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Qualitative Evaluation of Potential Impacts of Effluent of Genaveh Hospital Wastewater Treatment Plant on Soil and Plants

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Abstract

Increasing population growth, improve living standards and industrial development are factors which increase water consumption and waste production. Therefore, the use of treated wastewater in agriculture to overcome the problems of water scarcity, particularly in areas with water shortages, is important. In this study in addition to assessing the performance analysis of Genaveh hospital wastewater treatment plant, The quality of the output of effluent of wastewater treatment plant for use in agriculture based on Ayers water quality guidelines were assessed and its potential adverse effects on soil and plants were evaluated. In this study within six months physical and chemical parameters such as pH, EC, calcium, magnesium, sodium, chloride, nitrate, bicarbonate, TDS and heavy metals (iron, manganese, nickel, cadmium, cobalt, lead and zinc) in the output effluent were determined according to standard methods. According to the obtained results, the use of hospital effluent Genaveh in agriculture in term of concentration of sodium in terms of SAR, bicarbonate, chloride, Adsorbed sodium absorption ratio encountered with low to moderate limitation of electrical conductivity. Severe limitations in terms of nitrate nitrogen and heavy metals concentrations in the range are determined. In general results of this study indicate that to reuse the Genaveh hospital effluent in agriculture continuous monitoring of the output of effluent of wastewater treatment plant to meet environmental standards is essential.

Keywords: **effluent, wastewater treatment plant, Ayers and Westcot guideline, hospital, Genaveh.**

Introduction

Increasing growth of population, improved living standards, industrial development and technology transfer are factors which increase water consumption and waste production in societies and environmental contamination; this caused problems which urge the investment on treatment and sanitary disposal (Zafarzadeh et al., 2013). Currently, decision-makers are concerned with application of effluent discharged from wastewater treatment plants in agriculture to compensate the lack of water resources and provide food security (Mahvi et al., 2009). However, these waters contain minerals such as salts, sodium, chlorine, bromine, microorganisms, and in some cases, heavy metals or other harmful organic and inorganic compounds (Commission on Goscience, 2003). It is noteworthy that successful utilization of sewage in agriculture requires the consideration of its effects on the environment, agricultural yields and human health; otherwise, it will cause serious damage to nature and human society (Feizi, 2001).

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When using wastewater for irrigation, it is essential to consider the effects of inorganic and organic compounds existing in wastewater on the growth of plants and changes in the structure and chemical properties of soils (accumulation of nitrogen, phosphorus and heavy metals) followed by rises of toxins in the soil, plant and animal tissue and eventually human food chain as well as substances such as nitrate and toxic solutions leached from the soil into groundwater (Kalavarouziotis, 2008; Kiziloglu, 2008; Pales, 2009). Establishment of wastewater treatment plants alone cannot eliminate environmental concerns; instead, their performance needs to be evaluated consistently to meet environmental standards (Cirja et al., 2008). Therefore, potential advantages of treated effluents can be used by proper management in accordance with international physical, chemical and microbial standards. One of the most common guidelines in relation to physical and chemical parameters as well as heavy metals existing in irrigation waters is Ayers and Westcot guideline (Ayers and Westcot, 1985), as presented in Table 1 and 2. The Ayers and Westcot guideline is based on many studies conducted on factors such as percentage of leaching, changes on soil permeability changes due to EC, sodium absorption ratio (SAR), salinity tolerant plants, sodium, toxicity and other trace elements; therefore, it can be used to evaluate the quality of effluent used for agriculture (Danesh & Alizadeh, 2008). In the present research the quality of Genaveh hospital wastewater treatment plant effluent in terms of potential impact on soil and crops to extrapolate the quality parameters provided by Ayers and Westcot have been evaluated.

