Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.11, 2015

Marginal Water Treatment by Combination of Two Stages of Stepped Cascade Weir and Spray Aerator

Prof.Dr.Dheyaa Wajid Abbood[1] Dr.Ayad Sleibi Mustafa[2] Eitizaz Awad Jasim[3]
1.Mustansiriya University, College of Engineering, Civil Dep.
2.Anbar University, College of Engineering, Civil Dep.
3.Mustansiriya University, College of Engineering, Environmental Dep

Abstract

A combination of stepped cascade weir with spray aerator systems is one of the available ecological treatments to reduce the concentration of pollutants in marginal water and to solve the problem of the water shortage for irrigation and industrial uses in Iraq. An experimental treatment system for marginal water has been constructed and installed at Al- Mustansiriya University, College of Engineering during the period from August 2013 to July 2014. The performance of the treatment schemes has been evaluated by monitoring the quality of marginal water and effluent for some parameters such as pH, Cl^-, BOD_5, COD, Fe^{+2}, and Mn^{+2}**.** Results indicate that the removal efficiencies for COD and BOD_5 is ranged from (43% to 51%), and (44%-52%), that the removal efficiency of ions concentrations such as Fe^{+2}, Mn^{+2}, are (30 %-48%) %, and (33% -48%), respectively, while for Cations such as Cl-, the removal efficiency is (31%-42%).

Keywords: Marginal water, spray aerator, bio-treatment, stepped cascade weir.

1- Introduction

Marginal quality water is defined as that which poses a threat to sustainable agriculture and/or human health by virtue of its quality, but which can be used safely for irrigation provided certain precautions are taken**[1].** Marginal-quality water includes urban wastewater, agricultural drainage water, and saline or sodic surface water and groundwater. ***Urban wastewater*** usually refers to domestic effluent, wastewater from commercial establishments and institutions, industrial effluent, and storm water. Many farmers use treated or untreated wastewater for irrigation. In some areas wastewater is discharged into agricultural drains, and farmers use the commingled water for irrigation. **[2].**

Hydraulic structures, such as stepped cascades and weirs, involve air entrainment _aeration_ and oxygen transfer. Therefore, they can increase dissolved oxygen levels. Weir aeration occurs in rivers, fish hatcheries, and wastewater treatment plants **[3].**

A cascade aerator consists of a series of steps that the water flows over. In all cascade aerators, aeration is accomplished in the splash zones. The aeration action is similar to the flowing stream **[4]**.

In the gravity aeration of wastewater, the aeration process brings wastewater and air into close contact by exposing drops or thin sheets of wastewater to the air. Oxygen diffuses from the air into the wastewater and helps to increase the DO content of the wastewater **[5].** The efficiency of the natural aeration process depends almost entirely on the amount of surface contact between the air and wastewater **[6].** This contact is controlled primarily by the size of the wastewater drop or air bubble. In addition; the efficiency of the natural aeration process depends on the geometry shape of natural aeration type, material properties and flow conditions **[5, 6].**

The primary purpose of water aeration is to increase the oxygen saturation of the water. This can be achieved by using hydraulic structures because of substantial air bubble entrainment at these structures**.** **[7]**.Hydraulic structures can increase dissolved oxygen (DO) levels by creating turbulent conditions, where small air bubbles are carried into the bulk of the flow. **[8]**. The mechanism of aerating over weirs includes three steps. The first one includes minor aeration from water flowing over the weir directly to the jet. The second includes aeration on the surface of the pool from the jet depending on the intensity of surface agitation. The third and most contributing to the oxygenation process is the bubble aeration from air entrained in the jet and pool to which the jet is discharging. **[9]**

Aeration of the wastewater enhances the removal of the Biological Oxygen Demand (BOD), which is the amount of oxygen consumed by the microorganisms in oxidation of the pollutants in wastewater. Aeration is used in different units of a wastewater treatment plant: Pre-aeration, homogenization, biological treatment, nitrogen removal and aerobic sludge treatment. **[10]**.

The main objectives of this study are to improve the quality of marginal water using combination of stepped cascade weir with spray aerator, and to investigate the performance of the system to remove some measured pollutants in marginal water.

2- Materials and Methodology

Marginal water has been prepared from domestic wastewater, leachate wastewater, and some chemical substances. The experiment was performed with a constant flow rate of 0.4 m^3/hr. The laboratory model has been designed and constructed in environmental fluid laboratory at college of Engineering, Al-Mustansiriya University. The lab-scale model has been designed and installed as shown in Figure (1), which consists of different parts as follows:

1- Two Primary tank (42 cm *42 cm *80 cm) of (120) L.
2- Two layers stepped cascade weir, the first layer consists of three steps manufactured from aluminum of dimensions (36 cm *42 cm *80 cm), each step where perforated into 36 holes (10 mm), while the second layer consist of three steps manufactured from granite of dimensions (45 cm *30 cm *30 cm), (30 cm *30 cm *30 cm), and (20 cm *30 cm *30 cm) respectively, three rectangular weirs of dimensions (40 cm *30 cm), (25 cm *30 cm), (15 cm *30 cm) respectively
3- Two Clarification tanks the first for receiving outlet and the other for recycling treated water.
4- Two submerged pumps of maximum head (3.7 m) and maximum flow rate (3.75 m^3/hr), the first is into the primary tank for pumping marginal water, and the second is into the recycling tank for recycling treated marginal water, and Flow meter ranges between (0.4-4 m^3/hr).

