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Application of Rotating Biological Contactor with Packing Bed (RBCp) for Small Communities Wastewater Treatment to Be Used in Irrigation

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Abstract: Because of water shortage, collection and treatment of wastewater for agriculture use is necessity now a days. The cost of current methods of wastewater treatment by high technology, makes it difficult. These systems are not suitable for rural areas and small populations. In these regions, a cheaper and simpler technology with easier operation, such RBCp systems is could be more useful for wastewater treatment in order to use in irrigation. In this study the RBCp was used as a pilot system to show its performance in treatment of municipal wastewater to be used for irrigation. The system was operated in different hydraulic and organic load. Experimental setup was consisted of RBCp system with a simple cylinder in three parts with 18 litre effective volume. Its bed had a 20 cm diameter and 3.36m2 area. The physico-chemical and biological properties of effluent were measured for reuse in irrigation. The effect of hydraulic and organic load and retention time on efficiency of system were also investigated. The results showed that the RBCp could system was more efficient as compared with the similar methods. The RBCp chemical removed 17.48 gr/m^2.d BOD5. The physico – quality of RBCp effluents was safe to use for crop irrigation according to WHO guide line. However, the number of fecal coliform and nematode eggs (Engelberg Index) were greater than the critical values for unrestricted irrigation of the same guide line. This problem could be remedied by sand filter and chlorination. The use of RBCp system with sand filter and chlorination treatment in effluent for rural and small populated areas, were recommended.

Key words: RBCP · Biochemical Oxygen Demand · Nematode egg · Fecal Coliform

INTRODUCTION

Water shortage is one of the main barriers to country's development and independence. Therefore, sewage treatment and recycling plays a significant role in saving environment and water resources. The common methods of sewage treatment are costly in construction and launching and require high technological knowledge, hence suitable for populate cities. Having small populations and great distance from big cities, rural areas and small cities are unable to use these methods; they dispose their sewage in the wells. This method in coastal areas and areas with high levels of groundwater results in groundwater pollution, as well as loosing huge amounts of effluent which can be used in agriculture. Regarding to the fact that a noticeable portion of Iran's population live in small cities and rural areas, sewage treatment and reuse in these areas can recompense water shortage, especially in agricultural field. With easy construction, low-cost launching, simple application, minimum space and energy required as well as applicability in areas populated up to 30000, RBCp (Rotating Biological Contractor with Packing Bed) can be used for sewage treatment [1]. Generally, RBC is a bio Disc treatment method which contains three solid, liquid and gas parts. The solid part is the system's bed which can be made in different shapes. The liquid part is the sewage within the system and the gas part is air. In this method, the bed is positioned on the central axis rooted 40% in sewage and rotated around the axis [2]. Sewage purifying microorganisms grow on the bed and make a bio film (Figures 1 and 2). The bed rotation makes the bio film frequently in contact with the sewage and the air, through which the nutrients existing in the sewage are decomposed and the oxygen in the air is attracted by the bio film. When the film is too thick for the microorganisms in deep to receive nutrient and oxygen, they are no longer able to stick to the bed and fall into the liquid part.

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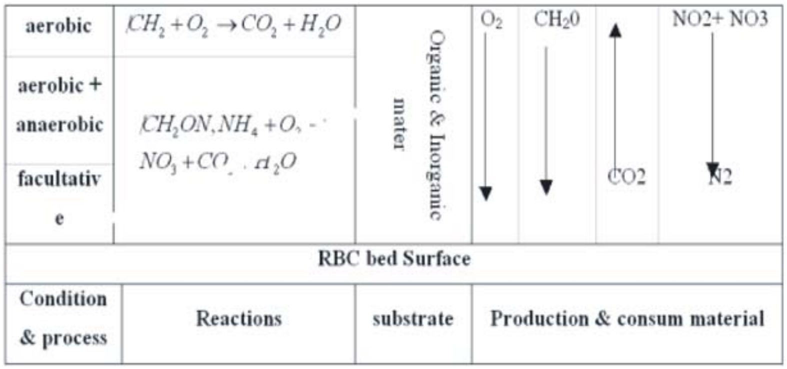


