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Research article

APPLICATION OF TREATED URBAN WASTE WATER CONSIDERING ENVIRONMENTAL AND ECONOMICAL ASPECTS; CASE STUDY: WASTE WATER TREATMENT PLANT OF KERMAN, IRAN

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ABSTRACT: This paper aims to study different treated urban wastewater applications; including, agriculture, industry, recreation and artificial recharge. The local and international criteria of water chemical parameters based on risk to environment and human health are used to assess the suitable usage of the treated wastewater. Kerman city in Iran was selected as case study. The quality of wastewater plant effluent was compared to local and international standards. Agriculture and groundwater artificial recharge were selected as feasible applicable sectors for the study. The question of research is which application of wastewater reuse is recommended from the viewpoint of environmental concerns. In addition, this research tend to estimate the economical benefits as well as development of new jobs by using wastewater in agriculture based on the climate circumstances of studied area. Considering the regional climate and soil conditions, pistachio was recommended to be irrigated by the treated wastewater. Moreover, the high return from pistachio production gives a high economical value to the treated wastewater. Then, economic value of treated wastewater was estimated 0.97 USD/m^3. Additionally, effluent reuse in the case study results 374 million USD added values as well as development of 672 new direct jobs in agriculture sector.
Key words: Waste water, water reuse, Environmental concern, Water value, added value.

INTRODUCTION

Increase in the world population and diminishing renewable water resources due to climate change, bulk water uses and water pollution cause water scarcity in many parts of the world especially in the Middle East. Therefore, using different technologies and unconventional waters such as salt water desalination or wastewater treatment are necessary to overcome the shortage. In many large cities, produced wastewater is significant and it used to be considered as waste due to deterioration of the water quality. This reusing scenario can reduce the adverse impact of wastewater release into the environment. Due to the wide range of technologies that now exist to recycle this wastewater to an acceptable level of consumptions, the chances for wastewater to be classified as a renewable water resource increases. However, the successful development of this reliable water resource depends upon close examination and synthesis of elements from infrastructure and facilities planning, wastewater treatment plant setting, treatment process reliability, economic and financial analyses, public acceptance, and water utility management [1]. Another research used Beijing in China as a case study and used a linear programming model to analyze different reuse scenarios concerning alternative wastewater charges and reuse prices [2]. In the study, the main users of the treated wastewater were agricultural irrigation and urban recreation sectors. According to the Global Water Intelligence (GWI) in its 2009 report on global water reuse between 2009 and 2016, it is expected that capital expenditure on advanced water reuse will grow at an annual rate of 19.5% [3] GWI also notes a growing use of reused water in applications other than the traditional agricultural market. Increasing urban water reuse is helping to reduce urban water stress and provide a higher return on investment to users of water reuse technologies [3]. In most areas around the world, the price charged by water suppliers is often unrelated to the value of water and it is too low. Therefore, to select the best application for the produced wastewater, it is necessary to evaluate the economical value of the treated wastewater. To aid in cost-benefit analysis under conditions where appropriate price incentives are absent, economists have developed a range of alternative or "non-market" methods for measuring economic benefits [4]. Residual method is the selected method for this study and it is based on added value to the final production.

Kerman city in East of Iran was selected as case study and local treated wastewater was studied. The objective of this paper is to compare the quality of the treated wastewater with national and international standards and find the best use for that water and weigh the economical return.

MATERIALS AND METHODS

Four different potential applications were considered for the treated wastewater. These applications are agriculture, industry, recreation, and groundwater artificial recharge. Quality standards for each application and economical considerations were the criteria for selecting the suitable application. As a case study, Kerman city, Iran, was selected for this research. Seasonal sampling from wastewater treatment plant were taken and analyzed for this study.

Study Area

Kerman city with average annual temperature of 15.5oC and annual precipitation of 146.5 mm is located in east of Iran within the arid zone belt of the world. The population of the city is about 515,000 and the projection is that the population will be increased by 875,000 by year 2021. The average water consumption in the city is 300 litres per capita. Therefore, the total annual domestic water consumption is 64 million cubic meters (MCM). Using 75% conversion factor the estimating wastewater of the city is about 48 MCM per year. Agriculture is the main activity of the people around the city and the main crop in the area is the pistachio.

