USING CONSTRUCTED WETLANDS TO IMPROVE WASTEWATER QUALITY IN JORDAN

Eng. Abeer Al-Balawenah
National Center for Agricultural Research and
Technology Transfer (NCARTT), Jordan

Abstract

Agricultural irrigation is considered to be the most economical way to dispose of municipal wastewater in sanitary manner in Jordan and reduce the gap between water supply and demand in Jordan, Hence, our concern should be targeted towards developing an energy–saving and resource-recycling system for wastewater purification.

This paper present a newly implemented research project about the Use Of Constructed Wetlands - Reed and Kenaf plants - In Improving Treated Wastewater Quality" which is currently being executed at the National Center for Agricultural Research and Technology Transfer (NCARTT). The project aims to improve the quality of treated wastewater so that it can be reused in the agriculture sector, thus creating additional water resources.

Now the project has completed the infrastructure preparation, and primary results show that the wetlands are performing well, with excellent reduction in fecal coliform count (from 50% to 88% with average about 70%), BOD5 (reduction range from 53% to 20% with average about 37.99%), and COD (reduction range from 61% to 4% with average about 29%), plus changes the conc. of some of heavy metals. and there is no changes in chemical water characteristics except reduction in TSS (from 69 to 46 ppm), another notes that the system performing well in hot season.

1- Introduction

Jordan is an arid to semi-arid country with land area of 89,900 km^2, located to the east of the Jordan River. Jordan's topographic features are variable. A mountainous range runs from the north to the south of the country. To the east of the mountain ranges, ground slopes gently to form the eastern deserts, to the west ground slopes steeply towards the Jordan Rift valley. The Jordan Rift valley extends from Lake Tiberias in the north, at ground elevation of -220 m, to the Red Sea at Aqaba. At 120 km south of Lake Tiberias lies the Dead Sea with water level at approximately -405m. The southern Ghors and Wadi Araba, south of the Dead Sea, form the southern part of the Rift Valley. To the south of Wadi Araba region lies a 25-km coastline, which stretches, along the northern shores of the Red Sea.

Due to the variable topographic features of Jordan, the distribution of rainfall varies considerably with location.
Rainfall intensities vary from 600 mm in the northwest to less than 200 mm in the eastern and southern deserts, which form about 91% of the surface area.
The average total quantity of rainfall, which falls on Jordan, is approximately 7200 MCM/year, and it varies between 6000 and 11500 MCM/year. Approximately 85% of the rainfall evaporates back to the atmosphere, the rest flows in rivers and wadis as flood flows and recharges groundwater.
Groundwater recharge amounts to approximately 4% of the total rainfall volume, surface water amounts to approximately 11% of total rainfall volume.

Jordan's population is growing rapidly at about 3.8%. In 2000, the population of Jordan was approximately 5 million. The settlement pattern is heavily influenced by water availability. About 91% of the total population live in the north - western part of the country, with 52% living in Amman and Zarqa area.
The uneven natural distribution of water resources has resulted in the formation of three demand areas with regard to water availability:
(A) Areas where available local water resources are meeting the demand.
(B) Areas where available local water resources are in excess of the demand. (C) Areas where available local water resources are insufficient to meet the demand, which necessitated the conveyance of water from distances exceeding 100 km, and heavy capital expenditure in conveyance of water resources to consumption centers.

Jordan shares some of its most important water resources with its neighboring countries. These resources form a large percentage of the presently exploited water resources, on which the country depends, for meeting present and future water demand.
One of the most important shared surface water resources is the Jordan River system. Other important shared water resource includes the groundwater resources of north Jordan

2- Our Water Dilemma?

Jordan suffers from water scarcity due to the dominance of arid and semi-arid climate. Water resources in Jordan originate mainly from rainfall, with potential evaporation more than 2000mm/yr. and only 4.5% of its area receives more than 300mm/year. 92 % of the total rainfall lost by evaporation.
Over grazing, depletion of available conventional waters resources and land degradation. Regarding the limited fresh water resources of the country where the total demands exceeds the available resources.

With sever limitations on the availability of water, conservative and efficient use of available water resources is major considerations for balancing future demand and supply. Land application of recycled water is advantageous because this disposal process removes some of the pollutants, and increase crop yields by supplying essential nutrients. However disadvantages of this practice may include degradation of quality surface and ground water through chemical and microbial contamination, and also heavy elements accumulation in soil profile to the toxic concentrations for crops at levels toxic to human beings and animals. Therefore the use of recycled water in agriculture production requires special agronomic practices and management guidelines to ensure practical and safe socioeconomically acceptable implementation of wastewater.

