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Potential Assessment of Water Harvesting From Local Wastewater Treatment Plants (Case Study: Rotating Biological Contactor, RBC)

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Abstract

In dry regions the reuse of treated wastewater plays a significant role in management, operation, scheduling and utilization of water resources. In design and operate of the sewage treatment plants , it is essential to measure and forecast the harvested water from wastewater plants and balance the groundwater depletion with these new resources. In this study, potential water harvested by local wastewater treatment plants, Rotating Biological Contactor (RBC) is determined and balanced with water requirement of plants. Based on the design basis of RBC, the production ratio of 80 % is used and the produced discharge ranges from 4 up to 8 liter per seconds, with 140000 cubic meters per year. To quantify the balancing between RBC produced water and irrigation water requirements, a plant-by-plant water requirement is calculated and the operation rule of groundwater wells in the case study are determined and proposed as an action plan to the operator of wells. Based on the results it was observed that the RBC can supply two times of pistachio orchard (23 hectares) irrigation requirements or 70 percent of the landscape and green space water needs in the case study.

Keywords: Irrigation requirement, Rotating Biological Contactor (RBC), Wastewater reuse, Water harvesting.

1. Introduction

Wastewater treatment plants (WWTPs) are very crucial in water reuse strategies for dry regions because of the growing of the cities, increase of the population, and the inevitability of treating high volume of untreated sewages as new harvesting sources (Singh et al, 2016; Seifi et al, 2020). The scheduling and management of WWTPs is important in environmental and water resource management to reduce the groundwater depletion (Zeng et al., 2016). Iran located in a dry region with limited access to the water resources with challenging shortcomings from the climate change. Kerman province as the main pistachio production region worldwide, suffered from 6550 million cubic meters of yearly depletion of groundwater that is 800 million cubic meters greater than the potential of aquifers. This over depletion of groundwater resulted in 0.6-1 meter of water level decline each year that produce land settlement and subsidence in this region (Eslami and Farzamnia, 2009). Recently, growing of population, urban development, and progress in industry and agriculture increased the water need and strengthened the water shortage crisis. On the other hand, water shortage and increases in water consumption resulted in increase the wastewater production that need to be treated in general or local plants (Taghvaei et al, 2011). Reuse of treated wastewater for agricultural and landscape demands serve benefits such as providing sustainable and low cost water resource, relief parts of treatment plant costs, decreasing the environmental effects of wastewaters that necessities the reuse of treated wastewater (Mehravran et al, 2015).

The generated wastewater by 1000 capita can supply irrigation needs of 1.5 up to 3.5 hectares agricultural farms (Tajrishi and Abrishamchi, 2015). Todays, the yearly

water demand of country is 15 percent greater than the total available water resources that should be supplied from alternative resources such as rainwater harvesting, wastewater reuse, and desalination plants. Developing reuse plants in wastewater treatment plants requires reliable maintenance and operation of treatment plants and needs accurate accounting and balancing between the demands and produced treated water. In the Rafsanjan plain, due to over depletion of groundwater and extra developed pistachio orchards the groundwater level has declined, water quality is reduced to salty waters with saline and sodic soils. Because of the challenges of water availability and the strategic importance of pistachio orchards, it is crucial to develop closed loops in water harvesting and consumption. Innovative technologies for wastewater treatment enable developing local treatment plants for low populated regions. One of these new methods is the Rotating Biological Contactor (RBC) packages that treat wastewater in a compacted module with precious operation and maintenance tasks (Khalil aria, 2009). The remained problem in the case of RBC is the potential production of these packages as an alternative to the groundwater wells. Although some studies investigated the applicability of treated wastewater in irrigation supplies (Seifi et al, 2020; Dehghani et al, 2019); they did not account the local packages such as RBC. Critically, they do not do not account for determination of which portion of water needs can be harvested from local treatment plants. The novelty of the current study is in two field, firstly this study account the quantity of treated water in local treatment plants regarding the landscape and agricultural needs, secondly it balances the groundwater depletion with the treated water reuse. Therefore, the main aim of the current study is to quantitatively investigate the potential applicability of RBC produced water as an alternative resource to the groundwater wells in a local scale, located at Rafsanjan plain. We measured the time series of treated water output from the RBC and calculated the water requirements of all plants in the case study to quantify the balances parts of irrigation requirements with RBC output.