Potential problems		Unit	Safety limit		
			Unlimited	Low to moderate	High
Salinity	Electrical conductivity	dS.m-1	>0.7	3 -0.7	<3
	Concentration of dissolved solids	mg.L-1	>450	2000-450	<2000
Permeability	SAR: 0-3		0.7>	0.2-0.7	0.2<
	SAR: 3-6		1.2>	0.3-1.2	0.3<
	SAR: 6-12		1.9>	0.5-1.9	0.5<
	SAR: 12-20		2.9>	1.3 - 2.9	1.3<
	SAR: 20-40		5>	2.9-5.0	2.9<
Specific Ion Toxicity	Sodium (Superficial irrigation)	SAR	>3	9 -3	<9
	Chloride	meq.L-1	>4	10 -4	<10
	Boron	mg.L-1	>0.7	3-0.7	<3
Other Effects	Nitrogen (NO3-N)	mg.L-1	>5	30-5	<30
	Bicarbonate	meq.L-1	>1.5	8.5-1.5	<8.5
	pH	-	Normal range 6.5-8.4		

Table 1: Quality of irrigation water based on Ayers and Westcot guideline

Parameter	Unit	Value	Parameter	Unit	value
Aluminum	mg.L-1	5.0	Iron	mg.L-1	5.0
Arsenic	mg.L-1	0.10	Lithium	mg.L-1	2.50
Beryllium	mg.L-1	0.10	Manganese	mg.L-1	0.20
Cadmium	mg.L-1	0.01	Molybdenum	mg.L-1	0.01
Cobalt	mg.L-1	0.05	Nickel	mg.L-1	0.20
Chromium	mg.L-1	0.10	Lead	mg.L-1	5.0
Copper	mg.L-1	0.20	Selenium	mg.L-1	0.02
Fluoride	mg.L-1	1.0	Vanadium	mg.L-1	0.10
Zinc	mg.L-1	2.0	Titanium	mg.L-1	-

Table 2: maximum concentrations recommended for trace elements in irrigation water (Ayers and Westcot,1985)

Studied Location

Genaveh, one of the counties in north of the Bushehr Province, is located on the south of Iran at coordinates 50°8′-50°53′E 29°10′-29°44′N. The annual rainfall is 150 mm, on average. The important hospital of Genaveh County is Amir Al-Momenin Hospital with 92 beds. On average, the hospital consumes 59.58 m3 per day. This hospital is adjacent to the Shahid Choroomi Hospital; therefore, wastewater treatment plant of Amir Al-Momenin Hospital treats the sewage discharged from Shahid Choroomi Hospital. Shahid Choroomi Hospital consumes 16.9m3 water per day. On average, these two hospitals convert 65% of water to sewage. As a result, the plant receives 49. 85 m3 sewage per day.

Materials and Methods

In this study to assess the quality of Genaveh hospital wastewater treatment plant effluent a period of 6 months from July 2013 to December 2013 and with monthly intervals some samples were taken from the input sewage and output effluent and physical and chemical parameters such as pH, TDS, electrical conductivity, calcium, magnesium, sodium, chloride, nitrate, bicarbonate, and heavy metals (iron, manganese, nickel, cadmium, cobalt, zinc, lead) were measured. All conditions for sampling and testing were in accordance with standard methods for examination of water and wastewater done (APHA, AWWA and WPCF, 2005). SAR and adj RNa were calculated by:

$$SAR = \frac{Na(meq/L)}{\sqrt{(Ca+Mg)/2}(meq/L)} \quad (1)$$

$$adjR_{Na} = \frac{Na}{\sqrt{\frac{Ca_x + Mg}{2}}} \quad (2)$$

Spectrophotometer (HACH-DR 2800) was used to determine the concentration of sodium, chloride and nitrate ions. In addition, concentration of heavy metals was measured by atomic absorption spectrometry equipped with graphite furnace; pH was measured by digital pH meter (HACH, Sension156), and electrical conductivity (EC) was measured by digital EC meter. Calcium and magnesium were measured by titration using EDTA. The concentration of bicarbonate was measured by titration using sulfuric acid (APHA, AWWA & WPCF, 2005). For higher accuracy, parameters were tested in three iterations. Data analysis was performed by SPSS, version 22.

Results and Discussion

Figures 1 to 8 show the changes in physical and chemical parameters in the wastewater treatment plant effluent during the study period. Table 3 indicates the mean, standard deviation, minimum and maximum levels of heavy metals in wastewater treatment plant effluent under the study during the study period.