Each part of the model is welded to the other by chloroform liquid for Acrylic parts and silicone for PVR and granite. The general arrangement of laboratory unit and the arrangement of cascade basins and spray positions are shown in the plates (1 and 2).

Samples were taken from the (Inlet tank, after spray aerator, after mixing basins, and effluent) as shown in plate (2) to test marginal water quality used during the experiment periodically.

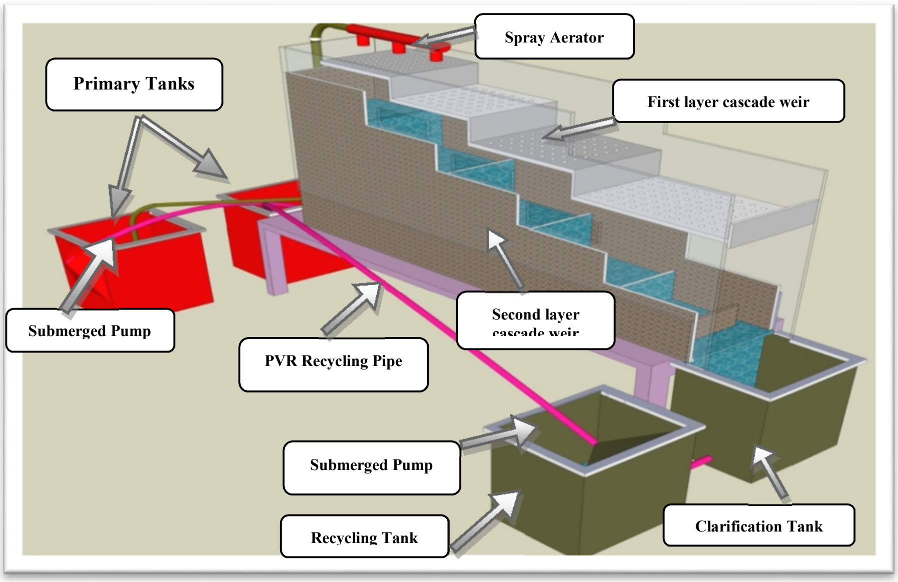

Figure (1): Schematic representation of lab-scale unit.

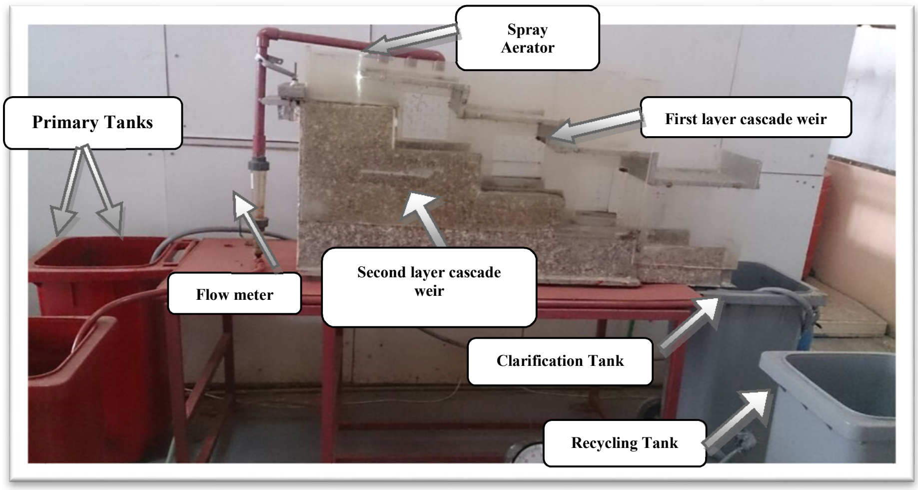

Plate (1): General arrangement of laboratory unit.

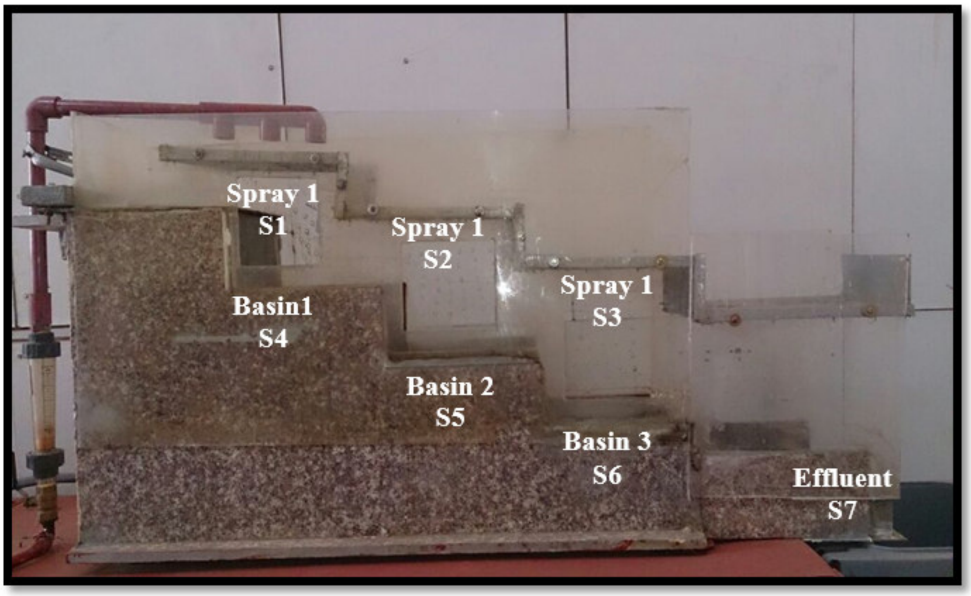

Plate (2): Arrangement of Cascade basins and Trickling Positions.