Kerman Wastewater System

The wastewater treatment plant is an active sludge system including 5 modules to cover 700,000 people. The total effluent of the plant is 105,000 cubic meters per day. At present, the first module is in operation. Table 1 shows the quality parameters of the treated wastewater and national and international standards from different agencies.

Table 1: comparing characteristics of treated effluent expelled from wastewater plant of Kerman City to standards [5]

Parameter	Unit	Wastewater plant effluent	Iran Dept. of Environment standard	U.S. EPA Standard	WHO standard	FAO standard
PH	----	7.6	6-8.5	6.5-8.4	6-8.5	6.5-8
EC	dS/m	3.5	-	0.7	0.7	0.7
TDS	mg/L	2000	-	-	450	450
TSS	mg/L	50	100	5	-	-
BOD_5	mg/L	21	100	30	-	-
COD	mg/L	45	200	120	-	-
DO	mg/L	1	2	-	-	-
Ca^{++}	mg/L	304.8	-	200	-	400
Mg^{++}	mg/L	79.4	100	25	-	61
Cl^-	mg/L	409	600	100	106	142
Turbidity	NTU	11.5	50	2	-	-
Total Coliform	mpn/100 ml	150000	1000	200	1000	-
NO^-_3	mg/L	4.64	-	30	5	5
PO^{3-}_4	mg/L	7.6	-	10	-	-
Cu	mg/L	0.000034	0.2	0.2	0.2	0.2
As	mg/L	0.000011	0.1	0.1	0.1	0.1
Ni	mg/L	0.0000036	2	0.2	0.2	0.2
Zn	mg/L	0.00002	2	1	2	2
Cr	mg/L	0.000011	2	0.1	0.1	0.1
Pb	mg/L	0.0000018	1	5	5	5

Application in Agriculture

Crops best suited for irrigation with treated wastewater effluent are trees, cereals, legumes and fodder crops [6]. While it is legal to grow vegetables that will be cooked after harvesting, this is only recommended when the quality of effluent is very high and where farmers are already proficient in controlled irrigation. Agricultural activities that require special attention include soil testing to identify fertilization practices that avoid over-application of nitrogen, proper pruning, and preventing animals from entering areas irrigated with treated wastewater. Figure 1 shows the comparison of plant effluent quality with the Iranian Dept. of Environment (DoE) standards.

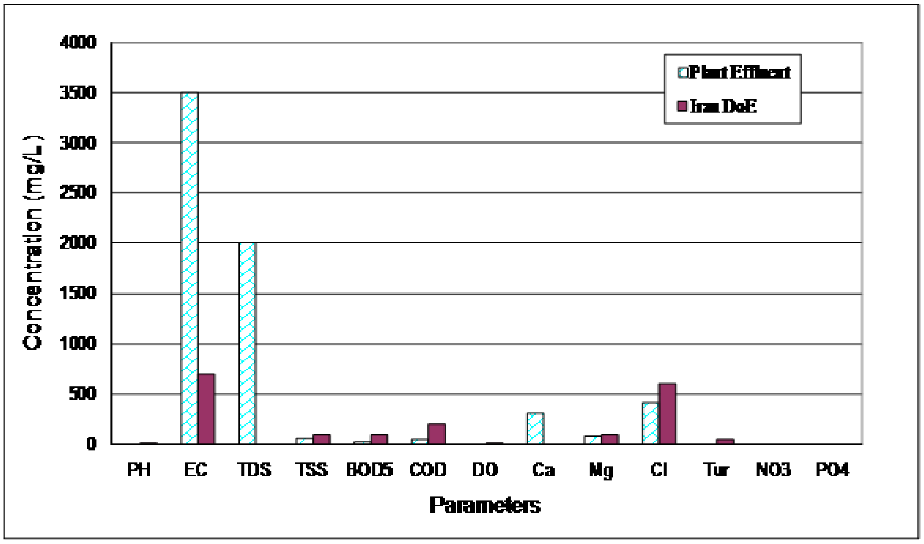

Figure 1: Comparison of treated wastewater with national DoE standard for irrigation

Application in Industry

For industrial purposes, the required quality of treated wastewater depends on the type of industry and acceptable concentrations of chemical properties of the reusable water are the important decision factor for most of the industries. However, the treated wastewater is suitable for many industrial purposes such as cooling towers and boilers [7].