2. Material and Methods

2.1. Rotating Biological Contactor (RBC) Wastewater treatment plant

The RBC module used in the current study is located in Rafsanjan University. The RBC module due to its easy operation, low cost of maintenance versus other treatment systems is suitable for local and low populated regions. The RBC packages are invented in 1900, using wooden plates for biological wastewater treatment. In 1929, Alen and Mateby used RBC for wastewater treatment. The development in RBC progressed for removal of organic carbon, nitrogen and phosphor from wastewater (Sahinkaya, 2006). The RBC package in this study is constructed with capacity of 100 cubic meters per hour for university wastewater treatment. The resource of the raw effluent enter to the RBC is collected by the university sewer collection system from restaurants, faculties and dormitories of the university. In this system as shown in figure 1, at first the raw wastewater pumped to the grit chamber and oil remover, then move to the grit chamber for sand removal. After that the wastewater enters to the settlement system, equalization tank and the pumped to the RBC main system with sewage pumps.

Table 1. The design features of RBC package in Rafsanjan University

Parameter	Unit	Value
Daily wastewater volume	m^3/day	100
Average Flow rate	m^3/hr	4.167
Maximum flow rate	m^3/hr	12.5
-	-	8
BOD_5 raw wastewater	Mg/l	350
Total BOD_5 in day	kg	35
COD raw wastewater	Mg/l	30
Total COD in day	kg	300
Dry solids in settling tank	%	3-2

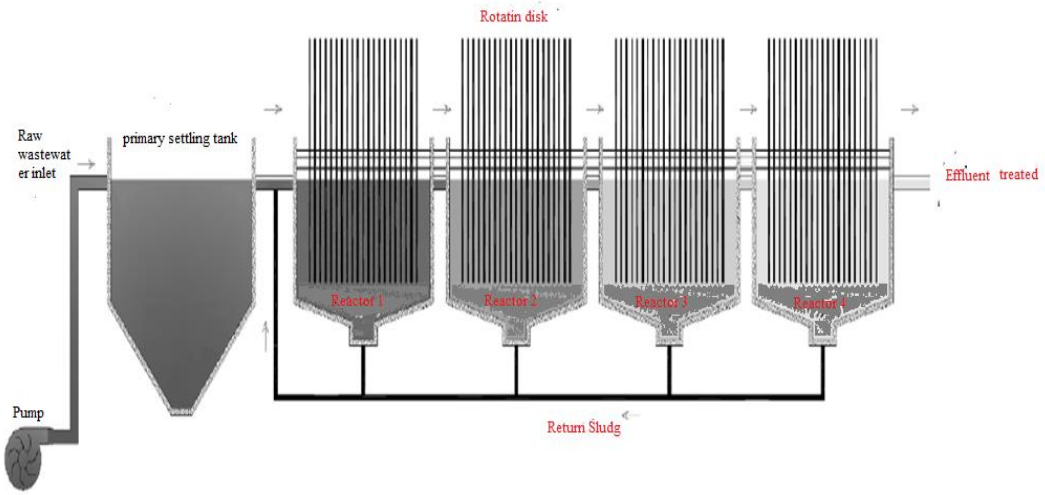

Fig. 1. Schematic of RBC package

Fig. 2. The RBC package of the case study

Fig. 3. The rotating disks in the RBC case study

In the RBC main module, aeration, sludge settlement and chlorination done. Finally, the treated wastewater passes through the sand tank filter. The design parameters of the RBC are given in table 1. In figure 2 the RBC package and in figure 3 the rotating disks are shown. The quality and quantity measurement are done in the inlet and outlet of the RBC in the current study to evaluate the potential applicability of this system as an alternative to the groundwater wells of the case study. In this paper the main focuses are on the balancing between irrigation needs and discharge produced by the RBC, so the quality parameters are not reported.

2.2. Water demands balancing with RBC productions

In the current study, based on the discharge records of treated effluent in the outlet of RBC package, and using the reference evapotranspiration calculation multiplying with the crop coefficient Kc, the irrigation water demand is calculated in different parts and plants of the case study farms. The water requirement of all agricultural plants and landscape species is determined. Then regarding with the extracted water from the groundwater well and produced treated effluent by the RBC package, the balancing between supply and demands is checked. By this comparison the potential applicability of local RBC packages is proved as an alternative water supply source and harvesting choice. Next section presents the results of the study.

3. Results and discussion

In this section the results of the water demand calculation in different parts and plants of the case study are presented and finally the balancing of these demands with the RBC production discussed. Table 1 presents the pistachio water needs of the pistachio orchard of the study. The pistachio orchard of the university has 23 hectares are, 12600 pistachio tree. By using the features of the water and soil such as, water EC, 2.3, soil EC 4, well discharge 10 l/s, and leaching requirement 14 % the calculations are done. As this table shows, for example in 2th solar month (Ordibehesht), water need of each pistachio tree in the case study region is 470 liters, and for the total orchards it is 5921 m3 and the share of pistachio orchard in this month is 7 day from 31 day. Using the results in table 1, enables the water allocation management of the pistachio orchard.

