Send Orders for Reprints to reprints@benthamscience.ae

BENTHAM OPEN

CrossMark

The Open Agriculture Journal

Content list available at: www.benthamopen.com/TOASJ/

DOI: 10.2174/1874331501812010064

RESEARCH ARTICLE

Reclaimed Wastewater Quality Assessment for Irrigation and Its Mid-Time Reuse Effects on Paddy Growth and Yield under Farmer Management

Kami Kaboosi* and Reza Esmailnezhad

Department of Water and Agriculture, Gorgan branch, Islamic Azad University, Gorgan, Iran

Received: January 02, 2018 Revised: March 03, 2018 Accepted: April 08, 2018

Abstract:

Introduction:

Many studies have been conducted on irrigation of upland crops with reclaimed wastewater while there have been a few reports about wastewater reuse for paddies. The majority of irrigation water requirement of paddy field in Bandargaz region (Iran) during the dry season within the last 12 years is dependent on effluent of treatment plant. Accordingly, different water parameters and 12 irrigation water quality indexes and economical- environmental filed management factor (fertilizer application rate) and crop growth and yield were studied in freshwater (FW) and wastewater (WW) filelds.

Explanation:

Unexpectedly, wastewater and freshwater salinity was less and more than the threshold salinity of paddy (2.0 $dS.m^{-1}$), respectively and due to the high concentration of chlorine, FW is not suitable for irrigation. Based on almost all of indices and standards for assessing irrigation water quality, WW was significantly better than FW.

Conclusion:

The average concentration of heavy metals in both FW and WW samples were in the order of Cr<Cd<Pb<Ni. However, results showed that concentration of heavy metals in WW was significantly more than FW. Nevertheless, these were below maximum allowable based on international standards and guidelines. The average nitrogen concentration in the reclaimed wastewater was 11.2 $mg.lit^{-1}$ that was more than the required nitrogen concentration (7 $mg.lit^{-1}$). So, a dilution strategy could be adopted when reclaimed water is used. No significant difference was observed in two type farms based on plant height, spike length, and 1000-seed weight, but this factor was significantly effective on seed per spike and seed yield so that they were higher in WW irrigated farms by 12.4 and 10 percent, respectively.

Keywords: Golestan, Heavy metal, Nutrients, Rice, Paddy, Waste water.

1. INTRODUCTION

Rice is one of the most important crops in the world, including Iran. Worldwide, about 162.7 million ha of rice is cultivated that seed production is 741.5 million ton. In Iran, rice harvested area and production were 529 thousand ha and 2.3 million ton, respectively [1]. Irrigation water for paddy rice production accounts for more than 70% of the total irrigation water in Asia and paddy rice is the largest consumer of freshwater resources in South and Southeast Asia [2].

Domestic wastewater reuse and land application are not new, and knowledge on this topic has evolved and advanced throughout human history (since the Bronze Age *ca.* 3200-1100 BC) which has gone through different stages of development [3]. Due to the availability constraint of the freshwater for irrigation, a vast majority of the

* Address correspondence to this author at the Department of Water and Agriculture, Gorgan branch, Islamic Azad University, Kami Kaboosi, Gorgan, Iran; Tel: 00989113738102; E-mail: kkaboosi@yahoo.com

reclaimed water is used for landscape and agricultural irrigation, especially in arid and semi- arid region [4 - 6]. There is no complete global data on the extent of wastewater usage for land irrigating mostly due to a lack of heterogeneous data. Nonetheless, the global figure commonly cited is at least 20 million hectares in 50 countries (around 10 percent of irrigated land) are irrigated with raw or partially treated wastewater [7 - 9] and it has been applied in nearly 120 countries [10]. It is also estimated that more than 10% of the world's population consumes crops irrigated with wastewater [2].

As an irrigation water resource, reclaimed wastewater can promote soil quality by nutrients and organic matter, biodegradable organic matter, beneficial microorganisms and soil biological activities. However, the most prevalent risks for irrigation use of wastewater are those associated with increasing pH, salinity, sodicity, and boron in water, as well as the potential accumulation of pathogens, nonessential toxic metals, and organic chemicals in the receiving soils [4, 11 - 14]. Water quality criteria, guidelines, and standards for irrigation are the result of scientific examinations on the suitability of water and wastewater based on its effects on soil, crop and health. Many organizations and countries such as the FAO in 1992 [6], WHO in 1989 and 2006 [15, 16], EPA in 1980, 1992, 2004 and 2012 [10, 17 - 19], Israel in 1952, 1999 and 2010 [2], Italy in 1977 and 2006 [2], France in 1991 and 2010 [2], Iran in 2000 [20], Jordan in 2002 [21], Cyprus in 2005 [2, 22], Portugal in 2006 [2], Spain in 2007 [2], Greece in 2011 [23] and South Korea in 2011 [2] have suggested and modified water quality guidelines or standards for safe wastewater reuse. Existing water quality criteria for irrigation and wastewater reuse were examined and water quality standards of many countries were analyzed to set agricultural water quality standard for indirect wastewater reuse considering for both paddy and upland crops [2].

Wastewater is a valuable source of plant nutrients needed for maintaining fertility and productivity levels of the soil. Irrigation with wastewater has been shown to increase which results in growth and yield of different plants such as paddy [5, 24].

