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Effect of waste water irrigation of sweet sorghum on soil and plant

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ABSTRACT

The experiment was conducted at Isfahan East Waste Water Treatment in 2011 growing season by using a randomized complete block design with three replications. The treatments were managed for irrigation: municipal water, untreated waste water and treated waste water. Results showed irrigation with untreated and treated waste water had significantly higher biomass (86.00 t/ha) than municipal water (66.00 t/ha). Highest ethanol yield (6540 l/ha) was obtained for sweet sorghum irrigated with raw waste water. Both pH and P was accumulated in the soil irrigated with untreated and treated waste water. At the end of growing season the amount of Cd, Pb and Ni were accumulated in these soils. The amount of measured heavy metals in sweet sorghum grain, leaf and stem were significantly higher in untreated waste water than both municipal water and treated waste water. Number of coliform in untreated waste water was significantly higher than treated and municipal water. The number of coliform in grain, leaf and stalk for surface non- sterilized was higher than surface sterilized but it was less than 100 MPN 100 ml-1. Based on the results, in order to produce bioethanol without accumulation of heavy metals in the soil, it is suggested to plant sweet sorghum and irrigated with treated waste water.

Keywords:

Bioethanol, Coliform, Heavy metal, Sweet sorghum, Wastewater

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Introduction

Water crisis is one of the challenges that dry countries of the world are facing with it. The lack of good quality water, the researchers have encouraged to use salinity, municipal and industrial waste waters. Therefore, treated waste water is widely used for irrigation all over the world [1]. Treated waste water is not only available as a water source for irrigation but also provide a wide variety of nutrients which enhance crop growth and yield [2][3]. Soil application of treated wastewater as water and nutrients source of agricultural irrigation represents a low cost alternative for wastewater treatment particularly applicable in dry regions. The application of treated wastewater to the soil- plant- system may mitigate the scarcity of water resources and the discharge of nutrients to water bodies by using soil and plants as natural filters [4]. Crop irrigation with treated wastewater constitutes an ecologically sound method for the disposal of effluent into the environment [5].Treated wastewater proves to be an economic asset rather than economic burden and helps in the improvement of environmental quality [6][7][8]. The rich resource from nutrient elemental especially nitrate has an advantage of less fertilizer consumption [9]. Sorghum (Sorghum bicolar (L.) Moench) is widely used for food and fodder all over the world and is consider as fifth most important cereal crop after wheat, maize, rice and barley. It has the ability to tolerate and survive under adverse conditions of intermittent and continuing drought [10][11][12]. Sorghum has also received considerable attention during the last years as an alternative source for energy production [13].The present investigation was undertaken to explore the potential using different wastewater qualities for the yield and ethanol production of sweet sorghum.

Materials and methods

The experiment was carried at Isfahan East Wastewater Treatment Plant, which has aerobic lagoon system, growing season by using a randomized complete block design with three replications. The treatments were managed for irrigation with municipal water which represent control, raw wastewater effluent and treated wastewater effluent. Each plot consisted of 6 rows of 10 m long and 0.5 m apart. The plots were 3.0 m a part. Before planting the soil samples were taken from 0-30 cm depth and pH, P, K, NO_3, N and soil texture was determined. Again at the end of growing soil samples from each plot were taken and the above measurements were determined. Sweet sorghum variety Sofra was sown in 0.75m furrows and following establishment, the plants were thinned to 10 cm apart so that the final plant populations were 200,000 plants ha^{-1}. At physiological maturity plants from two central rows were harvested. Biomass and brix value were measured. Theoretical ethanol yield was calculated according to [14]. Total E. coli (*Escherichia coli*) and fecal E. coli were measured according to [15] and heavy metals according [16].Statistical analyses were performed using SAS (2012) computer program. The means were compared according to Duncan's Multiple Range Test.

Results and Discussion

The results of soil analysis before planting and at the end of growing season for sweet sorghum irrigated with three water qualities are shown in Table1. Application of waste waters increased soil pH. It was 7.6 before planning sweet sorghum. At the end of growing season, soil pH decreased to 7.4 and 8.0 using municipal water and waste wasters as irrigation sources, respectively. According to FAO water qualitative standard [17], it was lower than the critical limit (8.5) for agriculture application. Soil pH was increased by application of waste waters [18]. At the end of growing season, the amount of N, NO_3, P and K was increased (Table 1). They are macronutrients and are necessary for sweet sorghum growth and development. Treated waste water is not only available as a water source for irrigation but also provide a wide variety of nutrients which enhance crop growth and yield [2][3].Irrigation sweet sorghum with waste waters significantly accumulates Cd, Pb and Ni in the soil (Table 2). The amount of Fe, Cu, Mn and Zn was not significantly different.

Among the three water qualities. The amount of Fe, Pb and Cd in the soil was higher than the EPA standard (Table 3). The amount of Cu, Mn and Ni were in the limit of EPA standard. The amounts of all the above heavy metals are higher than the EPA standard for drinking water. Concentration of Fe, Pb and Cd was higher than optimum limit which it is demonstrate the soil pollution possibility in continuously use of wastewater. The effect of water qualities on biomass, brix value and ethanol yield is shown in table 4. Biomass was not significantly different for raw waste water and treated waste water and on average was 86.66 t/ha. Both waste waters had significantly higher biomass than municipal water (66.66 t/ha). Higher biomass in waste waters could be due to the availability of nutrients and other growth substances growth substances which increase sweet sorghum biomass in waste waters There was no chemical treatment in the aerobic lagoon system, so the chemical compositions of raw waste water and treated waste water was not changed and the plant nutrient was the same for both waste waters. Waste water provides a wide variety of

Table 1. Soil analysis before planting and at the end of growing season among three irrigation qualities.