In the year 2001 treated wastewater represent 18% of the available water resources for irrigation but in the next decade, this source will exceed 25%. The impact of using this type of water on the crop productivity, soil properties, and ground water quality should be investigated. Quality of this recycled water varies with the variation of wastewater treatment technology, quality of domestic fresh water, influent properties and quantity, and standards of living.

The available water resource in Jordan was limited, and as population and industrial activities increase there will be further competition for water, both in terms of quality and quantity of supply, the option to reduce the gap between water supply and demand in Jordan is to consider wastewater as an irrigation resource. ***Hence, our concern should be targeted towards developing an energy–saving and resource-recycling system for wastewater purification.***

3- The Policy of the National Center for Agricultural Research and Technology Transfer (NCARTT) aims to:

- Develop a practical, environmentally safe and socially accepted method to use treated wastewater for agricultural production.
- Better utilization of available unconventional water resources by the agricultural sector to overcome water scarcity problems.

- Developing an energy–saving and resource-recycling system for improvement of treated wastewater quality.

4- New Research Project: Using Constructed Wet lands to Improve Wastewater Quality

Jordan, a country of limited resources, is facing a chronic imbalance in the water sector. This pauses obligations to search for new water resources to meet the needs of present and future generations, ***and to use the available resources in a more sustainable manner.***

A one-year research project "Use of Constructed Wetlands -Reed and Kenaf plants - In Improving Treated Wastewater Quality" is currently executed at the National Center for Agricultural Research and Technology Transfer (NCARTT). The project aims to enhance the quality of treated wastewater so that it can be reused, thus creating additional water resources.

Constructed wetland systems (CWL) ?

 # A natural process for the treatment of domestic wastewater with aquatic plants.

 # CWL are comparatively shallow bodies of slow-moving water in which dense stands of water, tolerant plants such as reeds and kenf are grown.

 # CWL is a generic term for a relatively new technology in wastewater treatment, which has been developing over the last two decades.

5- Project Objectives:

The principal objectives of sewage treatment are to allow municipal and industrial effluents to be disposed of without danger to public health or to the environment. When wastewater are treated with a view to producing effluents for irrigation, the most appropriate method will be that which meets the recommended quality criteria specified for the intended use at low cost and with minimal operational and maintenance requirements.

Specific objectives:

- Improvement of treated wastewater quality.
- Use a new and environment sound technology in re-treating wastewater.
- Development of the use of reed and kenaf plants in wastewater treatment.
- Use a natural method in treating wastewater.
- Enhancement of environment rehabilitation.

6- Constructed wetland system theory

During the past few years a new technology for treating municipal and industrial wastewater has emerged. This technology involves the construction of "artificial wetlands," which use the physical, chemical, and biological processes in nature to treat wastewater. These specially built wetlands are also referred to as "constructed wetlands" or "created wetlands." Constructed wetlands can be designed for whole communities, subdivisions, private developments, and even for individual homes suffering from failing on-site septic systems. Interest has steadily increased because of their low cost, efficiency and near non-existent maintenance.

A constructed wetland is an engineered, marsh like area where specially established organisms and plants feed on the organic and nutrients that are in the wastewater. Pollutants are transformed into basic elements, plant biomass, and compost.

6-1- How Do Constructed Wetlands Work?

Constructed wetlands offer all the treatment capabilities of natural wetlands but without constraints associated with discharging to a natural ecosystem. Like natural wetlands constructed wetlands accomplish water improvement through a variety of physical, chemical, and biological processes.

Constructed wetlands are established with special vegetation including cattails, bulrushes, reeds, sedges, and kenf. They may also contain a variety of submerged plants.

The specially established vegetation obstructs the flow and reduces the velocity of the wastewater. When wastewater is slowed, suspended, and dissolved material can settle out. The vegetation also provides surfaces for the attachment of bacteria films, aids in filtration and adsorption of wastewater constituents, transfers oxygen into the water column, and controls the growth of most algae by restricting penetration of sunlight.