Assessments of wastewater reused for agriculture has been performed in many countries, but the findings are not directly applicable to paddy fields because of paddy rice production require large volumes of water. Paddy fields are flooded before plowing, and the water level is kept as high as up to 10 cm during the growing season [25]. While there are many studies providing assessments of wastewater reuse for upland crop, few of the findings are applicable to paddy irrigation with wastewater [26] in respect of water quality assessment [27], changing physical or chemical properties of soil [24, 27] and crop growing [24, 28]. Specially, the effects of reclaimed wastewater on plant growth and crop production are rarely studied in field conditions and thus, this kind of study is scarce [26]. Therefore, the present study was undertaken to evaluate the effect of wastewater irrigation on growth and yield of rice crop in fields under farmer management and the safety of irrigation water containing toxic heavy metals based on different water quality standards. It was hypothesized that huge use of wastewater for paddy irrigation will not only reduce the paddy growth but also enhance the soil fertility and crop yield.

2. MATERIALS & METHODS

2.1. Study Area

Bandargaz city is located in the of Golestan province, Iran. The direct distance of Bandargaz municipal wastewater treatment plant from the Caspian sea (Gorgan Gulf) is about 1.7 Km. Also, the distance where the wastewater discharged into the Caspian sea to the Miankaleh protected zone is 35 Km (Fig. **1**). Plant was launched in 2005 with a capacity of 3100 $m^3.day^{-1}$. Wastewater using concrete pipe reached to the earth channels and then emptied to the sea (Fig. **1**). In Bandargaz region, irrigation water scarcity in the summer season, which coincides with the peak crop water requirement period, has caused the farmers interested to usage of treated wastewater as an unconventional water resource for supplying a large portion of water requirement in more than 700 ha of paddy field in around of plant [27]. Rice cultivation is dominant in this area and irrigation season is approximately 3-month (late-May to late-August) along with the peak of irrigation water requirement within July. There are more than 700 ha paddy farm that are located near Bandargaz wastewater treatment plant. The majority of the flow in these farmlands is dependent on effluent of treatment plant during the dry season. Within the last 12 years, farmers remove of manhole doors and directly pumping the treated wastewater for irrigation. Most farmers ignore the hazards of the indiscreet reuse of wastewater for irrigation. During the dry season, which is the most intensive agricultural irrigation period in the region, a large portion of paddy irrigation water supply in these areas depends on discharge from the plant.

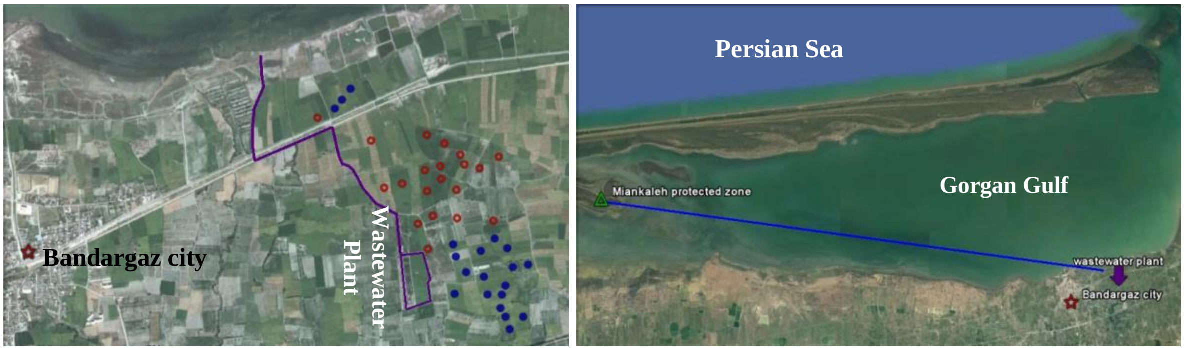

Fig. (1). Location of Bandargaz wastewater plant and fields irrigated by freshwater (blue) and wastewater (red).

2.2. Treatments

To study the effect of reclaimed wastewater (WW) on growth traits and yield of paddy crop and its comparison with the tube well freshwater (FW) farms in Bandargaz, 40 paddy farms were randomly selected (Fig. **1**). Half of these farms have been irrigated by freshwater and the rested half by the reclaimed wastewater in recent 12 years. A similar study method was used by Jang *et al*. [7]. All the farming operations, conducted under farmers' management during growth season, were recorded precisely including farm area, the value of used seed for planting, dates of planting and harvesting, growth season length and application amount of nitrogen, phosphate, and potassium fertilizers. During growth season, 7 samples from each water resource (totally 14 samples) were taken coincident with different phonological stages.

2.3. Water Quality Assessment

Water samples were taken from June to August 2016 with an approximate interval of two weeks according to phonological stage of rice crop. 14 water quality parameters including pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), calcium, magnesium, sodium, potassium, chloride, sulphate, carbonate, bicarbonate, nitrate (NO_3^-), phosphate (PO_4^-) and Total Hardness (TH) and four target heavy metals (Pb, Ni, Cd, and Cr) were measured. Total water properties were measured based on APHA [29]. Some irrigation water index such as Potential soil Salinity: PS [30], Sodium Adsorption Ratio: SAR [31], Kelley's Ratio equal to Exchangeable Sodium Ratio: ESR [32], sodium percentage 1: Na%1 [32], sodium percentage 2: Na%2 [31, 33], Magnesium Ratio [32], Ca:Mg ratio [34], Calcium Ratio [34], Residual Sodium Carbonate: RSC [31, 32], Residual Sodium Bicarbonate: RSBC [33] and Permeability Index: PI [32] were calculated. Values obtained from each water resource were treated as replicates. The concentration of heavy metals in samples was estimated by using atomic absorption spectrophotometer (Model AA-10, Varian Inc., Australia) fitted with a specific lamp of particular metal using appropriate drift blank. For minimizing time changes in water quality, samples were collected at 10:00. In order to assess the water resources for irrigation, different irrigation water quality standards including United State Salinity Laboratory: USSL [31], FAO 29 [34], FAO 47 [6], Shainberg and Oster [35], Indian irrigation water quality [36], Oster and Schroer -after [37]- and Indian Council of Agricultural Research [38] and different organizations and countries guideline for reclaimed wastewater reuse were considered.