3- Results and Discussions

Marginal water quality was evaluated along the period from August 2013 to July 2014. The treatment system has been operated using combination of spray aerator and stepped cascade weir. The system was monitored to characterize the marginal water quality parameters efficiencies under different conditions.

Results of pH indicated that the pH values increases in acid solution (3.21-4.62), (4.2-4.46), (5.54-8.26), and (6.14-9.5), low pH means high concentration of carbon dioxide and by aeration CO_2 stripped from marginal water causes increasing in pH value . For pH less than 7, the carbon dioxide is loosely bound to the water and can easily be stripped by aeration, raising the pH to a neutral value.On the other hand pH decreases in alkaline solution (8.43-8.29), (9.26-8.5), (10-9.91) due to the presence of bacteria with makes the alkaline solution.

The initial COD and BOD_5 organic loading of raw influent marginal water were calculated hourly which are ranged between (47.6-89) Kg/m^3/day, and (31-57) Kg/m^3/day respectively. The percentage reduction of COD and BOD_5 organic loading during the run time (4 hours) of the spray aerator, stepped cascade weir, and effluent are (49%, 55%, 51%), and (52%, 57%, 33%) respectively. The correlation between BOD_5 and COD initial organic loading and the percentage reduction for spray aerator, stepped cascade weir, and effluent was recorded as, (0.878, 0.983, 0.916), and (0.516, 0.692, 0.834) this is an indication of that the correlation between COD organic loading and the percentage reduction is less than in BOD_5 as shown in figures from (13 to 18).

Measurements of inorganic elements (Fe^{+2}, Mn^{+2}, and Cl^-) show that the initial concentrations are ranged between (20-59) mg/l, and (1.2-3.3) mg/l, and (0.81-1.96) mg/l respectively. The removal efficiencies of Fe^{+2}, Mn^{+2}, Cl^- during the run time of the spray aerator, stepped cascade weir, and effluent are (49%, 47%, 48%), (44%, 48%, 48%), and (46%, 43%, 42%) respectively. The correlation factor between these pollutant initial concentrations and the removal efficiencies after spray aerator, stepped cascade weir, and overall are (0.987, 0.911, and 0.936), (0.843, 0.927, and 0.848), and (0.878, 0.983, and 0.916) respectively, as shown in figures from (4 to 12).

The experimental results show that percentage reduction of COD and BOD_5 in spray aerator ranged from (41-49) %, and (43-51) %, while the removal efficiency of ions concentrations such as Fe^{+2}, Mn^{+2}, are (30-49) %, and (30-44) %, respectively. For Cations such as Cl^-, the removal efficiency is (31-46) %. In stepped cascade weir the removal efficiency of COD and BOD_5 is ranged from (21-52) % and (42-50) %. Results indicated that the reduction of ions concentrations such as Fe^{+2}, Mn^{+2}, are (32-47) %, and (33-48) %, respectively, while for Cl^-, the reduction efficiency is (32-43) %. The overall percentage reduction of COD and BOD_5 was measured as (43-51) % and (44-53) %, while the removal efficiency of ion concentrations (Fe^{+2}, and Mn^{+2}), were (20-59) %, and (33-48) %, respectively. The removal efficiency for Cl^- was (31% - 42%).

Stepped cascade weir with spray aerator with suitable recirculation removes or modifies the constituents of marginal water using two methods - **scrubbing action** and **oxidation action**. **Scrubbing action** is caused by turbulence which results when the marginal water and air mix together. The scrubbing action physically removes gases from solution in the marginal water, allowing them to escape into the surrounding air. Carbon dioxide and hydrogen sulfide and chlorine (Cl^-) can be removed by scrubbing action. Scrubbing action will remove tastes and odors from water if the problem is caused by relatively volatile gases and organic compounds. Also aeration provides the dissolved oxygen needed to oxide the iron and manganese, it takes 0.14 mg/L of O_2 to oxidize 1 mg/L of iron; and 0.29 mg/L of O_2 to oxidize 1 mg/L of manganese.

Oxidation reaction of iron is:

$4\ Fe^{+2}+O_2+10H_2O \longrightarrow 4Fe(OH)_3\downarrow+8H^+$ …(1)

Oxidation reaction of Manganese is:

$4\ Mn^{+2}+O_2+2H_2O \longrightarrow 4MnOH_2\downarrow+4H^+$ ….(2)

Figures (2) to (24) show the removal efficiencies of all parameters measured in the experimental work.

