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Management to Improve the Quality of Drainage Water for Reuse
(Irrigation and Drainage Network Behbahan Case Study)

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Abstract: Reusing is an important and natural method of managing drainage water. In areas where irrigation water supplies are limited, the drainage water can be used as a complementary new source of water. However, the drainage water quality determines which crops can be irrigated by that water. Since the use of the drainage water due to in appropriate amount of its salt and sodium can increase soil salinity and change exchangeable sodium percentage of the soil, the use of drainage water should be with careful planning and proper management. One of effective solutions in reducing pollution in the drainage water in the farm is matching planting with drainage water quality.The present article is conducted based on field surveys of eight farm of irrigation and drainage network of Behbahan (north and south) that due to drought (water shortage) - long irrigation intervals - poor distribution of water due distance of farming land from the intake valves are forced to withdraw drainage water by pumps from the channels. In this paper, matching the selective planting pattern of the mentioned fields with chemical properties of drainage water quality was tested . The results of chemical analysis of the quality of drainage water show an increase of 1.76 times of electrical conductivity, 1.3 times total dissolved solids,85 percent reduction of PH in the north network, 2.32 times increase in electrical conductivity, 1.8 times total dissolved solids, and 1.09 reduction of PH in the south network compared to Maroon River water quality.The relative performance of cultivated crops in the northern region in rice, corn, tomato is respectively 85, 58, and 85 percent , and in the south in beans common , mung, eating vegetables are respectively 10.7, 70, and 41.5 percent. Using the table of classification of the effect of irrigation water on permeability and considering the average quality of drainage water samples in both networks, SAR is between 6-12 and its salinity is more than 1.9 mmhos/ cm,and drainage water quality was considered good . This paper also examines the reasons for better quality of drainage water in some places of the network and solutions to nullify the social and environmental impacts of reusing agricultural drainage water in the agriculture of the region .Given the water crisis in the region, the quantity of water drainage that in some areas is permanent,and acceptable quality of drainage water, with proper management (combined use or mixing when salinity of drainage water is higher than the threshold for optimal production,and matching cultivation pattern with drainage water quality), in addition meeting a part of the agricultural needs of the region, one can save and create sustainable water resources for the region .Due to salinity, it is suggestedthat planting pattern be replaced with more resistant plants to replace the cultivation of maize, beans, and vegetable. In the end, given that no management had taken placed for reuse of drainage water in the region ,training sessions with the subject of terms and conditions of drainage water reuse was held for farmers that was welcomed by them.
Key Words: Drainage Water – Quality –Cultivation pattern- Proper management- combined

INTRODUCTION

Re-use is an important and natural method of managing drainage water. In order to develop the maximum benefit from a water supply and to help dispose of drainage waters, strategies for water re-use have evolved. In regions where irrigation water supplies are limited, drainage water can be used to supplement them. However, the quality of the drainage water determines which crops can be irrigated. Highly saline drainage water cannot be used to irrigate salt-sensitive crops. It could, however, be re-used on tolerant forages or in a saline agriculture-forestry system. Saline drainage water is being successively re-used for the irrigation of salt-tolerant crops and trees.The major degradation factor of re-used waters is the high concentration of ions. Waters with low ionic concentrations provide plants with an adequate supply of many of the essential nutrients needed for growth. However, as salinity increases, specific ions may become toxic or interfere with the uptake of other nutrients. In soils, the accumulation of ions increases the osmotic potential against which plants extract water. It can also degrade soil structure. Drainage and leaching of salts from the root zone are key factors in the management of salinity in agriculture. Another management factor is control of the range of salt tolerance expressed in crop species. Water re-use for agricultural crops has distinct economic incentives and a number of crops are known to be highly tolerant to salinity. However, as salinity increases in the irrigation water, there is a greater need to monitor and manage irrigation and drainage practices and to consider the sustainability of the system. It is possible to safely re-use agricultural drainage water if the characteristics of the water, soil, and the intended crop plants are known and can be economically managed. Poor quality water requires selection of crops with appropriate salt tolerances, improvements in water management, and maintenance of soil structure and permeability (tilth, hydraulic conductivity).When sensitive crop growth stages such as germination and early growth are excluded, the temporal weighted mean root zone salinity has been found to be a valid measure for evaluating crop response to salt. The arithmetic mean root zone salinity within the rooting depth integrated over the time of exposure is an effective approximation for estimating crop response. Plants respond to the weighted mean salinity within a specific growth period. Given the water crisis in the region, the quantity of water drainage that in some areas is permanent,and acceptable quality of drainage water, with proper management in addition meeting a part of the agricultural needs of the region, one can save and create sustainable water resources for the region .