The heavy metal pollution index (HMPI) was calculated by the following formula to show the level of contamination in water [39].

$$HMPI = C_i/S_i$$

Where C_i and S_i are heavy metal content in a water sample and permitted standard of the same metal (μg.Lit^{-1}), respectively. When the HMPI values exceed than 1.0, water is said to be contaminated by anthropogenic inputs and requires continuous environmental monitoring of the area [39].

2.4. Plant Sampling and Studied Traits

At the time of maturity, three plots (1*1 m^2) were randomly selected in each farm. Then, 10 samples were collected from each plot. Identical amounts of each field were obtained by average of samples. Values obtained from different farms were treated as replicates. Samples were oven-dried separately at 80ºC until a constant weight was achieved [39]. Yield and growing traits including plant height, spike length, number of seed per spike, thousand seed weight, seed yield, biological yield and harvest index (ratio of seed yield to biological yield) were measured.

2.5. Statistical Analysis

Data normality was evaluated and proved by one-sample Kolmogorov-Smirnov test at 5% probability level [40]. The data of water quality and crop traits were subjected to t- student test for assessing the significance of differences. Statistical test and calculating of some descriptive statistics were performed using SPSS software (SPSS Inc., version 21).

3. RESULTS AND DISCUSSION

3.1. Assessment of Water Quality for Irrigation

The results of t-test at 5% probability level on water quality parameters are presented in Fig. (**2**) and Table **1**. Carbonate was not found in any sample of FW and WW, and no significant difference was observed between FW and WW based on pH and bicarbonate concentration. Calcium, magnesium, sodium, chlorine and sulfate concentration in FW are significantly more than WW which can be resulted by the adjacency of this region wells with Caspian sea and seepage of brackish seawater into groundwater resources. This matter is discernable particularly from chlorine and sodium concentrations than the other ions in FW.

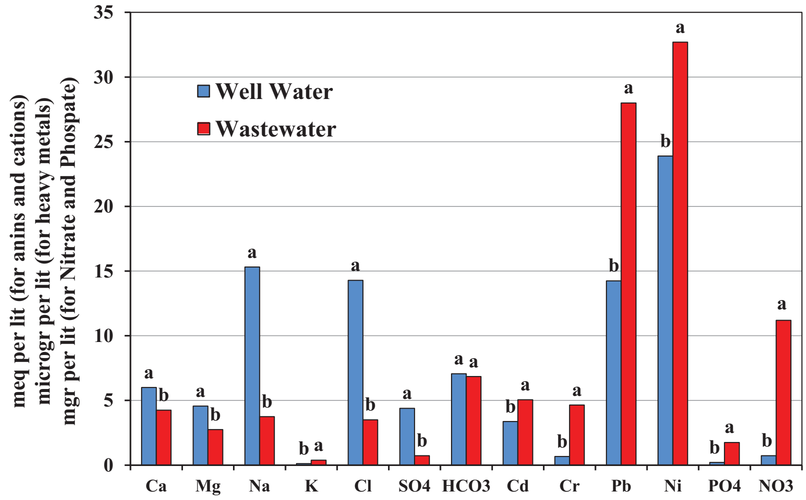

Fig. (2). Mean comparison of different water ions and metals in FW and WW.

Table 1. Different water quality index of FW and WW.

Index	pH	EC (dS.m^{-1})	TDS (ppm)	PS (meq.lit^{-1})	SAR	ESR	Na%$_1$	Na%$_2$
FW	6.97^a	3.08^a	1978.12^a	16.49^a	6.69^a	1.46^a	59.0^a	58.7^a
WW	6.99^a	1.46^b	937.95^b	3.87^b	2.01^b	0.54^b	37.1^b	33.5^b
Index	Mg Ratio	Ca:Mg	Ca Ratio	RSC (meq.lit^{-1})	RSCB (meq.lit^{-1})	PI	TH (ppm $CaCO_3$)	-
FW	43.26^a	1.31^b	0.23^b	-3.50^a	1.07^b	69.08^a	528.33^a	-
WW	39.29^b	1.57^a	0.38^a	-0.15^b	2.60^a	59.09^b	350.00^b	-

In each column, means followed by at least one same letter were not significantly different by t-test.

The standard of FAO [6, 34], Australia [41], EPA, Jordan and South Korea recommend the appropriate pH range for irrigation to be 6.5-8.4, 6.5-8.5, 6.0-9.0, 6.0-9.0 and 5.8-8.5, respectively [2]. Outside of the normal range, water might be suitable for irrigating, but has the potential to cause an imbalance of nutrients, corrosion or sedimentation of irrigation facilities, mobility of heavy metals in the soil and poisonous ions [2, 34]. In this research, the pH values of FW and WW are in the permitted range for irrigation based on different standards.

