by microorganisms, low DO or no oxygen levels may result.

5.6 Sulfate

The sulfate SO_4 can give water a bitter or medicinal taste and can have laxative effects. It must be tested because its effects on the water quality.

5.7 Ammonium

The ammonium (NH_4) testing is crucial for the environment and general public health. Reducing the amount of hazardous pollutants released back into the environment is possible by eliminating NH_4 from wastewater treatment facilities.

6. RESULTS

The results of the laboratory analysis were as follows: Table 1 shows the results of the wastewater when it enters the wetlands and the treated water when it leaves the wetlands station.

Table 1. Influent and effluent of wetland treatment

Parameters	Min	Max	Mean	Median	Efficiency%	IQS [21, 22]
pH_{in}	6.3	7.94	7.22	7.2	11.245	4-8.6
pH_{eff}	6.2	9.6	7.215606	7.1		
EC_{in}	2.89	7.9	5.541563	5.8	-64.735	0.7-3
EC_{eff}	3.01	17.8	8.334688	7.69		
TSS_{in}	34	754	154.7	84	91.67	60
TSS_{eff}	6	69	25.5	18		
COD_{in}	176	600	327.4483	320	76.66	100
COD_{eff}	10	246	123.9207	113		
NO_{3in}	3.03	9.98	6.261875	5.965	28.21	5-30
NO_{3eff}	1.8	8.4	4.81375	4.9		
DO_{in}	0	0.7	0.09375	0	78.94	
DO_{eff}	0	5	1.155	1		
SO_{4in}	53.7	1431	328.9344	305.65	67.6	<960
SO_{4eff}	30.7	882	290.9156	250.55		
NH_{4in}	3.3	42	16.83625	16.55	72.425	
NH_{4eff}	0.72	14	5.970625	4.95		

Note: All the parameters are in (mg/l), but EC is (ds/m), and pH is dimensionless. IQS: Iraqi Standard Specification.

Table 2. T-test according to the parameters

Parameters	Before Treatment		After Treatment		T Value	Significance
	Mean	SD	Mean	SD		
COD	327.448	122.0748	123.9207	73.65765	8.377	0.000
pH	7.22	0.48631	7.2158	0.66597	0.03	0.976
EC	5.5416	1.60768	8.3347	2.81466	-5.861	0.000
TSS	84	214.963	18	21.9	2.020	0.074
NH_4	16.83625	9.853634	5.970625	4.018111	7.825	0.000
NO_3	6.261875	2.297953	4.81375	1.826424	4.034	0.001
DO	0.09375	0.221341	1.155	1.002864	-5.790	0.000
SO_4	290.9156	222.9486	328.9344	300.0035	-1.555	0.13

7. STATISTICAL ANALYSIS

By conducting statistical analyzes of the data using the statistical package for the social sciences (SPSS), the following is a description of the results according to their sequence:

From Table 1, it is clear that there are differences between the readings in the results of the water entering and leaving the wetlands. To determine that the exiting water is suitable for agricultural use, a t-test was used to confirm it from a statistical standpoint, and Table 2 shows this.

We note from the previous tables that there are many molecules that agree with Iraqi specifications, and this suggests that wetland treatment needs to arrange some tests in order for the water to be suitable for agriculture.

There are no statistically significant differences at the significance level equal to (0.05) in the suitability of wastewater before and after treatment. To test this hypothesis, a t-test was used, and the results are shown in Table 2.

The preceding table makes it evident that there are statistically significant variations in the suitability of wastewater before and after treatment in wetlands. The differences were clear between their averages before and after treatment. Also, by observing the variables in which differences did not appear, significant differences in their averages are noted. This calls for more scrutiny of water treatment, testing it in agricultural areas, and examining its products in terms of health and safety.

8. EFFECTS OF LABORATORY TESTS

Laboratory tests were conducted on a number of polluting elements that make up wastewater by examining the amount of their presence before and after treatment and then judging the suitability of reusing this water for various uses, as well as the service of treatment in wetlands in ridding the environment of polluting components that are harmful to human health and the environment.

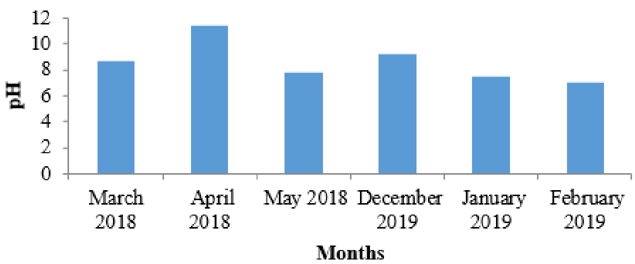

Figure 3. Average values of pH after treatment during a period of study

8.1 PH

The average pH measurement results for water samples collected from wetlands during the study period are displayed in Figure 3. It was found that this number fluctuates in size in accordance with the stage of the treatment process, and is consistent with the specifications of non-waste water after the end of treatment.