National standard developed by DoE is presented in Table 2. Waste waters are grouped into three categories, A, B, and C, in this guideline. The quality of the plant was compared with the DoE standards and as it is appeared, the treated waste water is in category C.

Table 2. National DoE standard for using treated wastewater in industry

Index	Plant Effluent	Category		
		A	B	C
pH	7.6	6-9	6-9	6-9
COD (mg/L)	45	<20	<75	>75
Hardness (mg/L)	N/A	<250	<500	>500
Alkalinity (mg/L)	N/A	<150	<500	>500
Sulfate (mg/L)	400	<250	<500	>500
Total Suspended Solids (mg/L)	50	<50	<100	>100
TDS (mg/L)	2000	<500	<1000	>1000
Chloride (mg/L)	405	<200	<500	>500

Application in Recreation

In order to evaluate the possible application of treated wastewater for recreation, DoE's standard was used. This standard has been shown in Table 3. The presented range for each parameter does not guarantee a safe environment but minimizes the risk of any diseases to be transmitted to human.

Table 3. National DoE standard for using wastewater in recreation

	Index	Total Coliform (mpn/100 ml)	Faecal Coliform (mpn/100 ml)	Escherichia (mpn/100 ml)	Enterococci (mpn/100 ml)	DO (mg/L)	pH
Recreation Type	Direct (average)	2000	400	200	50	≥ 5	6-9
	Direct (max.)	10000	2000	600	200		
	Indirect (average)	5000	2000	600	200		
	Indirect (max.)	10000	4000	1200	400		

Application in Artificial Recharge

Again, the DoE's standard for using of wastewater for groundwater artificial recharge was used. Figure 2 shows the comparison of plant effluent with the standard values.

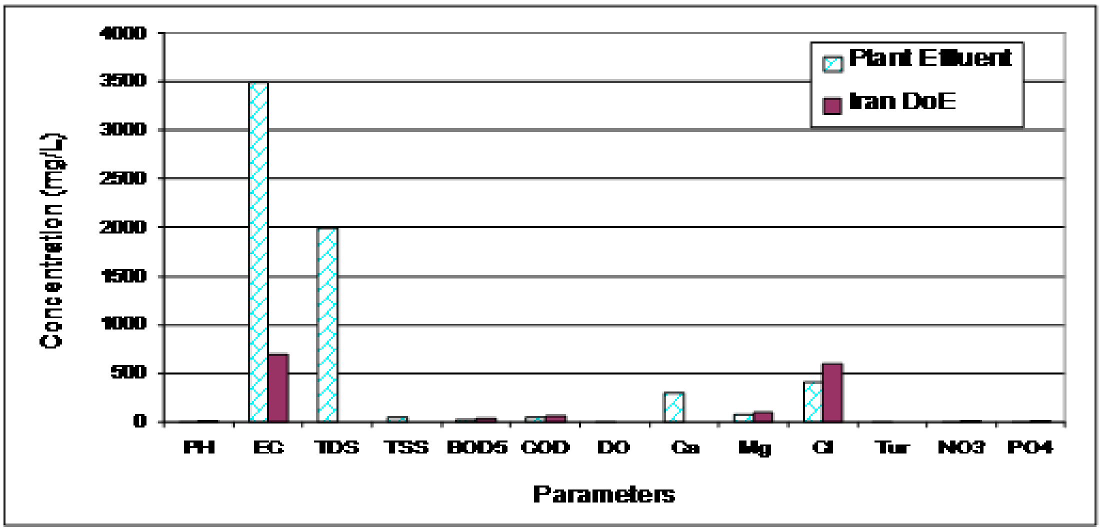

Figure 2. Comparison of plant effluent quality with national standards for artificial recharge