Salinity is the most important factor of irrigation water quality that can create a hostile environment. The salinity of FW samples was significantly greater than WW because of more concentration of cations and anions in freshwater. The allowed irrigation water EC for paddy crop was reported to be 2.0 dS.m^{-1} [2]. In this regard, wastewater and freshwater salinity were less and more than the threshold salinity of paddy, respectively.

Nitrogen (N), phosphorus (P) and potassium (K) are major nutrients for the crop. It was reported that reclaimed water has more essential nutrients (N, P, K) and some micronutrients for plant growth than freshwater [4, 42]. However, those Nutrients can give negative effects such as nutrient imbalances, groundwater contamination, over-growing and lodging, excessive vegetative growth, failure to ripen, increased susceptibility to pests and disease, reduced fruit set for crops, delays in maturation and decreases in food nutrient quality especially for paddy rice [2, 4, 6]. In consideration of the above negative effects of nitrogen on paddy rice growth, Taiwan, Japan and Jordan have set standards for allowable N in reclaimed water for paddy rice [2, 4, 43]. The amount of potassium, nitrate, and phosphate in the reclaimed wastewater is significantly more than freshwater that can lead to soil fertility (Fig. **2**). Mass loads of N, P and K can be calculated by multiplying irrigation water volume and the corresponding concentration. Considering the irrigation water requirement of paddy crop in the studied area (13000 $m^3.ha^{-1}$), 193, 145.6, and 22.8 Kg of potassium, nitrogen, and phosphorus are added to per hectare of rice during total growth season that is 3.3, 15.3 and 8.5 times more than irrigation by freshwater, respectively. Therefore, it seems that the main part of paddy nutrition needs to potassium and nitrogen, and some phosphorus requirement is supplied through reclaimed wastewater.

The significant difference of FW with WW treatment in various irrigation water quality indexes is related to the difference of the dominant ions concentration (Table **1**). The value of PS index is dependent on chlorine and sulfate concentration. The less amount of this index means the better quality for irrigation water; so that water with PS index greater than 5 is harmful for irrigation [44]. According to this, although using wastewater for irrigation doesn't have the potential risk of salinity, freshwater quality has this hazard.

It has suggested that the sodium problem in irrigation water could be very conveniently worked out on the basis of the values of ESR or Kelley's ratio. Generally, water is considered as unfavorable for irrigation if ESR be more than one [32]. Therefore, FW and WW are unfavorable and favorable water for irrigation, respectively.

The amount of $Na\%_1$ and $Na\%_2$ were very close to each other because of low concentration of potassium. As per the Bureau of Indian Standards the sodium percentage of 60 is the maximum recommended limit for irrigation water [32]. Thus, FW is at the border of unsuitable irrigation water. However, WW has good quality because the water with sodium percentage between 20 to 40 percent is described as good water [44].

Excess of magnesium (high Magnesium Ratio) in water affects the quality of soils, which causes poor yield of crops [32]. In magnesium dominated water (Ca:Mg ratio less than 1), the potential effect of sodium may be slightly increased. In other words, a given SAR value will show slightly more damage if the Ca:Mg is less than 1 [34]. Also, if irrigation water has calcium to total cation ratio less than 0.15, a further evaluation is needed. Such water may pose a potential problem related to plant nutrition [34]. The result showed that both water resources have good quality in the aspect of Magnesium Ratio, Ca:Mg ratio and Ca Ratio, although the WW is significantly better than FW.

High concentration of CO_3^{2-} and HCO_3^{-} represents alkaline nature of water. Use of such water promotes the precipitation of calcium and magnesium present in the soil solution which causes an increase in exchangeable sodium. For this reason, waters with high level of RSC or RSBC are unfavorable for irrigation uses. When RSC and RSBC are less than 2.5 and 5.0 $meq.lit^{-1}$ respectively, irrigation water is safe in the aspect of alkaline hazard [31 - 33].

Regarding the relative equity of bicarbonate concentration in wastewater and freshwater, the value of these two indicators in freshwater is less affected by the more concentration of calcium and magnesium in the tube well water and this difference is statistically significant. Nonetheless, for both water resources, these two indexes are within safe limits for irrigation and there is no limitation in using them.

Irrigation water is divided into 3 classes by amount PI [32]. In this study, both FW and WW belong to the first class (PI >75%) considered as good for irrigation.

Total hardness (TH) of the FW is significantly more than WW because of more concentration of calcium and magnesium. When the concentration of chloride in irrigation water is more than 4 $meq.lit^{-1}$, toxicity problems can occur, especially for sensitive crops [33]. In terms of chlorine concentration, FW and WW are brackish and fresh, respectively, indicating that FW is not desirable for irrigation due to the high concentration of chlorine.

Classification of Bandargaz FW and WW based on USSL [31] were C4S2 and C3S1, that represent FW has very high salinity and medium- sodium hazard while WW has high salinity and low- sodium hazard, respectively. Irrigation water was classified by Shainberg and Oster [35] based on EC and SAR to good, moderate and bad. In this study, FW and WW have good quality. Criteria of FAO 29 [34] and FAO 47 [6] guides showed that FW has severe limitation in the aspect of EC and Chloride. Nevertheless, WW is suitable for crop irrigation (Table **2**). Comparing water quality with Manual of Indian Council of Agricultural Research [38] indicated that FW cannot be used for irrigation of sensitive crops. However, Bandargaz WW has not any limits for irrigation of all crops. Indian assessment of irrigation water quality by EC, SAR, RSC [36] showed that FW and WW have marginally salinity (suitable for coarse textured soils) and good quality (suitable for all soils and crops), respectively. Oster and Schroer [37] considered EC and SAR for determination of potential of infiltration problem due to sodium in irrigation water. Both FW and WW have no negative effect on infiltration.