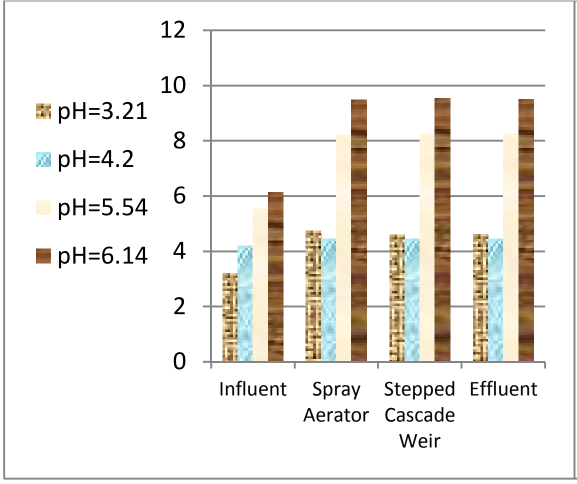

Fig. (2): Variation of acidic pH

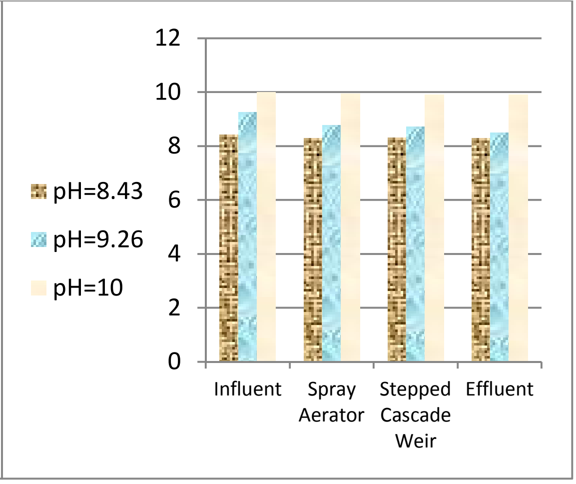

Fig. (3): Variation of alkaline pH

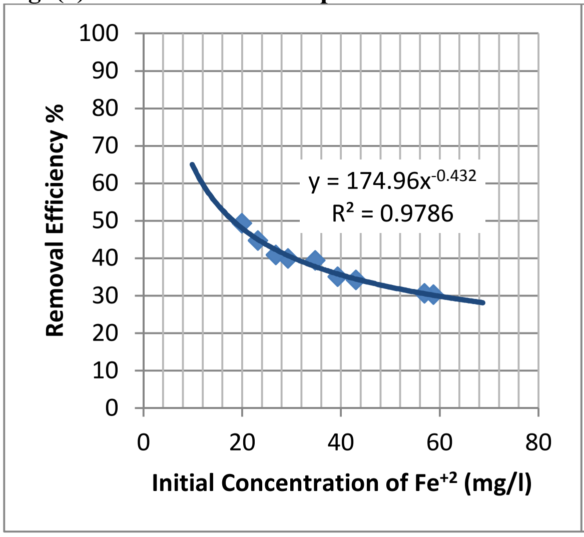

Fig.4:Removal efficiency with influent Fe^{+2} in spray aerator.

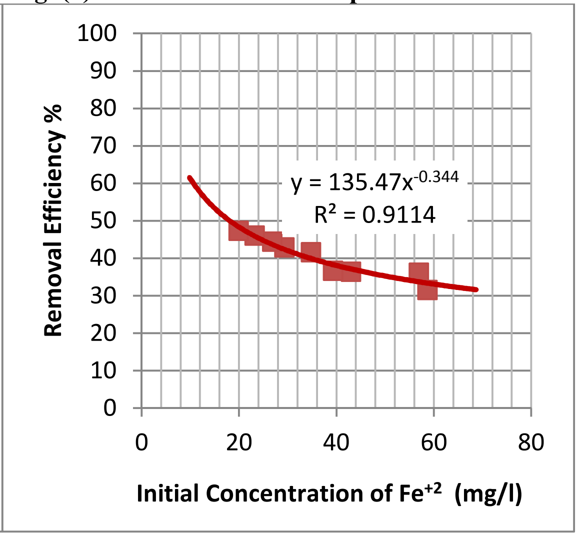

Fig.5:Removal efficiency with influent Fe^{+2} in stepped cascade weir.

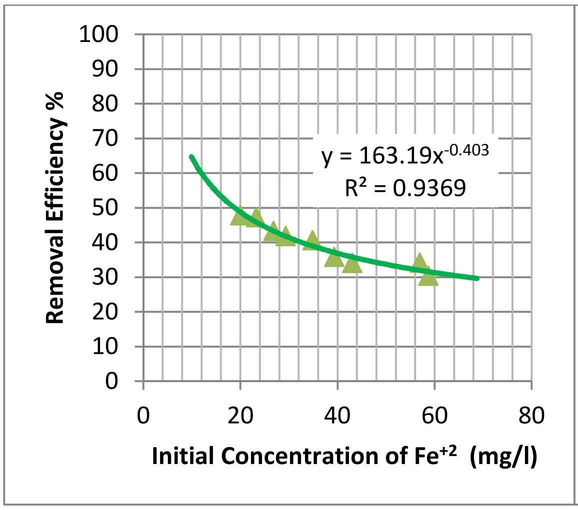

Fig.6: Overall removal efficiency with influent Fe^{+2}.

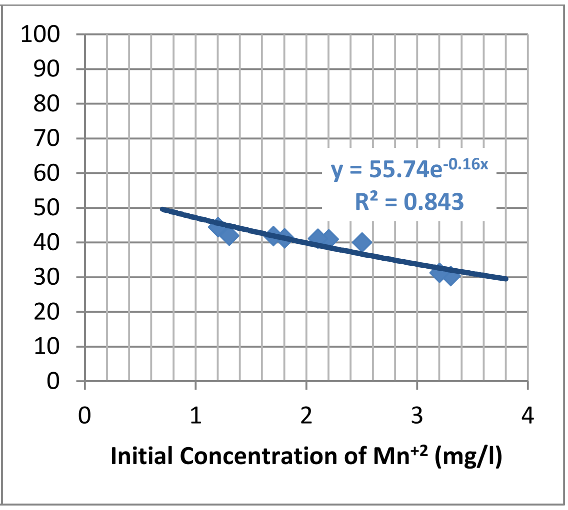

Fig.7:Removal efficiency with influent Mn^{+2}. in spray aerator.