Constructed wetlands have a shallow water depth and may cover a relatively large area. This improves dissolved oxygen content and thus enhances decomposition of organic matter and oxidation of dissolved metals. The decomposition process in constructed wetlands is similar to the decomposition occurring in most conventional water treatment plants except for the scale of the treatment area and the composition of microbial populations, which are likely to be different. In both cases, an optimal environment is created and maintained for microorganisms to conduct desirable biochemical transformations of water pollutants.

Subsurface flow systems can be designed for secondary or even advanced treatment of pretreated wastewaters. These systems consist of channels or trenches with relatively impermeable bottoms filled with sand or rock media to support emergent vegetation

6-2- What are the Advantages of Constructed Wetlands?

Advantages of constructed wetlands include relatively low construction costs (essentially grading, like construction, and vegetation planting) and low operating costs (monitoring water level and plant vitality and collecting samples). Properly designed and constructed systems do not require chemical additions or other procedures used in conventional treatment systems. The efficiency of these constructed wetlands systems for wastewater treatment has been very good, especially in terms of biological oxygen demand, total suspended solids and fecal coliform bacteria. With proper design and adequate treatment area, removal of nitrogen compounds and phosphorus are readily accomplished.
CWL can usually be constructed with local materials, environmentally safe method, attracts wildlife, It is perceived as a natural process, hence as a green process.

6-3- The plants Role in CWL

The common reed and kenaf plants have special characteristics, which adapt them for use as constructed wetland media. Scientific research proved that reed plants reduce the BOD and TSS in treated wastewater, while the kenaf plant decrease the concentration of nitrogen (N) and phosphorus (P) through absorbing them from water.

The common reed ***Phragmites Antractica*** is a perennial grass, characterized by its towering height of up to four meters and its stiff wide leaves and hollow stem. It is a colonial plant that spreads by rhizomes, these colonies form along the margins of streams and in marches and ditches. They can also form in brackish water. It grows aggressively and has the tendency to compete with other plants and form monospecific (one species) stands.

The reed’s solid content can reach 80% of its weight. Water used for irrigating the reeds is lost through drainage, evaporation, plant up take and microbial decomposition. The end product is nutrient–rich compost, which can be used as a valuable soil amendment.

Today and in the past, reeds have been harvested for building houses, thatched roofs, for making boats, jewelry, pin tips, and paper. It has been used for making weapons, for weaving mats and baskets, food, medicine, smoking implements, clothing and for salt and sugar products.

The common reed has the ability to transfer oxygen from its leaves, down through its stem, porous septa and rhizomes, and out via its root system to the rhizosphere. As a result of this phenomenon, a very large population of microorganisms capable is to be found in its rhizosphere. Hence, wastewater moving through a mass of reed roots is treated in a manner akin to that prevailing in a conventional sewage treatment works but without machinery.

Kenaf is a member of the *Malvaceae* family (***Hibiscus cannabinus. L***), it is an annual plant that grows a straight stem very quickly. It is widely cultivated in tropical and subtropical parts of the world. Kenaf is traditionally used for making products such as ropes and sacks, hemp, cloth, paper and broad manufactures. Sometimes the tops and leaves may be used as green fodder. When it is mature, it reaches 3 to 5 cm in diameter at the lower part of the stem and 3 to 4 meters in height.

7- Project Work Plan

- Infrastructure of constructed wetland project was initiated in Feb 2002. (The project duration from 2002 -2005).

- 18 beds were constructed in AL-Samara wastewater treatment plant (the largest treated wastewater plant in Jordan). According to the following dimension: -
    - 10 buds with (9.5 m length, 1.7m width, 0.8m depth)
    - 8 buds with (6.5 m length, 2.5m width, 0.8m depth)

- The project was designed to capture the treated wastewater effluent, store it in a holding pond and then re- treat in constructed wetland beds. The constructed wet land beds outlet also store in another holding pond, and proposed using it for irrigate forest trees in the early future.

- The beds were lined by hard plastic mulch to prevent leakage, and filled by zeotof grovel with different size.