Table 2. Water assessment based on FAO 29 and FAO 47 Guides.

Criteria	FW	WW
1- Salinity (affects crop water availability)		
1-1- EC_w	Severe	Low to moderate
1-2- TDS	Low to moderate	Low to moderate
2- Infiltration (Evaluated by EC and SAR)	None	None
3- Specific ion		
3-1- Sodium		
3-1-1- surface irrigation	Low to moderate	None
3-1-2- sprinkler irrigation	Low to moderate	Low to moderate
3-2- Chloride		
3-2-1- surface irrigation	Severe	None
3-2-2- sprinkler irrigation	Severe	Low to moderate
4- Miscellaneous Effects		
4-1- Nitrate	None	Low to moderate
4-2- Bicarbonate	Low to moderate	Low to moderate

Table **3** lists the levels of studied heavy metals detected in FW and WW and compare them with different national and world standards. The results showed that the average of heavy metal concentrations in both FW and WW samples were in the order of Cr<Cd<Pb<Ni. This finding was very close to order of Cd<Cr<Pb<Ni that reported by Chopra and Pathak [45] for wastewater and tubewell water. However, the study of Huong *et al*. [46] on surface water and Rhee and *et al*. [25] on FW and WW showed this order as Cd<Ni<Pb<Cr. Also, the paired two-sample t test showed that there was a significant level of Cd, Cr, Pb and Ni ($P<0.01$) concentrations in WW as compared to FW.

Table 3. Levels of detected and allowed heavy metals in irrigation water (μg.lit^{-1}).

Metal	FW	WW	FAO 47 [6], EPA [19], WHO [16]*; Cyprus [2], Jordan [21]	Korea [25, 47]	Greece [2]	Greece [2]	Iran [20]	Italy [48]
Cd	3.37±0.66	5.05±1.37	10	10	10	10	50	5
Cr	0.67+0.43	4.65+0.27	100	50	100	100	1000	100
Pb	14.25±2.39	28.00±3.23	5000	100	100	100	1000	100
Ni	23.90±4.46	32.70±7.23	200	200*	200	200	2000	200

* after Son et al. (2013).

The concentration of the Cr, Pb and Ni were found to be within safe limit in both FW and WW used for irrigation so that the maximum HMPI index for these metals in freshwater was 0.01, 0.14, and 0.12, respectively and in wastewater was 0.05, 0.28, and 0.16, respectively. However, in both water resources particularly in wastewater, Cd concentration was near to the maximum permission limits of different standards and even it was more than the maximum permission level based on Italian standard (Table **3**) so that the maximum value of HMPI index for this metal was 0.67 and 1.01 in freshwater and wastewater, respectively.

Comparison of the permitted concentration of these four metals in different standards shows that FAO 47, EPA and WHO standards are exactly equal, and within surveyed national standards, Iranian and Italian standards are the easiest and the most rigorous national standards. For this reason, the concentration of studied heavy metals satisfied the Iranian wastewater quality standards for agriculture [20] and those were within the recommended maximum concentrations. The values of the heavy metal concentration of FW and WW of this research were far less than the values observed by Chopra and Pathak [45].

3.2. Field Management and Rice Growth and Yield

When wastewater is used, farmers make changes to farm management due to the awareness of wastewater benefits, especially the presence of nutrition elements that are required by crop. The effect of irrigation water resource on farm management and crop growth and yield is shown in Table **4**. There wasn't any significant difference between freshwater and wastewater irrigated farms in terms of farms area and amount of seeding per hectare. On average, date of planting was two days earlier in wastewater irrigated farms than freshwater ones while date of harvest was two days later. Consequently, the difference between two farms type, because of increasing about 4 days (equal to 3.8%) growth season length affected by wastewater, was significant at 10% probability level.

Table 4. The effects of reclaimed wastewater on rice paddy filed management and crop growth.

Property	Unit	FW	WW	t	P value†	Difference
Farm area	ha	2.11	2.03	0.42	0.677	+0.08
Used seed for planting	$Kg.ha^{-1}$	123.75	122.25	0.48	0.634	+1.50
Planting date (from May)	day	3.90	2.05	0.676	0.503	+1.85
Harvesting date (from August)	day	6.31	8.11	-1.088	0.283	-1.80
Season length*	day	95.4	99.05	-1.826	0.076	-3.65
N fertilizer**	$Kg.ha^{-1}$	92.50	71.25	2.239	0.031	+21.25
P fertilizer**	$Kg.ha^{-1}$	130.02	101.26	2.286	0.028	+28.74
K fertilizer	$Kg.ha^{-1}$	25.1	20.1	0.623	0.537	+5.0
Plant height	cm	125.41	119.55	1.183	0.244	+5.86
Spike length	cm	27.66	27.62	0.53	0.958	+0.04
Seed per spike**	number	58.10	65.30	-2.033	0.049	-7.20
1000-seed weight	gr	25.25	24.91	0.883	0.383	+0.34
Seed yield*	gr per plant	1.453	1.601	-1.801	0.080	-0.148
Biological yield	gr per plant	2.919	2.883	0.222	0.825	+0.036
Harvested index	percent	51.25	58.50	-1.319	0.195	-7.25

† Significant value for t test based on freedom degree of 38 and statistical levels of 1, 5 and 10 percent are 2.709, 2.025 and 1.687, respectively.
* and ** are significantly affected by water treatment based on t test at 10 and 5%, respectively.