Fig. 1: Microorganisms and biochemical reactions in biofilm

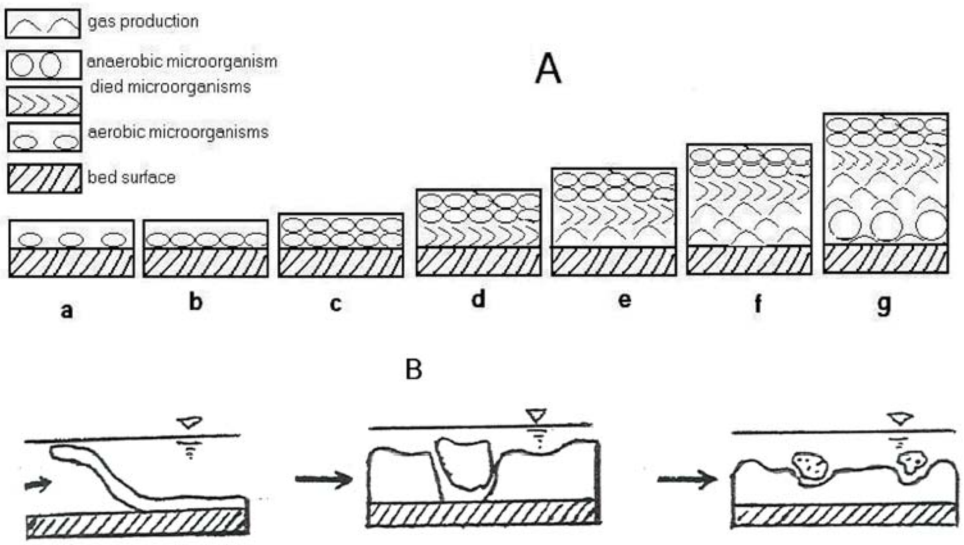


Fig. 2: Profile of intrinsic bacterial population of biofilm (A), decrease of biofilm thickness (B)

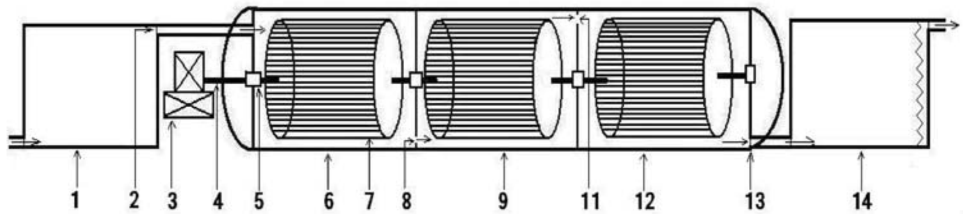
The first RBC was invented in Germany with wooden wheels. It was popularized and known worldwide. [2] found that increasing rotation speed up to 0.1-0.34m/s can raise the efficiency of system. Cheuny's research in 1986 on effect of hydraulic retention time in RBC performance indicated that high hydraulic retention time can increase the BOD and ammoniac elimination rate [3]. [2] claimed that sewage concentration, temperature, water load and disc rotation speed are effective factors in this treatment method. [4] presented a model of RBC, for sewage treatment in low-populated areas, designing with a jet mixed separator. this method was able to eliminate, colloidal and suspended particles in JMC and biologically remove dissolved materials in RBC. The results of mentioned method showed that the required retention time is 1-2 hours for municipal sewage treatment in 5-30g/m2 organic load and 2-6 hours for ammoniac elimination [1-3]. Other researchers are mainly on RBC or bio disk treatment. [5] presented a model of combined UASB/RBC, for sewage treatment for irrigation purposes. This study supports using a combined system UASB/RBC for treatment of domestic wastewater for reuse in irrigation.

The purpose of this research is to test an improved model of RBC (called RBCp) and its performance in municipal sewage treatment for reuse in agriculture.