Descriptive statistics / Parameters	Mean	Standard deviation	Minimum	Maximum
Iron	48.35	3.224	40.80	56.2
Cobalt	8.92	1.495	6.50	11.5
Nickel	5.96	0.968	4.30	7.8
zinc	18.86	2.082	16.20	22.7
Cadmium	0.15	0.022	0.12	0.2
Lead	6.82	0.893	4.80	8.2
Manganese	15.70	2.360	12.50	21

Table 3: Descriptive statistics of trace metals in the effluent (µg/L)

Adjusted SAR (adjRNa)

The amount of adjRNa in hospital effluent of Genaveh was 4.34 and EC was 2.22 ds/m, on average. Figure 2 shows the trend of changes in SAR during the studied period. According to Ayers and Westcot guideline, the evaluation suggests that the wastewater treatment plant -effluent can be used to irrigate crops with no limitation on adj RNa and EC.

Sodium

In order to evaluate the risk of sodium ions in superficial irrigation of crops, sodium adsorption ratio or SAR is used (Rahmani & Feizi, 2008). Destructive effects of sodium include decreased penetration, difficult germination, poor soil ventilation, and prevalence of root and plant diseases (Amin et al., 2010). The value of SAR was 7.20 for the wastewater treatment plant effluent. In Figure 2 the process of SAR index changes during the study period are shown.Quality assessment of wastewater based on Ayers and Westcot guidelines (Ayers and Westcot, 1985). suggest that the use of effluent for irrigation of agricultural crops in terms of toxicity level of sodium ions, encountered with low to moderate limitations.. Hassanlee and Javan through evaluating the efficiency of Marvdasht wastewater treatment plant showed that the use of the effluent of this wastewater treatment plant to irrigate crops in terms of SAR index faced low to moderate limitation (Hassanlee & Javan, 2005).

These finding are consistent with results of Al-Turki in relation with evaluation of the quality of the wastewater treatment plant of Buraidah in Saudi Arabia for reuse in irrigation (Al-Turki, 2010).

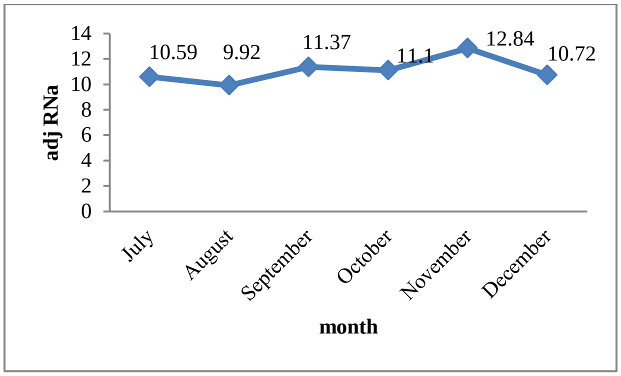

Figure 1: changes in adj RNa of the effluent

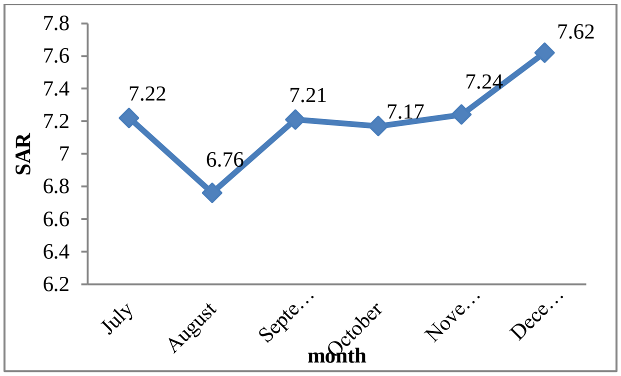

Figure 2: Changes in SAR of the effluent

Chloride

Chloride ion plays an important role in creating toxicity of plants and crops (Ayers & westcot, 1985). Chloride ion isn't absorb in the soil particles level but with moisture transmitted to soil and after absorption through root , such as sodium accumulates in the leaves. Tree plants perennial plants are sensitive to low concentrations of chloride, while most of one- year plants aren't sensitive (Pescod, 1992). The process of Chloride concentrations change in effluent of wastewater treatment plant house under the study is shown in Figure 3 and the average amount of chloride ion in the effluent of under study wastewater treatment plant is 6.43 mEq per liter. Therefore, the use of wastewater treatment plant wastewater for irrigating resistant plants such as alfalfa, wheat, barley, beets and mango is suitable. Research results Sabzevari and et al in relation with examine the quality of wastewater of wastewater treatment plant of Atieh sazan hospital in Hamadan suggests that the concentration of chloride in the wastewater treatment plant effluent for irrigating crops has low to moderate limitations (Sabzevari et al., 2005). The study result of Al-Khashman in relation with chemical assessment of sewage of Ma'an wastewater treatment plant in Jordan suggests that the use of the wastewater of mentioned wastewater treatment plant in terms of chloride ion has no restrictions (Al-Khashman, 2009).