8.2 EC

The conductivity of the wastewater was studied before and after treatment. The average measurement of EC in water samples collected from wetlands over the course of the study is displayed in Figure 4. Taking note of the findings shown in Figure 4, the average EC in the water samples varied from 7.3 to 11.3 dS/m. The value peaked in April at 11.3 dS/m, and it fell to its lowest point in February at 7 dS/m. From Figure 4, it shows that it does not match the conductivity exceeded by regular or irrigation water.

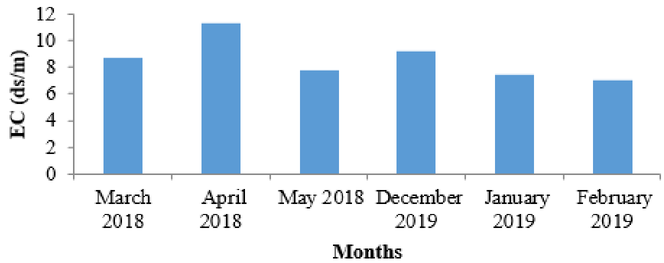

Figure 4. Average values of EC after treatment during a period of study

The availability of ions to plants in the root zone is reflected in EC, which is a measure of the concentration of salt and electrolytes in the solution. Soil EC values are influenced by a number of variables, such as soil type, irrigation techniques, salinity, temperature, and the amount of fertilizer applied. Since nutrient availability directly affects soil EC, monitoring nutrient contents via EC is essential. Lower EC levels may have a negative impact on plant health and yield, while higher EC levels can hinder nutrient uptake, increase osmotic pressure, waste nutrients, and cause environmental pollution. EC is a measure of the salinity and nutrient availability in the growing medium; it has no direct effect on plant growth.

8.3 Total suspended solids (TSS)

Figure 5 shows the results of the average measurement of the total suspended solids in water samples taken from wetlands during the study period.

In the results presented in Figure 5, the highest value was during February, while it reached the smallest value during April. After treatment, this total agrees with what should be in the water that can be used for irrigation.

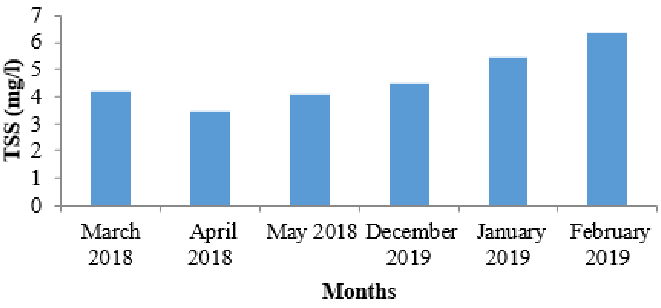

Figure 5. Average values of TSS after treatment during a period of study

8.4 Ammonium (NH_4)

This element is one of the elements that make up fertilizers, and its presence in the exhaust was small. After the completion of treatment, its presence agreed with the specifications of the water that can be used for irrigation. Figure 6 displays the findings of an average measurement of the total suspended solids in water samples collected from wetlands over the course of the study. The average ammonium values during the study period ranged from (4.3 to 9.6) mg/l, according to the results. Plants may absorb nitrogen in different ways based on the growing season. Summertime microorganism activity increases are the cause of the summertime increase in NH_4 removal, that undergo oxidation to form nitrates.

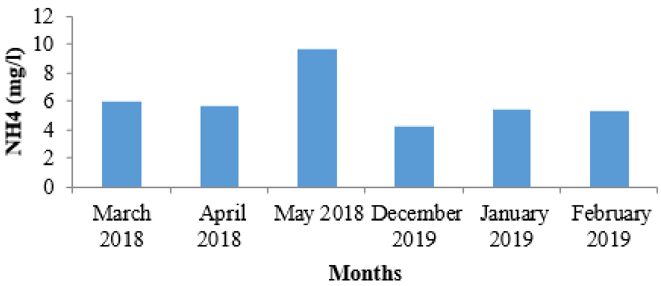

Figure 6. Average values of NH_4 after treatment during a period of study

8.5 COD

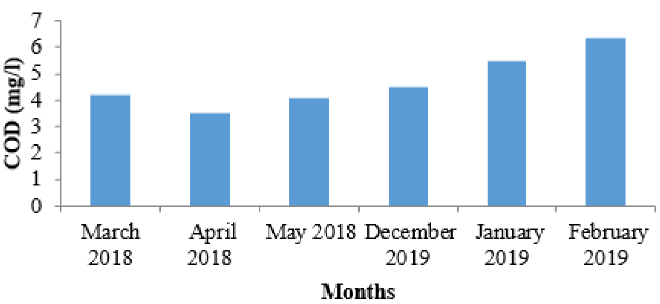

Figure 7. Average values of COD after treatment during a period of study

The increase of this element in the water indicates a lack of water or a defect in the treatment process. Figure 7 shows the results of the average measurement of COD in water samples taken from wetlands during the study period.