METHODS AND MATERIALS

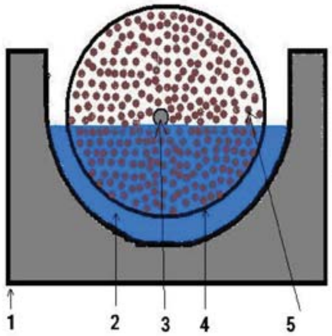
In this research, RBCp was designed in laboratory scale (90×30 cm) with fiberglass (Figure 3) and divided to three equal parts through vertical plates. The parts were connected parallel to each other and equipped with sensitive cells to check pH and temperature. RBCp's bed contains three steel rotating cylinders, each 20 cm in length and diameter. They were positioned and rotated around the central axis. The cylinders' base was from latticed steel and their body from thin steel rods

A- Vertical view



1-Primary Settling Tank	4-Shaft	7-Rotating cylinder	10- vertical plates	13- Sample point 4
2- Sample point1	5-Ball-bearing	8- Sample point2	11- sample point3	14-Final Settling Tank
3-Electrical motor	6-Stage 1	9- Stage 2	12- Stage 3	

B: Vertical section



1- fiberglass body
2- wastewater
3- shaft
4- Rotating cylinder
5- packing bed(ball-bearings)

Fig. 3: Schematic representation of the RBCp pilot plant

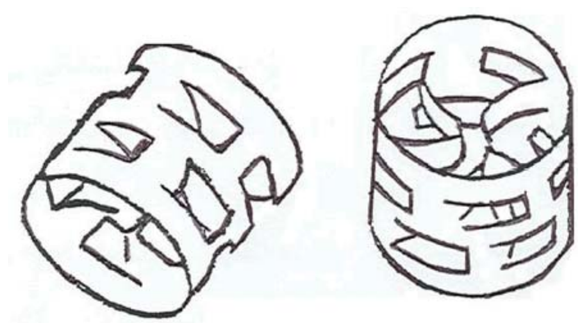


Fig. 4: Packing bed (ball-bearings) used in RBCp pilot plant

with 3 cm space. The cylinders were filled with poly propilen ball rings (Figure 4). These ball rings have the role of disc in RBC and resulted to this fact that the ratio of surface (Specific surface) to volume of RBC is 3 times more than the common RBC. Therefore, the biofilm is increased as well as the system's effectiveness. The ball rings were put into the cylinders randomly and to avoid stickiness caused by biofilm formation, about 15% of the space within the cylinders was left empty. The rotating cylinders were positioned on the central axis and joined to the system with 5 ball-bearings. The rotation force generated by a electrical motor is transmitted to the axis through three gears and a chain and make the cylinders rotated. The gears diameters were chosen in the manner that allows the system rotates in two different speeds; besides their temperature was adjustable in a 15-35°C range. Tables 1 and 2 show the features of RBCp and its ball rings.

Some municipal wastewater taken from Ekbatan wastewater treatment plant inlet was sent into the RBCp as food (Table 3). RBCp was firstly launched with batch flow, the temperature was controlled in 25±2.5°C and the first bio films were formed on the bed surface after 10 days. Due to bio film formation, the system flow changed to continuous. The first stage of research started with 0.025m^3/m^2 water load. In this stage, RBCp reached a stable state whithin a week. Then, the system performance was observed in three gradually increasing 0.5- 0.075 - 0.1 m^3/m^2.d water load, respectively. In these stages rotation speed was 16 RPM (0.17 m/sec).

To evaluate the quality performance of RBCp in sewage treatment and producing usable effluents for irrigation, DO (dissolved oxygen), PH, NO_3 and BOD_5 were measured daily during each stage. After reaching the system to stable state, parameters such as NE (Nematode egg), FC (Fecal coliform), EC (Electrical conductivity), carbonate, bicarbonate, Chloride, Boron and phosphate

Table 1: features of the ball ring used in the sample RBC_p

type	material	Size (in)	Density (lb/ft^3)	Specific Surface (ft^2/ft^3)	porosity
Ball ring	Poly propilen	1	5.5	210	95%