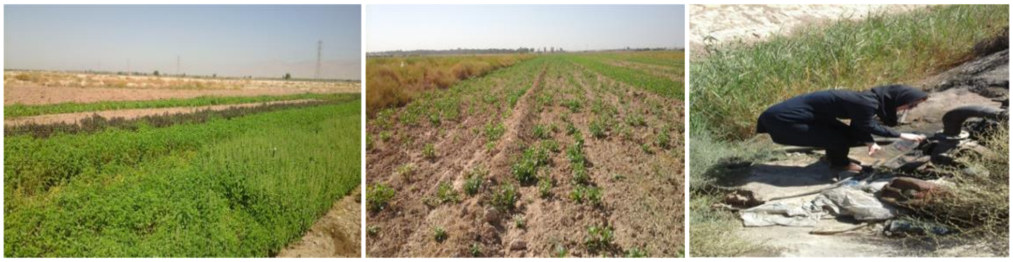
MATERIALS AND METHODS

Area of study

The lands dedicated to the Behbahan irrigation and drainage network, with a gross surface area of 13500 hectares includethe north and south network on either side of the Maroon River at 30° 36’ latitudeand 50° 14’ longitude which almost surround the city of Behbahan. The present article is conducted based on field surveys of eight farm of irrigation and drainage network of Behbahan (north and south) that due to drought (water shortage) - long irrigation intervals - poor distribution of water due distance of farming land from the intake valves are forced to withdraw drainage water by pumps from the drainage channels. (As shown in Figures 1 and 2). The aim of this study is to evaluate the appropriateness of the selected cultivation pattern of the aforementioned farms with the chemical quality of the drainage water. Therefore, we initially conducted a field survey of eight farms and sampled their drainage water consumption to determine its chemical quality, then we calculated the yield of the cultivated crop and recommended new cultivation patterns for farms that showed a lower yield.Next, we used the table of the impact of irrigation water on permeability to determine the drainage water’s environmental impact and quality , (Ayers and Westcot, 1985) , and by using other tables (FAO,1994) ,(Ayers and Westcot, 1985) we conducted the feasibilitystudy of irrigation methods that fit the drainage water quality. In the end, given that no management had taken placed for reuse of drainage water in the region ,training sessions with the subject of terms and conditions of drainage water reuse was held for farmers that was welcomed by them.

(A) (B) (C)

Figure1. cultivated crops in the northern region in rice,Farm 26,(A). tomato ,Farm 20,(B) and Drainage B_{5},(C).



(A) (B) (C)

Figure2. cultivated crops in the south region in eating vegetables,Farm 21, (A). beans, mung,Farm 33, (B). and Drainage D_{5},(C).

RESULTS AND DISCUSSION

The results of chemical analysis of the quality of drainage water (presented in Table1) show an increase of 1.76 times of electrical conductivity, 1.3 times total dissolved solids,85 percent reduction of PH in the north network, 2.32 times increase in electrical conductivity, 1.8 times total dissolved solids, and 1.09 reduction of PH in the south network compared to Maroon River water quality. Also, the average concentration of cations in the north and south were 2.35 times and 5.32 times, respectively; and the average concentration ofanions in the north and south were 3.72 times and 5.1 times, respectively; compared to Maroon Riverwater quality. Generally, the results ofdrainage water quality at north due to bursting springs water streaming on the floor of open-surface drainage channels with a 50% mixing ratio with the incoming drainage water into the channel, were better than the drainage water quality at south.In the southern area, only in the event that the upstream farmer is not using the channel water for any reasonand allows it to flow at night or when it is raining or due to improper drainage water valve adjustment,the drainage water and channelwater would be mixed.

Table 1. chemical analysis of the quality of drainage water

Name drain		electric conductivity	total dissolved solids mg/liter)	Cations and Anions (MILLI Eq/LITER)							Area	Farm numbers
	PH	EC(ds/m)	TDS	Ca^{++}	Mg^{++}	Na^{+}	Co_3^{--}	Hco_3^{-}	CL^{-}	SO_4^{-}		
B_3	6.83	2.992	2060	12.74	6.03	18.8	0	3.9	13.8	19.8	North	26
B_3	6.89	2.979	2065	12.67	6.2	18.8	0	3.7	13.9	20	North	27
B_5	6.97	2.857	1987	13.43	7.2	14.2	0	3.5	13.2	18	North	21
B_5	6.91	2.985	2048	12.53	7.92	15.5	0	3.95	13.5	18.4	North	2
B_5	6.99	2.704	1820	11.43	4.15	15.92	0	4	12.9	14.5	North	20,25
B	6.91	2.985	2125	12.59	5.87	18.32	0	5.4	14.7	19.3	North	64
D_5	7.36	3.800	2618	24.55	11.57	15.04	0	3.8	13.8	34.2	South	33
D_4	7.48	3.873	2615	29.58	9.32	12.48	0	3.4	12.3	35.7	South	21
*	8.1	1.648	1051	4.4	0.8	4.47	0	4	9	2.5		