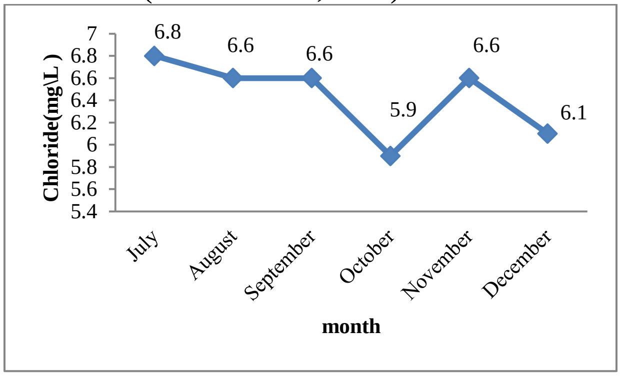

Figure 3: Changes in chloride of the effluent

Nitrate

Nitrate is one of the forms of nitrogen that depending on the refining process can be found in sewage effluent (Duncan et al., 2008). Nitrate nitrogen due to negatively charged is not removed through ion exchange with soil particles. If nitrates are not absorbed into the plant and microbes are not absorb it, directly goes into the underground aquifers and would be risky. Increasing the concentration of minerals, especially nitrogen, significantly affects the plant growth function and crops yield (Levy et al., 2011). Changing process in nitrate concentrations in effluent of under study wastewater treatment plant is shown in figure (4). Average of nitrate concentration in Genaveh Amir-AL-momenin hospital wastewater treatment plant effluent is 32.14 mg/L which suggest that that the use of effluent for irrigation of agricultural crops in terms of toxicity of nitrate ions associated with severe restrictions. High levels of nitrate in the output effluent indicates that poor denitrification in refinement process of hospital that are related to hydraulic organic load applied to wastewater treatment plant lack or imbalance of return sludge from secondary sedimentation tank, is inappropriate amount of food for microorganism (F / M) (Mahvi et al., 2009). Considering the criteria for recommended value in Ayers and Westcot guidelines, effluent the quality of wastewater treatment plant is not assessed desirably in terms of nitrate concentrations for irrigating crops. The result of analysis conducted by Akponikpe and et al in relation with the reuse of Domestic wastewater suggest that use of effluent of wastewater treatment plant in terms of nitrate has low to moderate limitations (Akponikpe et al., 2011). Also the study result of AL-Jaboobi and et al in relation with Effluent quality Sana'a in Yemen showed that nitrate concentrations in the wastewater treatment plant effluent for irrigating crops has low to moderate limitations (AL-Jaboobi et al., 2013).

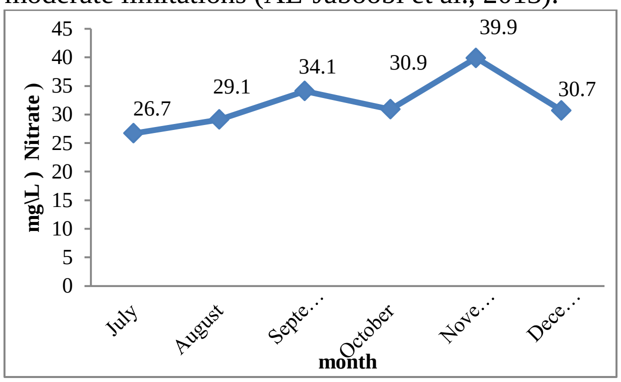

Figure 4: Changes in nitrate of the effluent

Bicarbonate

Bicarbonate, as one of the alkalinity agents, increases the potential soil degradation by precipitating calcium and magnesium ions (Ayers & Westcot, 1985). In Figure 5, the bicarbonate changes during the study period are shown. The analysis results indicate that the average amount of bicarbonate in the wastewater treatment plant effluent is 203.30 mg/L. comparing the obtained result with proposed criteria in Ayers and Westcot guidelines suggest the fact that bicarbonate concentration in the wastewater of wastewater treatment plant under the study is assessed desirably. The result of analyzes performed by Rahmani and Feizi(2008). in relation to the quality of wastewater treatment plant effluent of north of Isfahan suggest that use of wastewater of this wastewater treatment plant in agriculture in terms of bicarbonate concentration, faces low to moderate limitations. Also these findings are consisten with study result of Mouhanni and et al (Mouhanni et al., 2011).