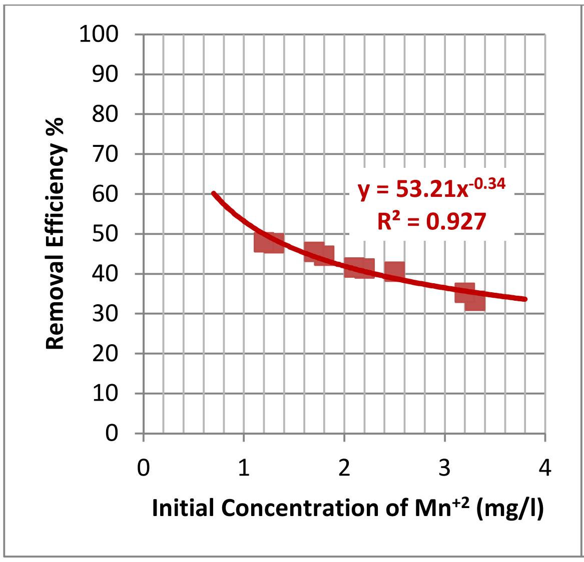

Fig.8:Removal efficiency with influent Mn^{+2} in stepped cascade weir.

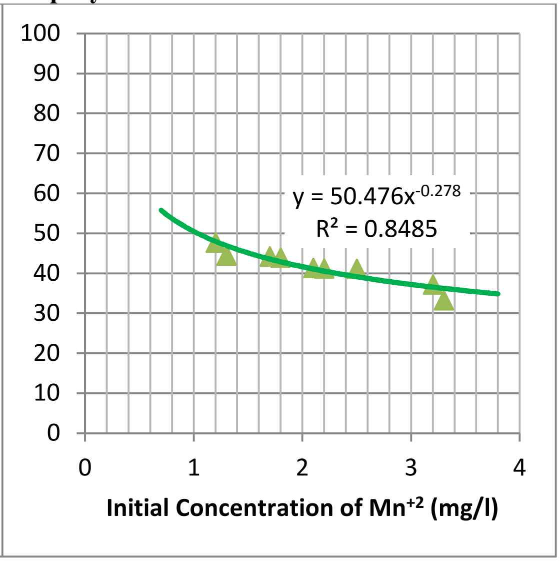

Fig.9: Overall removal efficiency with influent Mn^{+2}.

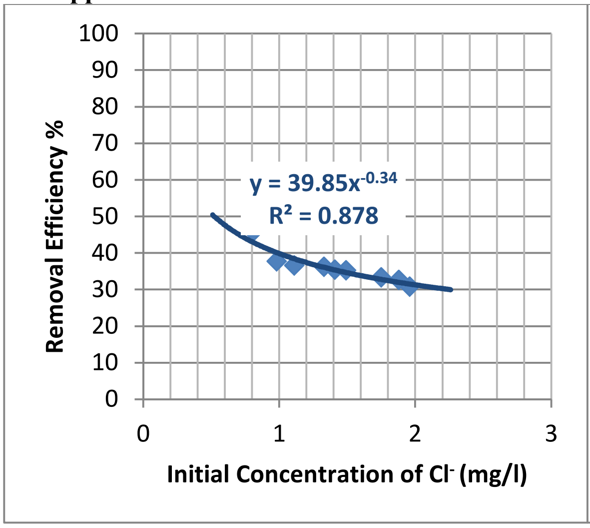

Fig.10:Removal efficiency with influent Cl$^-$ in spray aerator.

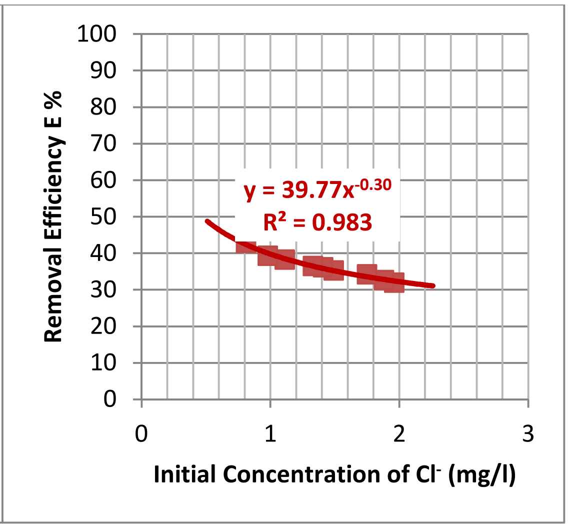

Fig.11: Removal efficiency with influent Cl$^-$ in stepped cascade weir.

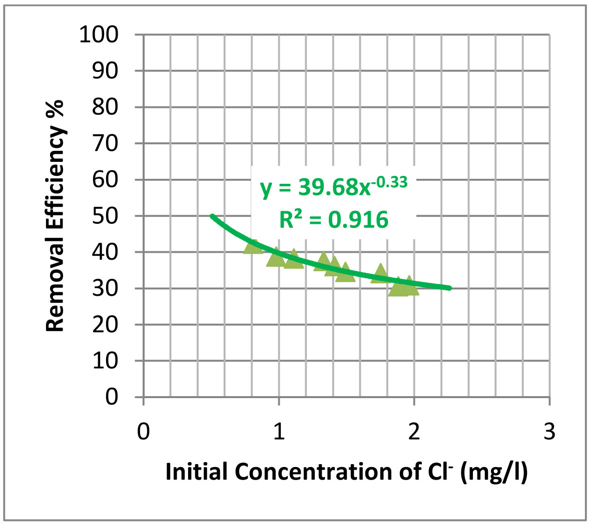

Fig. 12: Overall removal efficiency with influent Cl^-.