* Fresh canal water

Effects of salinity on crop growth and yield

Salinity in water or soil is an environmental factor that, in general, reduces crop growth. At relatively low salinity, especially among crop species such as cotton or the halophytic sugar beet, some salinity may actually improve crop production. This effect has been attributed in some instances to an improvement in water use efficiency of the plant (Letey, 1993). However, as salinity increases beyond some threshold tolerance, yield decline is inevitable. Usually, at low to moderate salinities, plant growth is simply reduced and there is a slight darkening in leaf colour. These effects are difficult to detect without comparisons with non-saline controls. When salt concentrations in the soil water reach toxic levels, leaves or shoots may exhibit visible symptoms of tip or edge burning or scorching due to high internal concentrations of salts. In some crops, salinity changes plant growth habit or increases succulence (Luttge and Smith, 1984; Shannon et al., 1994).

There is a wide range in plant species response to salinity. Sugar beet, sugar cane, dates, cotton and barley are among the most salt tolerant; whereas beans, carrots, onions, strawberries and almonds are considered sensitive (Maas, 1986). In general, salinity decreases both yield and quality in crops, and previous research has led to the development of large data bases on the salt tolerances of many crop species and varieties (Francois and Maas, 1978 and 1985).

Crop yield response functions

The salt tolerance of a crop can best be described by plotting its relative yield as a continuous function of soil salinity. For most crops, this response function follows a sigmoidal relationship. However, some crops may die before the seed or fruit yields decrease to zero, thus eliminating the bottom part of the sigmoidal curve.(Maas and Hoffman ,1977) proposed that this response curve could be represented by two line segments: one, a tolerance plateau with a zero slope, and the other, a concentration-dependent line whose slope indicates the yield reduction per unit increase in salinity. The point at which the two lines intersect designates the threshold, i.e. the maximum soil salinity that does not reduce yield below that obtained under non-saline conditions.This two-piece linear response function provides a reasonably good fit for commercially acceptable yields plotted against the electrical conductivity of the saturated paste (EC_e). EC_e is the traditional soil salinity measurement with units of decisiemens per metre (1 dS/m = 1 mmho/cm). For soil salinities exceeding the threshold of any given crop, relative yield (Y_r,),(EC_e) can be estimated with the following equations:

$$Y_r = 100 - b(EC_e - a) \qquad (1)$$

where a = the salinity threshold expressed in dS/m; b = the slope expressed in percent per dS/m; and EC_e = the mean electrical conductivity of a saturated paste taken from the rootzone.

$$EC_e = EC_{iw} * 1.5 \qquad (2)$$

EC_{iw}= electrical conductivity of the irrigation water

Table 2 makes use of the two aforementioned equations and the table of crop plants classification based on resistance to salinity, to calculate the relative performance of the current cultivation pattern.

Table 2. The relative performance of cultivated crops

Farm numbers	Crop Common name	EC_{iw}(ds/m)	EC_e(ds/m)	Slope(%) Per ds/m	Threshold (EC_e) ds/m	Rating	relative yield(%)
26	Rice, paddy	2.992	4.488	12	3	Sensitive	84.64
27	Corn	2.979	4.468	12	1.7	Semi-sensitive	66.78
21	Rice, paddy	2.857	4.312	12	3	Sensitive	82.24
64	Corn	2.985	4.477	12	1.7	Semi-sensitive	66.67
20	Tomato	2.704	4.056	9.9	2.5	Semi-sensitive	84.65
25	Corn	2.704	4.056	12	1.7	Semi-sensitive	71.7
33	Bean, common	3.800	5.700	19	1	Sensitive	10.7
33	mung	3800	5700	11	3	Semi-sensitive	7Z
21	eating vegetables	3.873	5.809	13	1.3	Semi-sensitive	41.5

Crop substitution and reuse for irrigation of salt tolerant crops

Crops differ significantly in their tolerance to concentrations of soluble salts in the rootzone. The difference between the tolerance of the least and the most sensitive crops may be tenfold. A number of salt tolerant crop plants are available for greater use of saline drainage effluent (presented in Table3). Raising the extent of the salinity limits through selecting more salt tolerant crops enables greater use of saline drainage effluent and reduces the need for leaching and drainage. (Tanji and Kielen,2002).