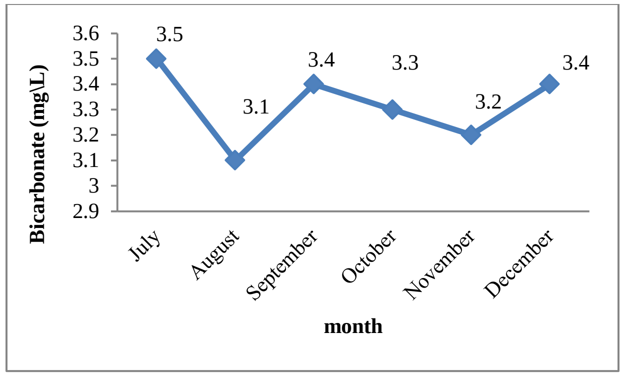

Figure 5: Changes in Bicarbonate of the effluent

pH

is one of the important effective parameter in biological process of refining the wastewater is pH and its changes. Generally favorable pH for the growth and activity of bacteria is in range of 6.5-8.5 and the activity of most of effective bacteria in reefing the wastewater is interrupted or stopped at pH greater than 9.5 (Amouei et al., 2010). It is a parameter influencing the relative solubility of nutrients and heavy metals that can affect plant growth and its performance (Ayers & Westcot, 1985). The mean pH of the effluent of under study wastewater treatment plant is 6.92 during the study which is in normal range and will not adversely affect the irrigated soil and plants. PH changes in output effluent of refinery are shown in figure6. The study result of Massoudinejad and et al in relation with examining the quality of effluent of Zamyad factory suggest that the pH is in the standard range (Massoudinejad et al., 2006). Nazemi and et al evaluated the performance of Imam Hossein hospital wastewater treatment plant in Shahrood; they concluded that the pH of effluent treatment plant has no limitation for irrigating crops (Nazemi et al., 2009).

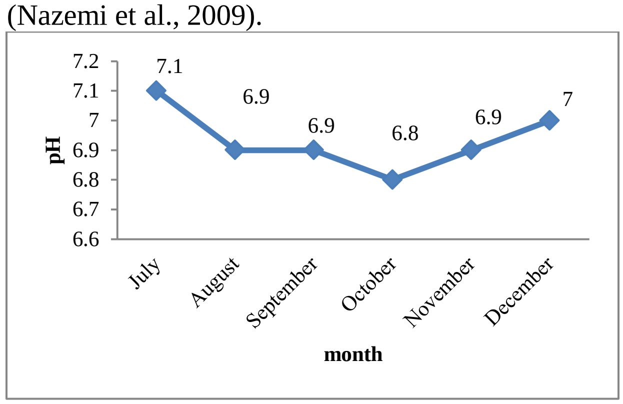

Figure 6: Changes in pH of the effluent

TDS

Average TDS in the effluent under study wastewater treatment plant is 1683.04 mg/L.
The process of TDS changes in the effluent of under study wastewater treatment plant is shown in figure 8. Comparing the obtained results with presented criteria in Ayers and Westcot guidelines suggest that TDS concentration in effluent of under study wastewater treatment plant has low to moderate limitations. The result of conducted research by Naseri and et al about assessing the reuse of Ardebil wastewater treatment plant suggest that TDS levels in effluent of wastewater treatment plant low to moderate limitations for irrigating crops (Nasseri et al., 2008). Also this finding is consistent with the result of Sabzevari and et al (Sabzevari et al., 2005).