RESULTS AND DISCUSSION

Application in Agriculture

The comparison of the wastewater plant effluent with the DoE standards for application in agriculture shows that Electrical Conductivity (EC) is relatively high and only crops with high tolerance to salinity can be used. In addition, the total coliform is high and it needs special attention in application of this water by farmers and it cannot be used for crops which are consumed raw. Considering the saline soil condition in the area and high EC in plant effluent, pistachio is the main recommended crop. Due to associated potential risk to human health, treated wastewater cannot be used for production of raw vegetables. Pistachio is one of the main agricultural crops in the area and there is no climatological or soil limitations for this plant and consume less water for sufficient production. In addition, pistachio plant has high economic return of approximately 16,000 USD/year/hectare compared to other highly consumed crops like burley and wheat that only returns 800 to 1000 USD/year/hectare.

Application in Industry

The main parameters which are used to evaluate the application potential of wastewater in industry are pH, TDS, TSS, COD, and chloride. The plant effluent analysis shows that treated wastewater in Kerman is in category C, therefore, it can be recommended for cooling tower purpose only. Since, there was no market and use as this application in the region, the treated wastewater was not considered for industrial use.

Application in Recreation

High value of total coliform and low value of DO in the quality analysis of the treated wastewater indicate that the wastewater plant effluent is not suitable for recreation and it is not recommended because of potential risks to human health.

Application in Artificial Recharge

Considering the soil type and aquifer characteristics in the region, the wastewater plant effluent can also be used for artificial recharge. Kerman aquifer is stressed from over exploitation and water level is dropping significantly every year. Therefore, the artificial recharge is feasible when other application is not possible. In the Kerman region, the natural precipitation is very low (146.5 mm per year) and in winter when the irrigation requirement is zero, the artificial recharge can help aquifer to recover.

Economical Evaluation of Treated Wastewater Application

The study shows application of the treated wastewater in selected agricultural product is the only feasible solution in the region considering the quality of the wastewater plant effluent. Residual method [4] was used to calculate the water value for the selected suitable crop, i.e. pistachio, in the region. In this method, all costs except water value are calculated and it is subtracted from the product market value. It is assumed that the added value is due to water. The field survey in the local area is summarized in Table 4 that shows the cost of pistachio production and Table 5 shows the economical value of the water to produce this crop.

Based on initial design of the wastewater plant for phase I that includes module 1 and 2, total capacity of the plant is 38.5 MCM per year which results of 374 million USD added values in the agriculture sector. It also increases the job opportunity for the region. Every 5 hectares (ha) of pistachio needs 1 farmer. The plant effluent is able to irrigate 3358 ha, therefore, there is a potential of hiring 672 new workers in this sector.

Table 4. Average of production cost of pistachio per hectare

Variable	Labour (man-day)	pesticide (litre)	Organic fertilizer (ton)	Chemical fertilizer (kg)	machinery (hour)	Land rent (hectare)
Usage quantity per hectare	128	20.2	30	895	48	1
Price (USD)	11	8	0.06	0.12	7	1064
Production cost (USD)	1408	161.6	1800	107.4	336	1064

Table 5. Estimated water economic value of pistachio using residual method

Gross production revenue (USD per hectare)	Cost of production inputs except water (USD per hectare)	Economic value of water (USD per hectare)	Volume of water usage (cubic meter per hectare)	Economic value of water (USD per cubic meter)
16,000	4,877	11,123	11,465	0.97

CONCLUSION

Nonconventional water resources are becoming more important these days due to water scarcity around the world. In this research, the possibility of reusing urban wastewater was studied. Different potential users including agriculture, industry, recreation and artificial recharge were considered and the quality of treated wastewater plant effluent was compared with the national standards for each application. At the end, agriculture and artificial recharge were identified as the most feasible application for the study area. Application of treated wastewater still needs environmental and health considerations to prevent any adverse impact on environment or transmitting diseases. A monitoring program for soil and water parameters should be in place.

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