Table 2: features of RBCp pilot plant

factor	quantity
Length (m)	0.9
Width (m)	0.3
Height(m)	0.2
Rotating cylinder length (m)	0.2
Rotating cylinder diameter (m)	0.2
Effective volume (m^3)	0.18
Bed total surface (m^2)	3.36
Bed surface to volume ratio m^2/m^3	190
Rotation per minute [1](RPM)	16-19
Rotation speed [2](m/sec)	0.17-0.20
Temperature[3] (centigrade)	20-25
Hydraulic load [4](m^3/m^2.d)	0.025-0.10

1. Rotation per minute is adjustable in 16-20 range.
2. Rotation speed is adjustable in 0.17-0.20 m/s range.
3. The temperature is adjustable in 15-35±2.5 range.
4. The water load is adjustable in 0.025-0.1m^3/m^2.d range.

Table 3: Composition of influent wastewater

factor	Quantity
Dissolved oxygen (mg/l)	0
pH	7.8-7.1
Total Nitrogen(mg/l)	15-20
Total Suspended Solids(mg/l)	180-220
BOD(mg/l)	225
Total Nitrogen (mg/l)	53
Fecal Coliform (MPN/100ml)	130000000
Nematode Egg (N/1000ml)	12

had been analyzing in each stage. Fecal Coliform (FC) measurement was done two by two with Briliant green Bile broth and Tripton Water culture medium and storing in 44.5°C for 48 hours [6]. Nematode Egg (NE) was measured through Balenger method [7] and all physical and biological experiments were done according to standard methods' guidelines [6]. To do chemical and physical experiments, 1-liter plastic bottles pre-washed with distilled water and to investigate biological factors 0.5 -liter sterilized glass bottles were used.

RESULTS

The study indicates that except nitrate, BOD_5 and PH, other parameters have not been changed significantly during different stages of the research. Therefore, the results are presented in general and the main part of the discussion will focus on PH, BOD_5 and nitrate. As seen in Figure 5, when the water load is low the main part of BOD_5 is consumed in the first stage and the following stages have negligible effect on BOD_5 elimination, though, as the water load increases the following stages become more influential. Following the increase in the water load, more BOD_5 is seen in the system outlet due to decrease in waste water hydraulic retention time. Decreasing of this factor results from decreasing of heterotrophic microorganisms and ammonia oxidant exposure time. Therefore, 96.8% BOD_5 elimination rate in 0.025 m^3/m^2 water load decline to 77.7% in 0.1 m^3/m^2.d water load. Dissolved oxygen concentration was zero in the waste water before entrance to the system, but it has been increased after passing three BOD_5 stages and maximized in the outlet flow. Drop in hydraulic retention time decreases the dissolved oxygen concentration, fewer amount of oxygen is accessible to microorganisms and the amount of effluent parameters increases.

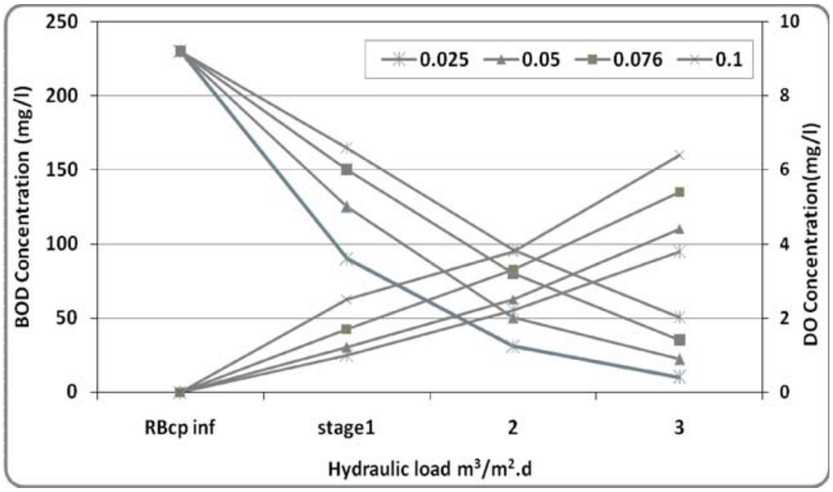


Fig. 5: Effluent DO and BOD concentration from stages in different hydraulic load