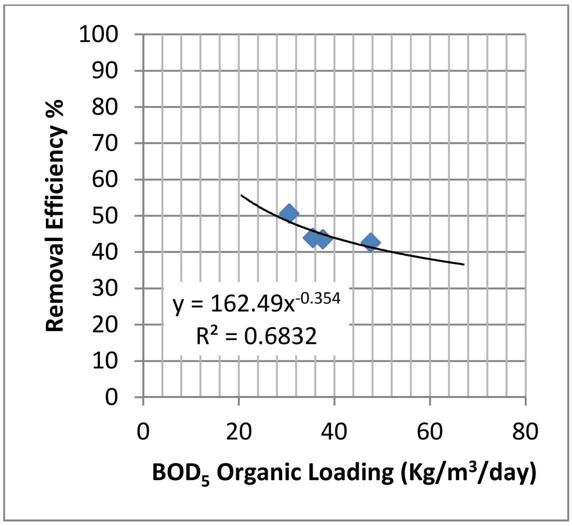

Fig. 13: Reduction efficiency with influent BOD_5 organic loading in spray aerator.

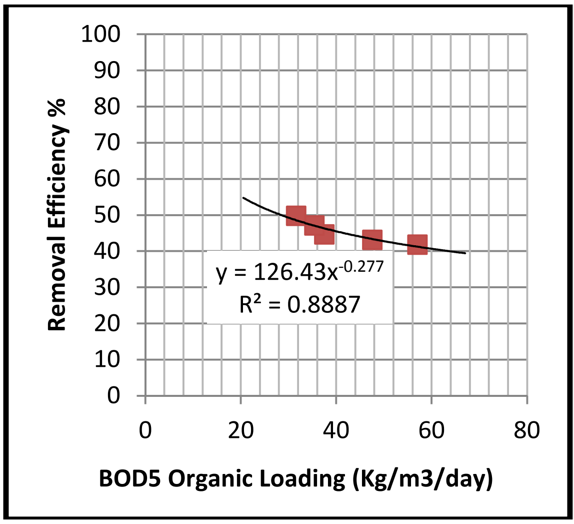

Fig.14: Removal efficiency with influent BOD_5 organic loading in Stepped cascade weir.

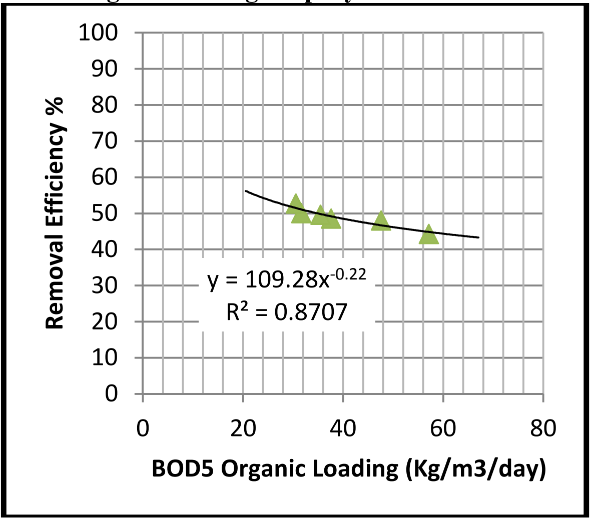

Fig.15: Overall removal efficiency with influent BOD_5 organic loading.

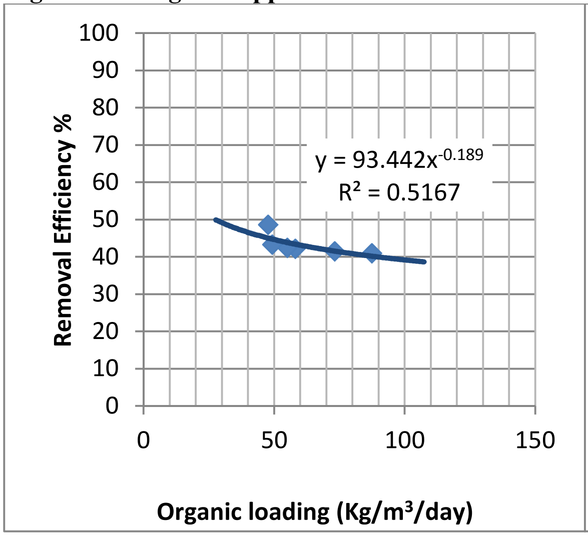

Fig.16: Removal efficiency with influent COD loading in spray aerator.

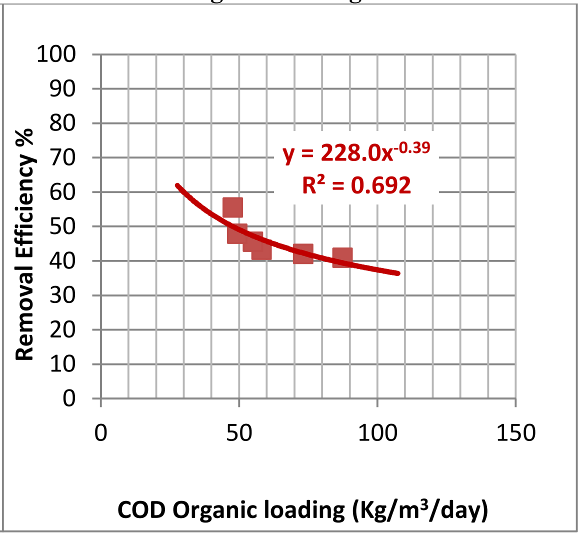

Fig.17: Reduction efficiency in Stepped Cascade organic weir with influent COD organic loading.