Table 2. Water needs calculations of pistachio trees in the case study in ten day scale

			Calculations regarding the leaching								
Solar Month	decade	Net Pistachio tree Water Need (liters)	Gross Tree Needs With Leaching (liters)	Total Pistachio orchard (m^3)	Tree Per Month (liters)	Total Orchards per month (m^3)	Share From the well (day)	Fixed share (day)	Share (hours)	Discharge of bubblers (l/h)	Irrigation time
1	3	62	103	1300	183	2311	2.67	3.00	72	27	6.8
2	3	117	195	2455	470	5921	6.85	7.00	168	27	17.4
3	3	159	264	3322	699	8810	10.20	11.00	264	27	25.9
4	3	200	332	4188	894	11265	13.04	14.00	336	27	33.1
5	3	242	401	5055	1123	14153	16.38	17.00	408	27	41.6
6	3	173	287	3610	917	11553	13.37	14.00	336	27	34.0
7	3	83	138	1733	527	6643	7.69	8.00	192	27	19.5
8	3	28	46	578	218	2744	3.18	4.00	96	27	8.1
12	3	28	46	578	138	1733	2.01	3.00	72	27	5.1
Yearly Total	Total per tree	3360	5582		5582						
Total orchard (m^3)		42340		70332		70332		90	2160		

Table 3. Landscape plants water needs

month	Gross total (m^3)	Total Pomegranate Jujube(m^3)	Grape total (m^3)	Flowers total (m^3)	Milk thistle total (m^3)	Rosemary total (m^3)	Eucalyptus total (m^3)	Rose total	Pine total (m^3)	European ash total (m^3)	Cedar (total)	Olive (total)	Chinaberry total (m^3)	Others (m^3)
1	205	180	119	108	164	123	283	308	460	495	460	61	61	130
2	280	827	433	247	224	168	386	420	628	676	628	157	157	410
3	310	1360	725	357	415	353	428	465	695	749	695	234	234	767
4	325	1540	794	407	520	455	449	488	729	785	729	299	299	1016
5	375	1780	912	378	600	525	518	563	841	906	841	376	376	947
6	318	1393	759	318	509	446	439	478	714	769	714	307	307	744
7	225	321	309	225	270	225	311	338	505	543	505	176	176	303
8	147	0	0	147	176	147	202	220	329	354	329	73	73	288
9	125	0	0	63	75	63	173	94	280	151	280	46	46	12
10	125	0	0	63	75	63	173	0	280	0	0	0	0	46
11	125	0	0	63	75	63	173	0	280	0	0	0	0	81
12	125	0	0	63	75	63	173	94	280	151	280	46	46	115

Table 4. Total landscape species water needs

month	Gross total (m^3)	Total Pomegranate Jujube(m^3)	Grape total (m3)	Flowers total (m3)	Milk thistle total (m3)	Rosemary total (m3)	Eucalyptus total(m3)	Rose total	Pine total (m3)	European ash total (m3)	Cedar (total)	Olive (total)	Chinaberry total (m3)	Others (m3)
1	512.5	131.8	1.3	32.5	49.2	36.9	853.5	153.8	6919.6	495.1	283.2	55.3	10.9	59.0
2	700.0	605.1	4.8	74.0	67.2	50.4	1165.8	210.0	9451.2	676.2	386.8	141.8	28.0	185.8
3	775.0	995.5	8.0	107.0	124.4	105.8	1290.7	232.5	10463.8	748.7	428.2	210.9	41.6	347.3
4	812.5	1127.3	8.7	122.0	156	136.5	1353.1	243.8	10970.1	784.9	448.9	269.7	53.2	460.2
5	937.5	1303.0	10.0	113.5	180	157.5	1561.3	281.3	12657.8	905.6	518.0	338.9	66.9	428.9
6	795.8	1019.9	8.3	95.5	152.8	133.7	1325.4	238.8	10745.1	768.8	439.7	276.6	54.6	336.9
7	562.5	234.9	3.4	67.5	81	67.5	936.8	168.8	7594.7	543.4	310.8	159.1	31.4	137.2
8	366.7	0	0	44.0	52.8	44.0	610.6	110.0	4950.6	354.2	202.6	65.7	13.0	130.2
9	312.5	0	0	18.8	22.5	18.8	520.4	46.9	4219.3	150.9	172.7	41.5	8.2	5.2
10	312.5	0	0	18.8	22.5	18.8	520.4	0.0	4219.3	0.0	0.0	0.0	0.0	20.8
11	312.5	0	0	18.8	22.5	18.8	520.4	0.0	4219.3	0.0	0.0	0.0	0.0	36.5
12	312.5	0	0	18.8	22.5	18.8	520.4	46.9	4219.3	150.9	172.7	41.5	8.2	52.1
Total	6713	5417	45	731	953	807	11179	153.8	6919.6	495.1	283.2	55.3	10.9	59.0

In table 3 the water need calculation for landscape plants are shown, and table 4 shows the total landscape water needs. Comparing the results in table 3-4 with those in table 2 indicates that the landscape plants need more water than the pistachio plants and adaptation with the water shortage requires re-patterning the crops in the landscape.