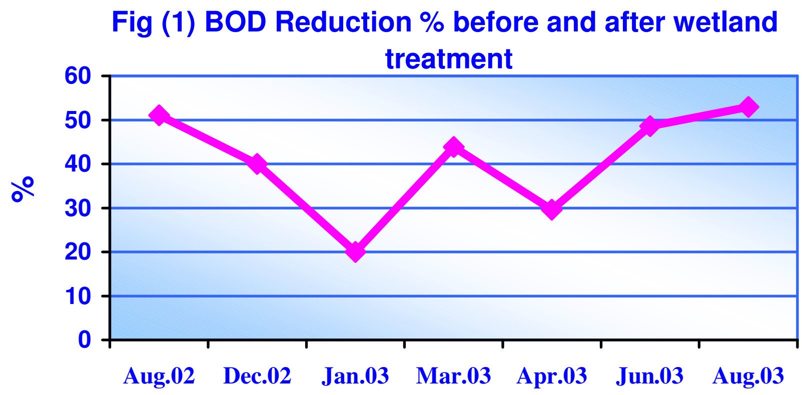
- Experiment was conducted in the site using randomize complete block design with three replication, to compare between:
    - 3 beds will be planted by reed plant.
    - 3 beds will be planted by kenf plant.
    - 3 beds without plantation used as control.

- The remaining beds will be used for studying some constructed wetland parameters.
- The beds were planted by Reed and Kenf at the end of Oct. 2002.
- Monthly inlet and outlet treated wastewater samples will be taken to test BOD, TSS, COD, TDS, N, P, K, EC, pH and heavy metals.

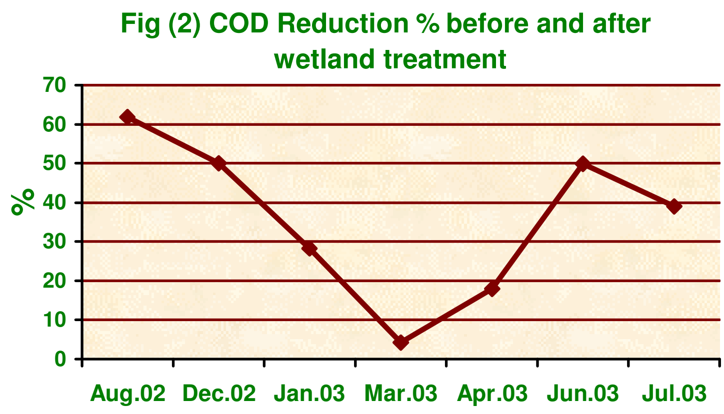
8- Primary Results

To determine the effectiveness of wetlands, water quality has been monitored at two sites (wetlands inlet and outlet). The results show that the wetlands are performing well, with excellent reduction in BOD, COD some of heavy metals. This results before plantation so it's expected to be better after plantation.

For example, BOD reduction percent differences between wetland inlet and outlet range from 53% to 20% with average about 37.99%), see Fig. 1

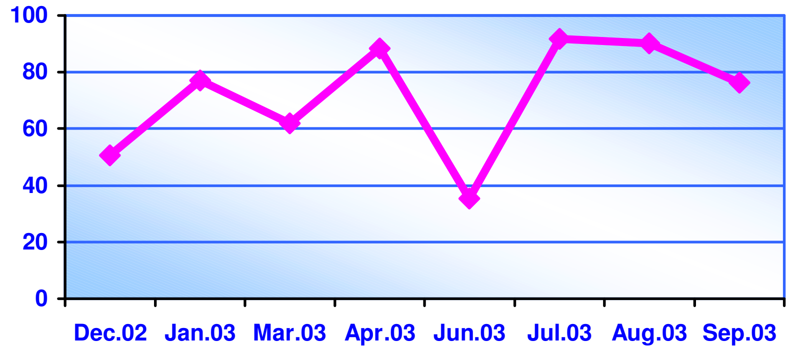


COD reduction percent differences between wetland inlet and outlet range from 61% to 4% with average about 29%), see Fig. 2.



Excellent reduction percent in fecal coliform count (from 50% to 88% with average about 70%), see Fig. 3.

Fig.(3): Fecal Coliform Reduction %



Water Chemical characteristics have been monitored at two sites (wetlands inlet and outlet). Table (1) shows the differences between inlet and outlet, the results show that there is an excellent reduction in P, NO3. But the other parameter was changed smoothly in different ways.

Figures (4 & 5) show that the wetlands are reducing the conc. of Zn, Cd and Co. and without any changes in Cr and Pb conc.