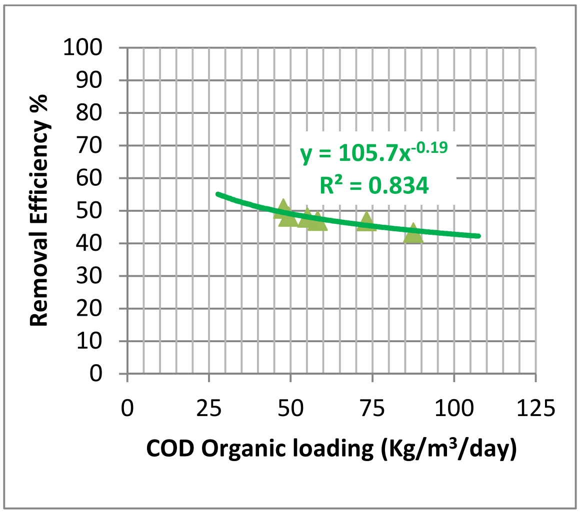

Fig.18: Overall removal efficiency with influent COD organic loading.

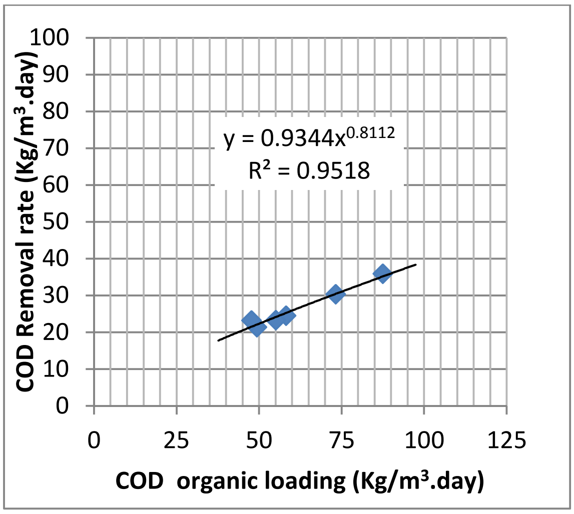

Fig 19: Relationship between COD loading rates COD removal rate in spray aerator.

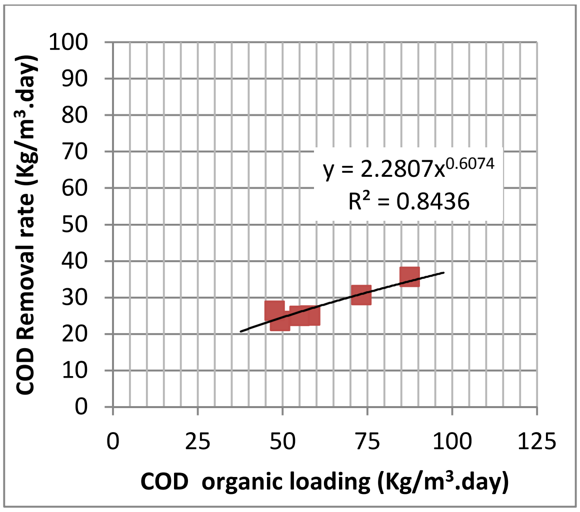

Fig.20: Relationship between COD loading rates and COD removal rate in stepped cascade weir.

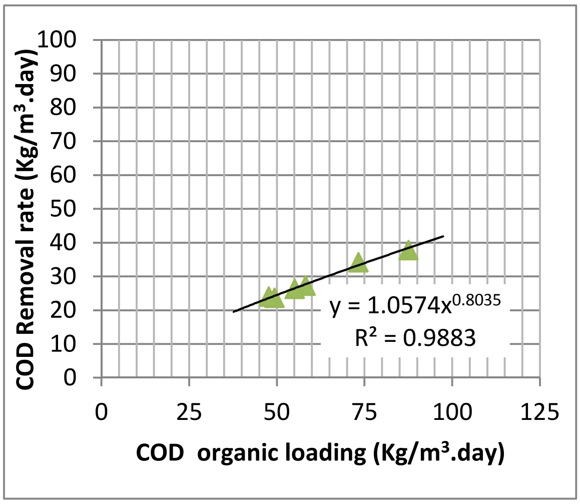

Fig 21: Relationship between COD loading rates and overall COD removal.

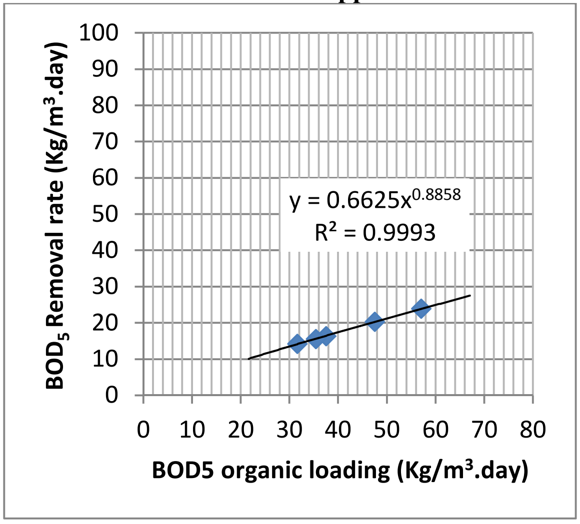

Fig.22: Relationship between BOD_5 loading rates and BOD_5 removal rate in spray aerator.