Table 3. Salt tolerance of herbaceous crops

Crop Common name	Tolerance based on	Threshold (EC_e)	Slope	Rating	References
Barley	Grain yield	8.0	5.0	Tolerance	Ayars et al., 1952
Wheat, Durum	Grain yield	5.9	3.8	Tolerance	Francois et al., 1986

It is recommended that according to the level of salinity of the used drainage water, the cultivation pattern should be replaced with more resistant plants including the crops listed in table 3, toreplace the cultivation of maize, beans, and eating vegetables that showed a lower relative yield. (Table 4) represents the amount of the relative yield of the proposed pattern. The results indicate that the proposed crops will work without a yield reduction.

Table 4. The relative performance of the proposed cropping pattern

Farm numbers	Crop Common name	EC_{iw} (ds/m)	EC_e (ds/m)	Slope(%) Per ds/m	Threshold (EC_e) ds/m	relative yield %
33	Barley	3800	5700	5.0	8.0	111
33	Wheat, Durum	3800	5700	3.8	5.9	102
21	Barley	3800	5700	5.0	8.0	111
21	Wheat, Durum	3800	5700	3.8	5.9	101
27	Barley	2979	4468	5.0	8.0	117
27	Wheat, Durum	2979	4468	3.8	5.9	105

To determine the drainage water quality for irrigation in terms of its impact on permeability

One of the most common guidelines in relation to the physical and chemical parameters of irrigation waters is Ayers and Westcot guideline. In this paper, to evaluate the drainage water quality for its application in agriculture, we used Ayers and Westcot table factors such as changes in soil permeability under the impact of EC and SAR.(Table 5)

shows the amount of sodium absorption ratio and drainage water quality rating for irrigation in terms of its impact on the permeability.

Sodium hazard and irrigation water infiltration

The parameter used to determine the sodium hazard is SAR - Sodium Adsorption Ratio. This parameter indicates the amount of sodium in the irrigation water, in relation to calcium and magnesium. Calcium and magnesium tend to counter the negative effect of sodium.

$$\mathrm{SAR} = \frac{Na(\frac{meq}{l})}{\sqrt{\frac{Ca\left(\frac{meq}{l}\right)+Mg(\frac{meq}{l})}{2}}} \qquad (3)$$

Table 5. the amount of sodium absorption ratio and drainage water quality rating for irrigation in terms of its impact on the permeability.

Name drain	EC_{iw}(ds/m)	SAR sodium adsorption ratio (meq/litre)	Rating	Area	Farm numbers
B_3	2.992	6.13	Good	North	26
B_3	2.979	6.12	Good	North	27
B_5	2.857	4.42	Good	North	21
B_5	2.985	4.81	Good	North	2
B_5	2.704	5.7	Good	North	20,25
B	2.985	6.03	Good	North	64
D_5	3.800	3.53	Good	South	33
D_4	3.873	2.81	Good	South	21

Feasibility of irrigating method according to the type of consumed drainage water quality

The problem of cations such as calcium, magnesium and sodium in the irrigation water will appear after they penetrate the soil. Also, most plants are sensitive to salinity and will be damaged when they are irrigated with saltwater through sprinkler irrigation (Maas,1985).Sodium and chlorine are some of the most common toxic elements in the irrigation water used for plants. On the other hand,when salt water is used, the irrigation method influences the amount of product yield reduction. (Benes et al, 1996) showed that the direct use of salt water for the two crops of pepper and barley, did not result in reduced yield or damaged leaves but its use it in a sprinkler irrigation system reduced yield and damaged leaves. This method increases the concentration of sodium and chlorine in the leaves, and the impact of both is proportionate to the concentration of salts dissolved in the soil (Downton,1977) .The water quality in pressurized systems influences the uniform distribution since it blocks the droppers. In the micro-irrigation method, most of the risk of clogging the droppers or other outletsis due to the calcium deposits. This risk is greater for the bicarbonate waters and is probable when the water acidityis over 6. In this research,with the use of the table(Ayers and Westcot, 1985) the quality limitation degree for bicarbonate was low to medium, the acidity in the northern area had low limitations and in the southern area it had low to moderate limitation. The electrical conductivity had low to medium limitation and the total dissolved salts caused serious limitations for drip irrigation method and according to the high amount of cations, there was the possibility of dropper clogging. In this research, the implementation of this method is not recommended. Due to the high amount of sodium and chlorine in the drainage water in this research, the selected cultivation pattern with the use of sodium and chlorine concentration range table was chosen according to the type of the crop (FAO, 1994).