Based on the results of water demand calculations, the balancing determined between the shares of groundwater depletion with the treated effluent by the RBC package. In table 5, the percentage of landscape water demands supplying with the treated outputs of RBC packages are presented. As this table shows, the RBC package has the potential to provide the total demands of frosts in the landscape in all of the months, except the required demands in the summer season. Also using these results a time table for scheduling the irrigation of different users in the case study are proposed for the operators to increase the reliability of water demand needs. This result shows that using subsurface drip irrigation in the dry and hot region of the case study, has great importance and applicability as a new harvesting method for water shortage management. Especially in the green spaces and landscape irrigation, where there is not any eating or food uses from the plants, treated wastewater from the RBC package has low environmental risk and harmful effects. The results of study by Hasanli and Javan (2005) shown that treated

wastewater from Marvdasht city is applicable for irrigation needs and landscape irrigation as an alternative to the surface and groundwater resources, in agreement with the current study.

Based on the total treatable wastewater produced by the RBC 14000 CMS, the economic feasibility of the RBC package is remarkable and in comparing with the regional price of water production 450000 rails per cubic meter, developing treatment plants in local scales is valuable. This is in agreement with the results of Poordara et al. (2004) results that used hospital wastewater effluet for irrigation of green fields.

Furthermore, in Table 6, the quality of treated wastewater and the quality of raw influent in RBC package are presented. As this table shows, the treated wastewater has acceptable quality for landscape irrigation and the RBC package can be used as an alternative for local water harvesting from raw wastewater.

Table 5. The allocation portion of landscape frost water demand with the RBC treated wastewater

Month	Total demands of landscape (m3)	Average daily demand (m3)	Percent of total landscape demands suppliable with RBC	Demands of frost portion (m3)	Daily demands of frost from well (m3)	Daily demands of frost from RBC package (m3)	Percent of the daily demands of frost supplied by the RBC package (%)	Is RBC production enough for the frost?
1	9595	310	65	6884.8	222.1	148.1	135.1	Yes
2	13747	443	45	9974.5	321.8	214.5	93.2	Yes
3	15879	512	39	11525.1	371.8	247.9	80.7	Yes
4	16947	547	37	12286.0	396.3	264.2	75.7	75%
5	19460	628	32	14141.0	456.2	304.1	65.8	65%
6	16392	529	38	11887.2	383.5	255.6	78.2	80%
7	10899	363	55	7806.7	260.2	173.5	115.3	Yes
8	6944	231	86	4920.2	164.0	109.3	182.9	Yes
9	5538	185	108	4105.8	136.9	91.2	219.2	Yes
10	5133	171	117	4069.4	135.6	90.4	221.2	Yes
11	5149	172	117	4079.9	136.0	90.7	220.6	Yes
12	5584	193	104	4137.3	142.7	95.1	210.3	Yes

Table 6. The quality parameters of raw and treated wastewater

Parameter	Unit	Raw Value	Treated Value	Standard Value
BOD_5	mg/lit	330	85	100
COD	mg/lit	889	123.5	200
TSS	mg/lit	589	75	100
Focal Coliform	mg/lit	1150	383	400
TDS	mg/lit	1649	1649	2000
Total Coliform	mg/lit	1300	980	1000
Na	mg/lit	-	122	900 (FAO)
Ca	mg/lit	-	51..4	400 (FAO)
Mg	mg/lit	-	14.5	60 (FAO)
So4	mg/lit	-	48.7	500
Cl	mg/lit	-	325	600

4. Conclusions

In dry regions the reuse of treated wastewater plays a significant role in management, operation, scheduling and utilization of the water resources management regarding the sewage treatment plants. In design and operate such plants, it is essential to measure and forecast the harvested water from wastewater plants and balance the groundwater depletion with these new produced waters. In this study, potential water harvested by local wastewater treatment plants, Rotating Biological Contactor (RBC) is determined and balanced with water requirement of plants. Based on the design basis of RBC, the production ratio of 80 % is used and the produced discharge ranges from 4 up to 8 liter per seconds, with 140000 cubic meter per year. To quantify the balancing between RBC produced reuse water and irrigation water requirements, a plant-by-plant water requirement is calculated and the operation rule of groundwater wells in the case study are determined and proposed as an action plan to the operator of wells. Based on the results it was observed that the RBC can supply two times of pistachio orchard (23 hectares) irrigation requirements or 70 percent of the landscape and green space water needs.

5. Conflicts of Interest

No potential conflict of interest was reported by the authors.

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