Farmers in the Bandargaz region have found that wastewater leads to fertile soil due to the presence of nutrients. Therefore, they reduced application of chemical fertilizers in paddy farms as this reduction of nitrogen and phosphorus fertilizers was significant at 5% probability level (Table **4**). Application of nitrogen, phosphorus and potassium fertilizers in WW irrigated farms was 23, 22 and 20 percent less than FW irrigated farms, respectively which is a kind of economic and environmental management. However, if the amount of nitrogen, phosphorus and potassium in wastewater added to the amount of direct consumed fertilizers, it is found out that total imported nutrition materials to the WW irrigated farms are more than the ones under FW irrigation. This point was also emphasized by Jung *et al*. [26]. For example, considering the ratio of 46% for net nitrogen to nitrogen fertilizer, N added to fields by both fertilizing and irrigating ways was 52.1 and 178.4 $Kg.ha^{-1}$ in FW and WW farms, respectively. One of the effects of high nitrogen consumption in paddy field is a significant prolonged growth period by 6% [50] which is consistent with the results of this research.

The appropriate nitrogen fertilizer demand depends on characteristics of soil, farming pattern and cultivated variety. So, the total amount of nitrogen required during the growth and maturity period needs to be reviewed [43]. In general, paddy rice requires 90 $Kg.ha^{-1}$ of net nitrogen in a complete cycle [43]. With respect to irrigation water requirement of 13000 $m^3.ha^{-1}$ in Bandargaz region, the average required nitrogen concentration is about 7 $mgN.lit^{-1}$. Meanwhile, the average nitrogen concentration in the reclaimed wastewater was 11.2 $mg.lit^{-1}$. So, original nitrogen fertilizer can be replaced by nitrogen in the reclaimed wastewater. The "nitrogen excess" phenomenon in reclaimed wastewater is concerned and a dilution strategy could be adopted when reclaimed water from traditional secondary treatment is used [43].

No significant difference was observed in two type farms based on plant height, spike length, and 1000-seed weight, but this factor was effective significantly at 5% probability level on seed per spike such that it was in farms with WW irrigation about 12.4% higher than FW irrigated farms. Insignificant effect of reclaimed wastewater on paddy crop height [51] and 1000-seed weight [26] was reported.

According to the dependency of seed yield to yield component including 1000-seed weight and seed per spike [26], the effect of water type on seed yield was significant at 10% probability level so that this trait was 10% more in WW irrigated farms than ones with FW irrigation. This conclusion is closely in line with findings of other researches which reported increasing seed yield of paddy by 15-19% under reclaimed wastewater irrigation [7, 26, 28]. It seems that this difference was resulted from lower water salinity, chlorine and sodium concentration, and more nutritional materials in wastewater than freshwater. N fertilizer had a significant effect on paddy yield [50, 52]. Hereof, it was reported that significant correlation between nutrient input in irrigation water (N and P) and paddy seed yield which led to an increasing productivity in reclaimed wastewater irrigated fields [7, 26]. However, insignificant decrease of seed per spike and seed yield and significant decrease of 1000-seed weight were reported because of the adverse effect of excessive salts and high concentration of trace metals in wastewater [51]. There wasn't any significant difference between irrigated farms with WW and FW in respect of biological yield and harvest index; although, harvest index was 14% more in farms with wastewater irrigation.

CONCLUSION

There was a significant difference between freshwater and wastewater in almost all parameters and indices which can be resulted by the adjacency of this region wells with Caspian sea and seepage of brackish sea water into groundwater resources and wastes in WW. According to different guidelines, the potential hazard associated with Bandargaz reclaimed wastewater reuse for irrigation was low. The results showed that the average of heavy metal concentrations in both FW and WW samples were in the order of Cr<Cd<Pb<Ni and there was a significant level of Cd, Cr, Pb and Ni concentrations in WW as compared to FW. However, the concentrations of the Cr, Pb and Ni in both FW and WW used for irrigation were found to be within safe limit based on different national and world standards. There was no observed adverse effects on the use of reclaimed wastewater for paddy rice cultivation but also there was a statistically significant indication that rice growth and yield from reclaimed wastewater reuse was even greater than that from control plots irrigated with groundwater. These results imply that reclaimed wastewater reuse can be a practical alternative to conventional irrigation. However, long-term monitoring of soil chemical characteristics and related health concerns are recommended.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGMENTS

Authors would like to thanks from contribution of Islamic Azad University- Gorgan branch.

REFERENCES

[1] FAO, (2017) FAOSTAT. Available from: http://www.fao.org/faostat/en/#home [Accessed on April 24,2017]

[2] Jeong H, Kim H, Jang T. Irrigation water quality standards for indirect wastewater reuse in agriculture: a contribution toward sustainable wastewater reuse in South Korea. Water 2016; 8(169): 1-18.