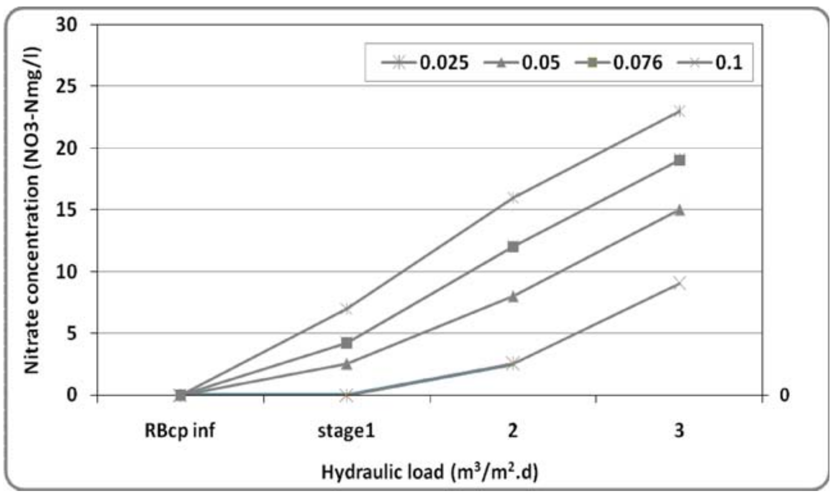


Fig. 6: Effluent pH and nitrate concentration from stages in different hydraulic load