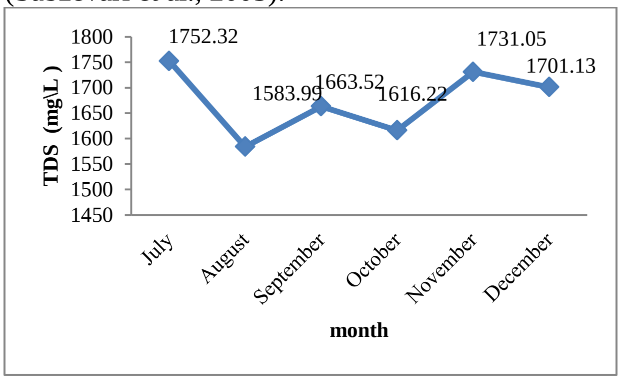

Figure 7: Changes in TDS of the effluent

EC

The electrical conductivity is directly related to the total anions and cations (Hassan Aghla et al., 2002). The EC changes in effluent of under study wastewater treatment plant are shown in diagram 8. Average EC of effluent of under study wastewater treatment plant during the study was 2.23 ds / m. According to the classification criteria of irrigation of Ayers and Westcot in terms of EC, the use of effluent of under study wastewater treatment plant is associated with low to moderate limitations. The study result of Massoudinejad and et al about investigating the reuse of effluent of Zamyad factory for irrigation suggest that applying the effluent of mentioned wastewater treatment plant in terms of EC has low to moderate limitations moderate (Massoudinejad et al., 2006 Based on the previous analyses, it can be concluded that the effluent used for irrigation of some crops can reduce the agricultural products in absence of salinity management methods. Due to the high salinity of the effluent, irrigation will be followed by 10% reduction in yields of corn, potatoes, turnips, clover, grapefruit, oranges, almonds and plums and 25% reduction in yields of more sensitive plants such as beans, carrots and apricots (Ayers & Westcot, 1985; Mass, 1984).

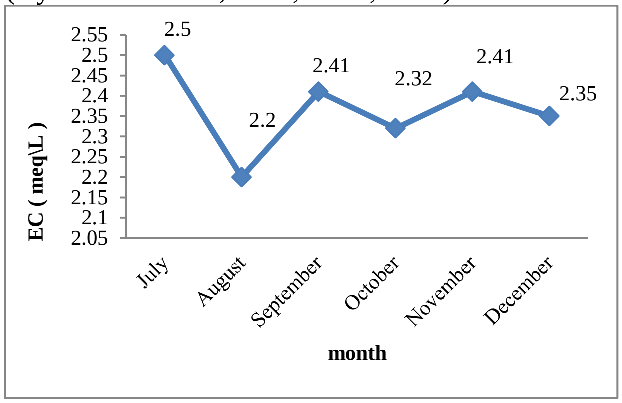

Figure 8: Changes in EC of the effluent

Heavy Metals

Long-term use of wastewater for irrigation often leads to the increased levels of heavy metals (Larcheveque et al., 2006). When the capacity of the soil to hold heavy metals (due to the increased level of heavy metals in the soil) decreases, heavy metals are released into the groundwater or in the form of solutions usable for plant absorption (Sharma et al., 2007). High concentrations of heavy metals in plants can influence the transfer and balance of essential elements through competitive adsorption (Schat & Ten Bookum, 1992). Table 3 lists the mean, standard deviation, maximum and minimum concentrations of heavy metals (iron, manganese, nickel, cadmium, cobalt, lead and zinc) in Genaveh hospital wastewater treatment plant effluent. Comparing the measured values and maximum allowable values recommended in Ayers and Westcot guideline, it can be concluded that the concentration of heavy metals in wastewater treatment plant effluent is within the determined range, which is consistent with studies in Mexico city (Mireles et al., 2004) and in Turkey (Alaton et al., 2007). It is vital to consider the long-term effects of heavy metals in soil and plants tissues that need to be monitored periodically based on a proper management of effluent quality, soil and irrigated crops.

Conclusion

According to the results obtained in this study, the performance of Genaveh Hospital wastewater treatment plant - effluent in removing all parameters except TDS and nitrate is suitable. In terms of concentration of parameters EC, sodium, chloride, bicarbonate and adj RNa index for agricultural use is with low to moderate limitation and in relation to the concentration of nitrate ion has a severe limitation. Therefore, it can be concluded that in order to avoid adverse effects of prolonged use of Genaveh hospital wastewater treatment plant effluent on irrigated soil and crops requires continuous monitoring of effluence and fixing the flaws in ventilation system and the return sludge flow. In that case, the effluent can be used to grow plants resistant to salinity and resistant to moderate concentrations of other parameters. Since the use of refined effluent reduces the cost of water needed for irrigation in farms, in the present condition of dehydration, we can through optimize the management of wastewater for irrigation crops in area and for irrigation of green space of hospital can be used.

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