Table No. (1)

Water chemical characteristics results before and after wet land treatment

Location	pH	EC (dS/m)	TDS (ppm)	meq/L						
				Ca	Mg	Na	Cl	CO3	HCO3	SO4
IN	8.28	2.744	1756.16	4.67	4.45	12.212	11.65	0.75	6.6	2.332
OUT	8.2368	2.75	1760	5.8645	4.5	12.643	13.224	0.6645	6.2632	2.8566

Location	SAR	ppm			
		P	NO3	K	TSS
IN	5.88	15.47	21.068	39.938	55.4
OUT	5.6058	4.7253	14.457	43.721	48.054

Photo (1) Water samples before and after wetland treatment

Fig (4) heavy metals conc. results before and after wetland treatment

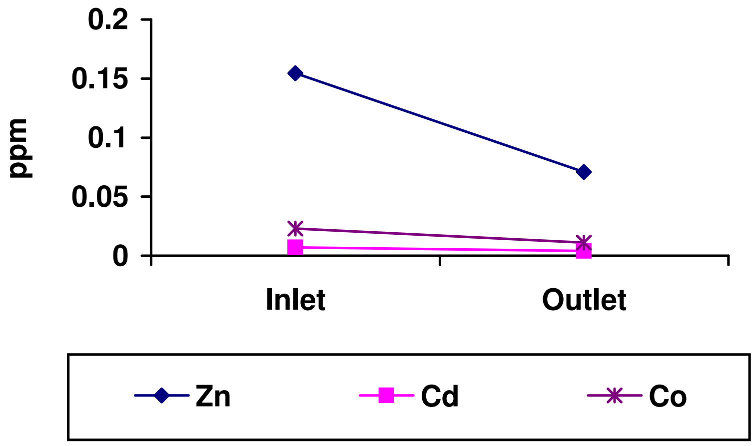
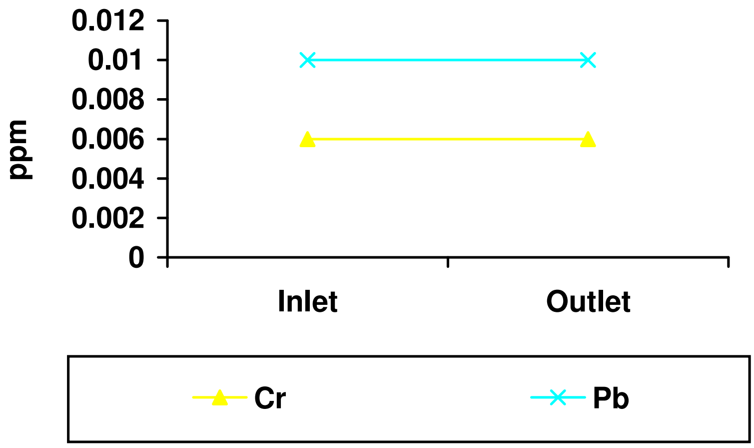


Fig (5) heavy metals conc. results before and after wetland treatment



9- Expected Outputs

- Recommendation about the use of reed and kenaf plants in re-treating wastewater, especially their efficiency in wastewater retreating, plants growth habitat and amount of water re-treated.

- Treated wastewater quality improvement.

- The possibility of using the results of the experiments in implementing the use of constructed wet land systems for wastewater re-treatment on a national scale.

References

1- Tchobanoglous, G. Franklin L.B., et al: wastewater engineering – treatment, Deposal and Reuse – 3rd edition. Metcalf and Eddy, INC.
2- Ozaki, Y. (Resource- Recycling System for Domestic Wastewater Treatment Using Biogeofilter Ditches Planted with Useful Plants) JARQ33, 243-249 (1999).
3- Inagaki, H.: (Report of Kenaf Development) Bulletin of the Earth and Human Env. Forum, Japan (1994).

Arabic References

1- عبد النبي فردوس، علي الشروف ، 1999 . واقع المياه الحالي والمستقبلي في الأردن وأثره على الزراعة، المؤتمر الوطني للمياه. عمان. ألاردن. 15ص.

2- عادل الشوبكي 1999. استعمال المياه المعالجة كمصدر مائي هام في الأردن. مجلة المهندس الزراعي. عدد 66.

3- بشار الشريدة، 1995، تقنيات معالجة بعض المواد الكيماوية المتراكمة في التربة، الأسبوع العلمي الأردني الثالث، ورقة عمل - المجلس الأعلى للعلوم والتكنولوجيا.

4- سياسة مرافق المياه، 1997 . وزارة الري. عمان. الأردن.