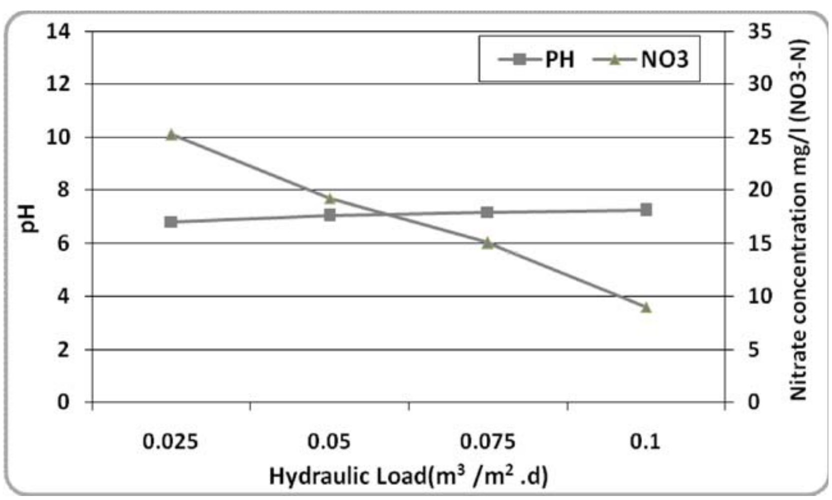


Fig. 7: Effluent pH and nitrate concentration in different hydraulic load

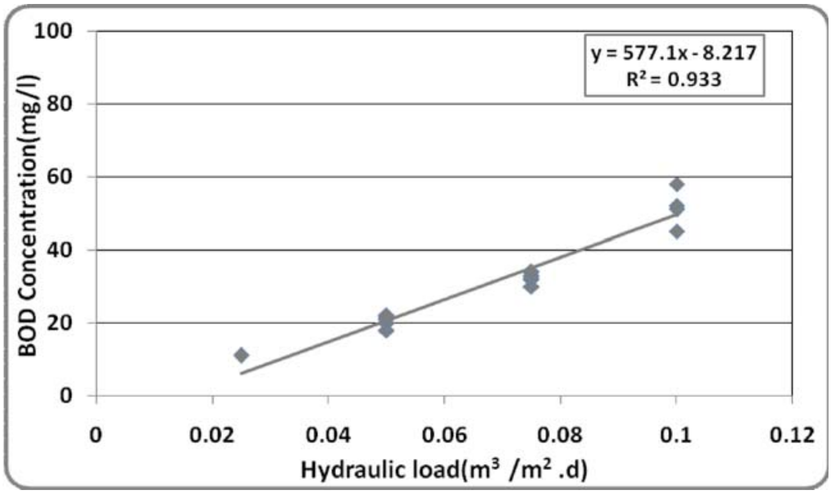


Fig. 8: Relationship between effluent BOD concentration and Hydraulic load

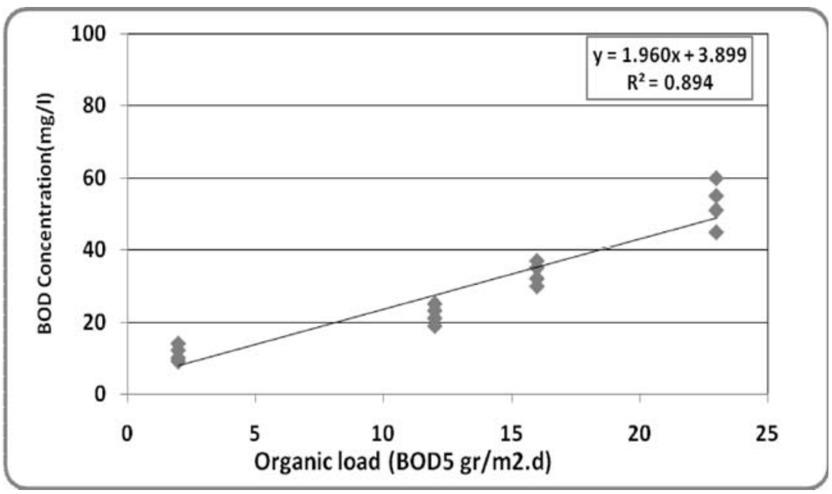


Fig. 9: Relationship between effluent BOD concentration and organic load

Figure 6 shows that nitrification rate has reverse relationship with the concentration of organic matters existing in the effluent; the more effluent BOD_5 the less nitrification. The results support the previous researches. According to previous studies, nitrifying organism (nitrosomonas and nitrobacter) has no nitrification ability in existence of high organic matters concentration; they start nitrification only when organic materials concentration drops significantly [8]. It is also observed that following the increase in water load and decrease in retention time, the effluent BOD_5 concentration raises and the effluent nitrate concentration drops. Besides, in 0.1 m^3/m^2.d water load, there is no nitrification in the first stage due to the short retention time and nitrate concentration of 24mg/1 in 0.025 water load decreases to 9mg/1 in 0.1 m^3/m^2.d water load. Figure 7 shows that increase in nitrate concentration can decrease pH rate, which can be explained by H^+ production and its compounding with bicarbonate ion and making carbonic acid. Nitro-compounds and organic materials elimination are calculated through the following equations.

$$CH_2O + O_2 + Hetrotroph\ micoorganisms \rightarrow CO_2 + H_2O + New\ cells$$

$$CH_2ON, NH_4^+ + O_2 + micoorganisms \rightarrow NO_3 + CO_2 + H_2O + New\ cells$$

$$55\,NH_4^+ + 76O_2 + 109HCO_3 + Nitrosmonas \rightarrow C_5H_7NO_2 + 54NO_2^- + 104H_2CO_3$$

$$400\,NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3 + 165O_2 + Nitrobacter \rightarrow C_5H_7NO_2 + 3H_2O + 400NO_3^-$$

Figures 8 and 9 indicate the relationship between water load and effluent BOD_5 concentration as well as the relationship between organic load and effluent BOD_5 concentration which can be used in designing RBCp system with 0.025-0.1 m^3/m^2.d range of water load and 5-25 g/m^2 range of organic load for municipal sewage.