Considering that when the sodium and chlorine levels exceed 6-8 miliequivalent per liter, sprinkler irrigation is not recommended either. So, the surface irrigation method is recommended for the crop. It should be noted that all the farmers in the studied farms used the surface irrigation method.

Drainage water reuse challenges and recommending an appropriate approach
Soil salinity, lower crop yield

Salt concentration is one of the most important quality parameters of the water. the salts dissolved in water are associated with soil salinity and thus, the salts dissolved in water as a whole have some impact on the plant growth and quality and crop yield. Too much salt degrades the soil. A proper management of the use of salty water should observe the following points: choice of the crop type and recognition of the salinity-sensitive phase of the plant-determining the irrigation method–reducing irrigation intervals–irrigation hours (there should be no irrigation when it is hot) because most evaporation occurs in the middle hours of the day in hot and dry areas, therefore it is essential to attempt irrigationduring the night and at cool hours – irrigation before planting (to rinse out the salts of the previous period) - mixing of waters.

Sodium, due to its impact on the soil, is of one of the most unique cations.Exchange sodium in unconventional water, when it is above a certain threshold relative to its ratio to the total concentration of salt in the soil, may change the soil's physical and chemical properties and especially its structure. Increased salinity and sodium in the soil due to irrigation with drainage water will reduce available water conditions for the plant and degrades the soil structure in the long term. An increased amount of calcium via adding gypsum to the land to create a suitable area through the modified of sodium absorption ratio equation(SARadj) is an effective solution to resolve the "sodiumization" of the soil.

Socio - cultural aspects

An important aspect of successful programs of drainage water use in agriculture is the acceptance of it as a source of irrigation water by the farmers as well as the acceptance of the public to purchase and consume the products that have been irrigated through this source (Salgot, 2008). To attain this, it is necessary that the farmers and the peoples hould become fully aware of the importance of drainage water reuse in the area because of water shortage and its implementation method. Also, if possible, their opinions must be collected and reviewed and used in the formulation of programs. In line with this, education and promotion as well as securing the public confidence in terms of caring for their health and ensuring the protection of natural resources (soil, surface water, groundwater, plants, etc.) can resolve a lot of socio-cultural problems.

Reviews the challenges accompanying the application of waste water in agriculture shows that many of these challenges can be resolved with careful planning and correct administrative procedures.

The drainage water reuse methods are as follows

Drainage water of sufficiently good quality might be used directly for crop production. Otherwise, drainage water can be reused in conjunction with freshwater resources .Conjunctive use involves blending drainage water with freshwater. Alternatively, drainage water can be used cyclically with freshwater being applied separately. In cyclic use, the two water sources can be rotated within the cropping season (intraseasonal cyclic use), or the two water resources can be used separately over the seasons for different crops (interseasonal cyclic use). The choice of a certain reuse option depends largely on: drainage water quality; crop tolerance to salinity; and availability of freshwater resources. The quantity and time of availability of drainage water is of major importance. (Tanji and Kielen,2002).

Holding a training session

In this session,since the farmers had no knowledge of the terms and conditions of the drainage water reuse,the following points wereeducated. 1- Proper cultivation patternchoice according to the drainage water quality, 2- With regard to the type of the cultivated species,the farmer should be informed of the salinity-sensitive growth period to avoid drainage water use at that time, 3-Planning and selection of the proper method of drainage water reuse, 4-Employing proper methods of planting and irrigation, and 5- Irrigation before planting (to rinse out the salts of the previous period).

CONCLUSION

The drainage water use as a permanent source of water in agriculture, in addition to meeting a portion of the water needs of this sector, would result insaving and maintaining the existing water sources as well. Water drainage use in agriculture has a lot of benefits but if it is attempted without careful planning and correct management and supervision, may lead to numerous and intense social, economic and environmental impacts, e.g. people's outrage, lack of appropriate market for the supply of crops,lower crop yield, soil salinity and "sodiumization", especially in arid and semi-arid areas. If the network management planning is such that the drainage water is used in a mixed proportion or alternately in these farms, it will prevent soil degradation over time, and the quality of drainage water will be better on the way back to the environment.

Recommendations and guidelines for the management of drainage water reuse
Planning and monitoring the drainage water reuse.
Setting up and implementing detailed and efficient monitoring systems.
The use of appropriate standards and guidelines.

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