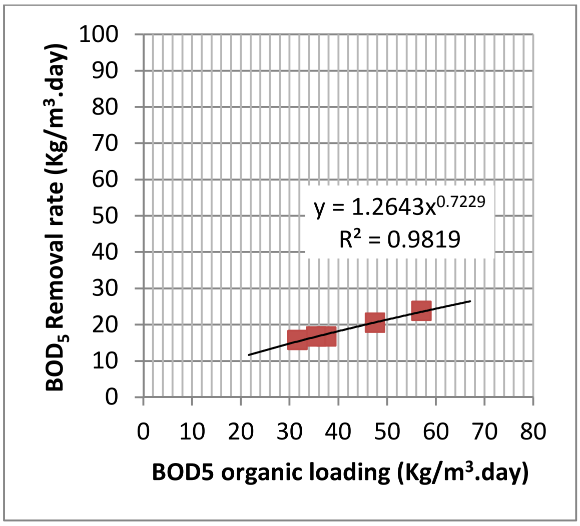

Fig 23: Relationship between BOD_5 loading rates and BOD_5 removal rate in stepped cascade weir.

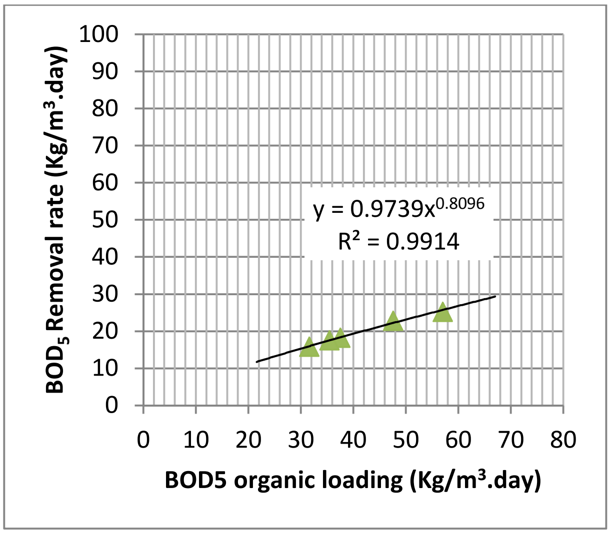

Fig 24: Relationship between BOD$_5$ loading rates and overall BOD$_5$ removal.

4- Conclusion

4-1 A combination of cascade aeration and spray aerator system show its effectiveness in removing and reduction pollutants from marginal water.

4-2 The ranges of organic loading used in the experiments for COD, and BOD$_5$ were (48 Kg/m^3.day-87 Kg/m^3.day), and (31 Kg/m^3.day-57 Kg/m^3.day), while for Fe^{+2},Mn^{+2}, and Cl$^-$ were (20 mg/l-59 mg/l), (1.2-3.3 mg/l), and (0.81 mg/l-1.96 mg/l),and the range of pH used in the experiments was between (3.21-10).

4-3 The overall removal efficiency of COD, and BOD$_5$ were (51%), and (53%) respectively, while the removal efficiencies of Fe^{+2}, Mn^{+2}, and Cl$^-$ are approximately equal for the same run time (4 hours) which ranged between (31%-48%), (33%-48%), and (31%-42%) respectively .

4-4 pH value in alkaline solution increases by aeration due to the stripping of CO$_2$ this causes rising in pH value, while base pH decreased by aeration.

References

[1] C.L.Abbott and N.J.Hasnip. (1997). the safe use of marginal quality water, a guide for the water resources planner, Department of international development, 1.
[2] T.Shittu. (2007). Agriculture use of marginal quality water: opportunities and challenges, Feed the cities, Nigeria, 428.
[3] T.Bagatur, (2009), Evaluation of pre aeration with V-notch weir and cascade structures in clarifiers, journal of environmental engineering, 135:176-184.
[4] Minnesota Rural Water Association (MRWA) 2010, Aeration; http://www.mrwa.com/OP-Aeration. pdf, 2010.
[5] M. Sanjib, N.V. Tambada, B. K. Sngh , B. C. Mal, Aeration Characteristics of a Rectangular Stepped Cascade, Water Science and Technology, 2010.
[6] G. Tchobanoglous, F. L. Burton, H. D. Stensel, Wastewater Engineering: Treatment and Reuse, 4th edition, Metcalf & Eddy, Inc., Tata Mcgraw - Hill Publishing Company Limited, p.1819, 2003.Vol.: 37 2010-01-29.
[7] Baylar, A., & Emiroglu, M. E. (2002). "The effect of sharp crested weir shape on air entrainment" Canadian Journal of Civil Engineering, 29(3), 375–383.
[8] Baylar, A., & Bagatur, T. (2001). "Oxygen transfer efficiency: Aeration performance of weirs". Water Engineering & Management, Part: 2, 148(4), 14–16.
[9] EL Monayeri, O.D. "Enhancement of Self Purification of Streams Using Stepped Cascade Aeration" Ph.D. Thesis, Environmental Engineering Department, Zagazig University, Egypt, 2009.
[10] Doan, H., and Lohi, A., (2009), Intermittent Aeration in Biological Treatment of Wastewater, American journal of Engineering and applied Science, 2 (2): 260-267, 2009.