[3] Angelakis AN, Snyder SA. Wastewater treatment and reuse: past, present, and future. Water 2015; 7: 4887-95. [http://dx.doi.org/10.3390/w7094887]

[4] Chen W, Lu S, Jiao W, Wang M, Chang AC. Reclaimed water: a safe irrigation water source. Environ Dev 2013; 8: 74-83. [http://dx.doi.org/10.1016/j.envdev.2013.04.003]

[5] Singh PK, Deshbhratar PB, Ramteke DS. Effects of sewage wastewater irrigation on soil properties, crop yield and environment. Agric Water Manage 2012; 103: 100-4. [http://dx.doi.org/10.1016/j.agwat.2011.10.022]

[6] Pescod MB. Wastewater treatment and use in agriculture (FAO 47). Rome, 1992; pp. 113.

[7] Jang T, Jung M, Lee E, Park S, Lee J, Jeong H. Assessing environmental impacts of reclaimed wastewater irrigation in paddy fields using bioindicator. Irrig Sci 2013; 31: 1225-36. [http://dx.doi.org/10.1007/s00271-013-0401-5]

[8] Chen W, Lu S, Peng C, Jiao W, Wang M. Accumulation of Cd in agricultural soil under long-term reclaimed water irrigation. Environ Pollut 2013; 178: 294-9.
[http://dx.doi.org/10.1016/j.envpol.2013.03.036] [PMID: 23590877]

[9] Water for people, water for life. Barcelona: UNESCO 2003.

[10] Guidelines for water reuse. Washington, DC 1992; p. 262.

[11] Albalawneh A, Chang TK, Chou CS. Impacts on soil quality from long-term irrigation with treated greywater. Paddy Water Environ 2016; 14: 289-97.
[http://dx.doi.org/10.1007/s10333-015-0499-6]

[12] Chen W, Lu S, Pan N, Jiao W. Impacts of long-term reclaimed water irrigation on soil salinity accumulation in urban green land in Beijing. Water Resour Res 2013; 49: 1-10.
[http://dx.doi.org/10.1002/wrcr.20550]

[13] Chen W, Lu S, Pan N, Wang Y, Wu L. Impact of reclaimed water irrigation on soil health in urban green areas. Chemosphere 2015; 119: 654-61.
[http://dx.doi.org/10.1016/j.chemosphere.2014.07.035] [PMID: 25150469]

[14] Lyu S, Chen W. Soil quality assessment of urban green space under long-term reclaimed water irrigation. Environ Sci Pollut Res Int 2016; 23(5): 4639-49.
[http://dx.doi.org/10.1007/s11356-015-5693-y] [PMID: 26527339]

[15] WHO. Guidelines for the safe use of waste water and excreta in agriculture and aquaculture: measures for public health protection. Geneva: World Health Organization Press 1989; p. 187.

[16] WHO. Guidelines for the safe use of wastewater, excreta and greywater. Geneva: World Health Organization Press 2006; p. 114.

[17] EPA. Protocol development: criteria and standards for potable reuse and feasible alternatives. Washington, DC 1980.

[18] EPA. Guidelines for water reuse. Washington, DC 2004; p. 480.

[19] EPA. Guidelines for water reuse. Washington, DC 2012; p. 643.

[20] DOE. Iranian standard for wastewater discharge and reuse. Department of Environment Press 2000; p. 55.

[21] WHO. A compendium of standards for wastewater reuse in the Eastern Mediterranean region World Health Organization Press. Regional Office for the Eastern Mediterranean 2006; p. 242.

[22] Brissaud F. Criteria for water recycling and reuse in the Mediterranean countries. Desalination 2008; 218: 24-33.
[http://dx.doi.org/10.1016/j.desal.2006.07.016]

[23] Agrafioti E, Diamadopoulos E. A strategic plan for reuse of treated municipal wastewater for crop irrigation on the Island of Crete. Agric Water Manage 2012; 105: 57-64.
[http://dx.doi.org/10.1016/j.agwat.2012.01.002]

[24] Carlos FS, Santos BL, Andreazza R, Tedesco MJ, Morris L, Camargo FAO. Irrigation of paddy soil with industrial landfill leachate: impacts in rice productivity, plant nutrition, and chemical characteristics of soil. Paddy Water Environ 2017; 15: 133-44.
[http://dx.doi.org/10.1007/s10333-016-0535-1]

[25] Rhee HP, Yoon CG, Son YK, Jang JH. Quantitative risk assessment for reclaimed wastewater irrigation on paddy rice field in Korea. Paddy Water Environ 2011; 9: 183-91.
[http://dx.doi.org/10.1007/s10333-010-0212-8]

[26] Jung K, Jang T, Jeong H, Park S. Assessment of growth and yield components of rice irrigated with reclaimed wastewater. Agric Water Manage 2014; 138: 17-25.
[http://dx.doi.org/10.1016/j.agwat.2014.02.017]

[27] Kaboosi K. The assessment of treated wastewater quality and the effects of mid-term irrigation on soil physical and chemical properties (case study: Bandargaz treated wastewater). Appl Water Sci 2017; 7(5): 2385-96.
[http://dx.doi.org/10.1007/s13201-016-0420-5]

[28] Jang T, Lee SB, Sung CH, Lee HP, Park SW. Safe application of reclaimed water reuse for agriculture in Korea. Paddy Water Environ 2010; 8: 227-33.
[http://dx.doi.org/10.1007/s10333-010-0203-9]

[29] APHA. Standard methods for examination of water and wastewater. Washington, DC: American Public Health Association 2017; p. 541.