Noting the results presented in Figure 7, we find that the average values of COD in water samples ranged between 90.2 and 156.2 mg/l. The highest value was during April (156.2 mg/l), while it reached the smallest value during January (90.2 mg/l).

8.6 Nitrate (NO_3)

Figure 8 displays the findings of the average nitrate measurement made during the study period in water samples collected from wetlands. Because the wastewater is rich in organic nitrogen and ammonium, which oxidize to form nitrates, we find that the average NO_3 values during the study period ranged between (3.5–6.3) mg/l and the values oscillated between summer.

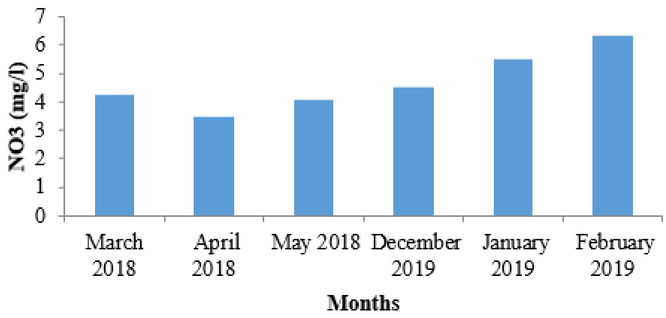

Figure 8. Average values of NO_3 after treatment during a period of study

8.7 DO

Figure 9 shows the results of the average measurement of DO in water samples taken from wetlands during the study period. Through the results during the study period, it was found that the average DO values ranged between 0.68 and 1.64 mg/l, and there was an oscillation in the values between summer and winter because the concentration of DO in water is related to temperature, pressure, and the amount of material in the wastewater that will consume the oxygen.

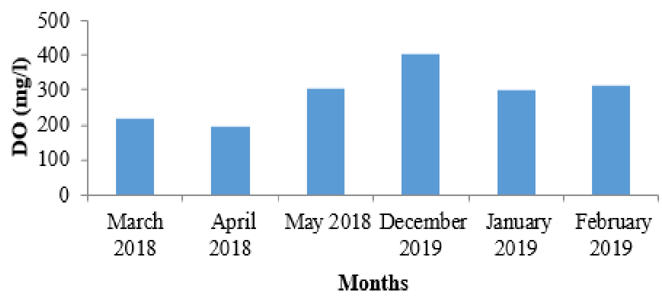

Figure 9. Average values of DO after treatment during a period of study

8.8 Sulfate (SO_4)

Figure 10 shows the results of the average measurement of SO_4 in water samples taken from wetlands during the study period. Through the results during the study period, it was found that the average SO_4 values ranged between (195.8 and 403.6) mg/l. There were no significant sulfate decreases in the wetland treatment because it depends on both influent organic matter and plant root, which exudates have little effect on sulfate removal.

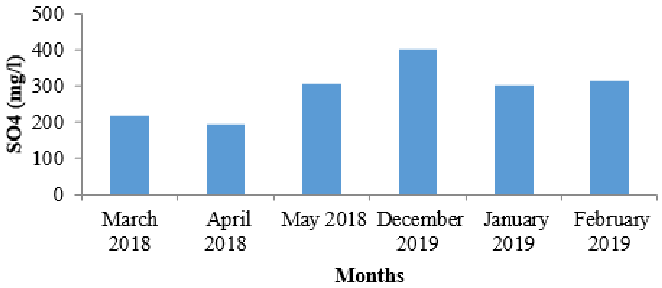

Figure 10. Average values of SO_4 after treatment during a period of study

9. CONCLUSIONS

Constructed wetlands represent an alternative treatment system to conventional treatment systems. Horizontal subsurface flow wetlands exhibit high treatment efficiency for organic and suspended solids. It can be concluded from this study:

The proposed system had successfully produced effluent that met the irrigation quality standard for all parameters, except for COD. In this study, COD removal was 76.66%, TSS was 67%, NO_3 was 28.21%, and NH_4 was 72.43%.

This study proposed a promising low-cost solution that has remarkable implications for the quality of the treated effluent.

The worldwide problem of water scarcity suggests that reusing wastewater is a widely accessible substitute solution to the problem of insufficient water supply, so it can concluded that the constructed wetland under study lowered the concentrations of all the pollutants in the pretreated wastewater. Throughout the course of the monitoring period, the efficacy of contaminant removal varied. Reusing the treated wastewater from the artificial wetland for irrigation is possible.

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