Table 4: Comparison effluent quality for reuse in irrigation

Factor	Unit	Effluent	Standard limit	acceptable	unacceptable
pH	-	6.8-7.29	FAO	6.5-8.4	*
Cl	mg/l	47.2	FAO	100	*
Na	mg/l	34.3	FAO	70	*
B	mg/l	0.28	FAO	0.7	*
CO3	mg/l	47.6	FAO	100	* HCO3
	mg/l	82	FAO	90	* NH4
	mg/l (NH4-N)	0-4	IRIEPO[1]	5	* PO4
	mg/l (PO4)	31	IRIEPO	50	* BOD
	mg/l	11-50	IRIEPO	100	* SAR
	-	0.8	FAO	3	* TSS
	mg/l	35	IRIEPO	100	* TDS
	mg/l	550	FAO	<2000	*
Fecal coliform	MPN/100ml	$1.8\text{-}5.2\times 10^{2}$	WHO	≤1000	*
Nematode egg	N/1000ml	3-5	WHO	≤1	*

1-Islamic republic iran Environ Protection Organization

References: [8,9]

DISCUSSION

The high concentration of dissolved oxygen existing in the effluent shows that oxygen demand and mixture is done more appropriately in this method comparing to original (common) RBCs. The qualitative study of the effluent indicates that RBCp can eliminate BOD_5 up to 17.48 g/m^2 which is lower than the original RBC performance (23.75 g/m^2.d) [2,9]. Regarding the high ratio of surface to volume in RBCp (three times more than the original RBC) it can be concluded that RBCp effectiveness and efficiency in identical volume unit is 2 times higher than that of other methods. Since the main purpose of this research is to study the RBCp performance in producing effluent appropriate for irrigation, observing the summarized results of the effluent and comparing them with WHO, FAO and Environmental Organization standards Ttable 4), shows that the chemical and physical quality of the produced effluent is not only appropriate for the unrestricted irrigation of agricultural crops but also, it is included significant amounts of nutrients in nitrate and phosphate form which can be attracted by the plants.

The biological study of the effluent quality suggests that the number of FC and NE exceeds the standard norms and makes it inappropriate for unrestricted irrigation. Besides, the bicarbonate concentration in the effluent is more than the standard norms so it is not usable in sprinkler irrigation but it can be used in other methods of irrigation. Due to efficient performance of sand filters in NE elimination, it is suggested that to reach suggested sanitary criterion in case of NEs and coliform bacteria, the RBCp effluent is filtered with a sand filter and disinfected with chlorination.

Suggestions and Implications: Regarding the low cost of RBCp construction and launching and utilization and its significant efficiency in municipal sewage treatment in the studied water load and its applicability in small population areas, it is suggested that the decision makers in ministry of energy, ministry of agriculture and environmental organization encourage its utilization in rural areas, small cities and towns.

REFERENCES

1. Giusepped, A., 1997. Rotating Biological Contactor Solid Contact System for The treatment of Wastewater from small Communities. Wat. Sci. Tech., 35(6).
2. Calvin, P.C. Pooh and J. Mikucki, 1975. Factors Controling RBC Performanc. J. Wat. Pollut. Control. Fed., 51(3): 601-611.
3. Ahn, K.H. and J.S. Cang, 1991. Performance Evaluation of compact RBC settling tank system. Wat. Sci. Tech., 23(10): 1467-1476.
4. Watanabe and Y.K. Iwasaki, 2003. Performance of jet Mixed separator and rotating Biological contactor. Wat. Sci. Tech., 53(6): 63-70.

5. Tawfik, *et al.*, 2007. Treatment of domestic sewage in a combined UASB/RBC system,process optimization for irrigation pruposes. Water Sci. Technol., 48(1): 131-138.
6. A.P.H.A., 1992. Standard methods for the Examination of Water and Wastewater. 18th. Edition, APHA, AWWA,WCPE.
7. Ayres, R.M., 1989. Enumeration of Parastic Helminths in Raw and Treated Wastewater. (A brief practical guide).
8. WHO, 1989. Health guidelines for the use of wastewater in agriculture and aquaculture. Technical series No. 778. Geneva. World Health Organization.
9. Pescod, M.B., 1992. Wastewater Treatment and Use in Agriculture. FAO Irrigation and Drainage, pp: 47. Rome-Italy.