[30] Ramakrishna A, Nagaraju D, Balasubramanian A, Siddalingamurthy S. Assessment of groundwater quality for irrigation in the Tattekere watershed, Periyapatna and Hunsur Taluks in Mysore district, Karnataka, India. Int J Curr Eng Tech 2015; 5(2): 942-8.

[31] Wilcox LV. Classification and use of irrigation waters. Washington, DC: US Department of Agriculture Press 1955; p. 28.

[32] Karunanidhi D, Vennila G, Suresh M, Subramanian SK. Evaluation of the groundwater quality feasibility zones for irrigational purposes through GIS in Omalur Taluk, Salem District, South India. Environ Sci Pollut Res Int 2013; 20(10): 7320-33.
[http://dx.doi.org/10.1007/s11356-013-1746-2] [PMID: 23636597]

[33] Zouahri A, Dakak H, Douaik A, El Khadir M, Moussadek R. Evaluation of groundwater suitability for irrigation in the Skhirat region,

Northwest of Morocco. Environ Monit Assess 2015; 187(1): 4184.
[http://dx.doi.org/10.1007/s10661-014-4184-9] [PMID: 25467415]

[34] Ayers S, Westcot DW. Water quality for agriculture (FAO 29). Rome, 1985; p. 174.

[35] Shainberg I, Oster JD. Quality of irrigation water. New York: International Irrigation Information Center 1978; p. 65.

[36] Jangir RP, Yadav BS. Management of saline irrigation water for enhancing crop productivity. J Sci Indus Res 2011; 70: 622-7.

[37] Phocaides A. Handbook on Pressurized Irrigation Techniques. 2nd ed. Rome: Food and Agriculture Organization of the United Nations 2007; p. 282.

[38] Minhas PS, Gupta RK. Quality of irrigation water: assessment and management. New Delhi: Indian Council of Agricultural Research 1992; p. 123.

[39] Singh A, Agrawal M. Effects of Waste water irrigation on physical and biochemical characteristics of soil and metal partitioning in Beta vulgaris L. Agric Res 2012; 1(4): 379-91.
[http://dx.doi.org/10.1007/s40003-012-0044-4]

[40] Smirnov N. Table for estimating the goodness of fit of empirical distributions. Ann Math Stat 1948; 19(2): 279-81.
[http://dx.doi.org/10.1214/aoms/1177730256]

[41] Myers BJ, Bond WJ, Benyon RG, *et al.* Sustainable effluent- irrigated plantations: an Australian guideline. An Australian Guideline CSIRO Forestry and Forest Products, Melbourne, 1999; p. 286.

[42] Pirsaheb M, Sharafi K, Dogaohar K. Comparison of Mashhad Aolang wastewater treatment plant effluent with wells water quality for irrigation. J Water Wastewater 2013; 4: 116-21.

[43] Chiou RJ. Risk assessment and loading capacity of reclaimed wastewater to be reused for agricultural irrigation. Environ Monit Assess 2008; 142(1-3): 255-62.
[http://dx.doi.org/10.1007/s10661-007-9922-9] [PMID: 17929185]

[44] Tripathy DP, Bhushan Dhar B. Environmental Pollution Research. APH Publishing New Delhi 2002.

[45] Chopra AK, Pathak C. Accumulation of heavy metals in the vegetables grown in wastewater irrigated areas of Dehradun, India with reference to human health risk. Environ Monit Assess 2015; 187(7): 445.
[http://dx.doi.org/10.1007/s10661-015-4648-6] [PMID: 26092239]

[46] Huong NTL, Ohtsubo M, Li L, Higashi T, Kanayama M. Assessment of the water quality of two rivers in Hanoi City and its suitability for irrigation water. Paddy Water Environ 2008; 6: 257-62.
[http://dx.doi.org/10.1007/s10333-008-0125-y]

[47] Choi J, Yoon CG, Rhee HP, Son Y, Cho M, Ryu J. National risk assessment of irrigation on farmland near wastewater treatment plants in Korea. Paddy Water Environ 2016; 14: 281-8.
[http://dx.doi.org/10.1007/s10333-015-0498-7]

[48] Angelakis AN, Durham B, Marecos Do Monte MHF, Salgot M, Witgens T, Thoeye C, *et al.* Wastewater recycling and reuse in EUREAU countries: trends and challenges. Desalination 2008; 218: 3-12.
[http://dx.doi.org/10.1016/j.desal.2006.07.015]

[49] Son YK, Yoon CG, Rhee HP, Lee SJ. A review on microbial and toxic risk analysis procedure for reclaimed wastewater irrigation on paddy rice field proposed for South Korea. Paddy Water Environ 2013; 11: 543-50.
[http://dx.doi.org/10.1007/s10333-012-0347-x]

[50] Ramazani A, Jalali AH. Effect of nitrogen fertilizer and transplanting date on yield, yield components and stem lodging of rice in Isfahan region. J Crop Prod Process 2013; 3(9): 45-54.

[51] Alghobar MA, Suresha S. Effect of wastewater irrigation on growth and yield of rice crop and uptake and accumulation of nutrient and heavy metals in soil. Appl Ecol Environ Sci 2016; 4(3): 53-60.

[52] Asadi R, Alizadeh A, Ansari H, Kavoosi M, Amiri E. Effect of the amount of water and nitrogen on water productivity, yield, and yield components in two different rice cultivation methods. J Water Res Agr 2016; 30(2): 145-57.