Characteristics	Before planting	Municipal water	Raw waste water	Treated waste water
pH	7.6	7.4	8.0	8.0
P(ppm)	16.5	17.0	44	44
K(ppm)	430	430	370	410
NO_3(ppm)	7	7.5	19.5	23
N(ppm)	0.026	0.029	0.034	0.038
Silt (%)	45	43	43	48
Sand (%)	10	10	12	10
Soil texture	Clay	Clay	Clay	Clay

Table 2. Mean comparisons* for heavy metals in the soil before planting and at the end of growing season among three irrigation qualities.

Heavy metals PPM	before planting	Municipal water	Treated waste water	Raw waste water
Cd	0.02c	0.02c	0.12b	0.31a
Pb	4.10c	5.06b	10.11a	10.54a
Ni	1.33b	1.98b	3.50a	3.55a
Fe	1230.64b	1442.57a	1491.83a	1500.61a
Cu	2.98a	3.13a	3.46a	3.94a
Mn	19.43b	63.08a	63.27a	64.05a
Zn	4.01b	8.49a	9.37a	9.41a

* Values within each row followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

Table 3. EPA standard for heavy metals and E. Coli for drinking water, waste water, soil and plant.

Heavy metal* or Colifom**	Drinking water	Waste water	Soil	Plant
Fe	0.1	5	-	-
Cu	1.3	0.2	20	2-15
Pb	0	5	10	0.1-10
Cd	0.005	0.1	0.06	0.2-0.8
Mn	0.1	0.2	85	15-100
Ni	0.1	0.2	40	1-10
Zn	5	1	-	-
Total coliform	0	1000	-	-
Fecal coliform	0	400	-	-

*ppm

**MPN $100mL^{-1}$

Table 4. Mean comparisons* among three irrigation qualities for brix value, biomass and ethanol yield

Water qualities	biomass (t/ha)	Brix(%)	Ethanol yield (l/ha)
Municipal water	66.66b	16.16a	4585.45c
Raw waste water	87.33a	18.00a	6540.07a
Treated waste water	86.00a	16.66a	5946.91b

* Values within each column followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test

Table 5. Mean comparisons* for heavy metals in sweet sorghum stalk among three irrigation qualities.

Heavy metals (PPM)	Municipal water	Treated waste water	Raw waste water
Cd	0.04c	0.10b	0.21a
Pb	4.83b	11.99b	74.06a
Ni	0.32c	0.73b	2.01a
Fe	24.28b	25.28b	83.37a
Cu	1.57c	4.92b	9.40a
Mn	2.35c	10.19b	15.99a
Zn	2.84b	4.94b	8.57a

* Values within each row followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

Table 6. Mean comparisons* for heavy metals in sweet sorghum grain among three irrigation qualities.

Heavy metals(PPM)	Municipal water	Treated waste water	Raw waste water
Cd	0.04b	0.08ab	0.16a
Pb	4.07b	14.07b	66.12a
Ni	0.16b	0.6b	1.56a
Fe	20.52b	27.63b	50.86a
Cu	0.88b	1.79b	6.89a
Mn	1.02c	7.15b	13.6a
Zn	1.28c	3.37b	8.36a

* Values within each row followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test

Table 7. Mean comparisons* for heavy metals in sweet sorghum leaf among three irrigation qualities.

Heavy metal (PPM)	Municipal water	Treated waste water	Raw waste water
Cd	0.06b	0.11ab	0.19a
Pb	11.63b	16.94b	70.87a
Ni	0.54b	0.78b	1.74a
Fe	24.20b	34.59b	107.64a
Cu	1.22b	1.71b	6.78a
Mn	5.86b	1.50b	21.80a
Zn	3.11b	5.59b	11.09a

* Values within each row followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

Table 8. Number of total coliform in MPN 100 mL^{-1} of soil before planting and at the end of experiment for three water qualities.

Treatment	Soil before planting	Municipal water*	Treated waste water*	Raw waste water*
Coliform	1.18x 10^3a**	1.15x10^3a	1.50 x10^3a	2.40x10^3b

* Number of coliform in the soil at the end of experiment.

**Values by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

Table 9. Number of total coliform in MPN100 ml^{-1} of sweet sorghum stalk, leaf and grain among three irrigation qualities when the surface was not sterilized.

Treatment	Stalk	leaf	Grain
Municipal water	1.00x10^2a*	3.80x10^2a	8.00x10^1a
Treated waste water	1.60x10^2a	2.40x10^2a	1.10x10^2a
Raw waste water	1.10x10^2a	7.50x10^2b	1.60x10^2a

* Values within each column followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

Table 10. Number of total coliform in MPN 100 mL^{-1} of sweet sorghum stalk, leaf and grain among three irrigation qualities when surface was sterilized.

Treatment	Stalk	leaf	Grain
Municipal water	5.10x10^1a*	2.40x10^1a	3.40x10^1a
Treated waste water	2.90x10^1a	6.60x10^1a	4.30x10^1a
Raw waste water	3.70x10^1a	3.70x10^1a	2.40x10^1a

* Values within each column followed by the same letter are not significantly different by (p= 0.05), using Duncan's multiple range test.

nutrients which enhance crop growth and yield [2][3]. Irrigation with wastewater lead to significant increase on total yield, leaf fresh and dry weight, stem fresh and dry weight, stem diameter and leaf number in plant [18].

Brix value was not significantly difference among the three irrigation water qualities, however sorghum plant irrigated with raw waste water had higher brix value (18.00 percent) than the other two irrigation water qualities. Waste water application increases carbohydrates in sorghum [18][19]. Theoretical ethanol yield was highest (6540 l/ha) with raw waste water and lowest with municipal water (4585 l/ha). Theoretical ethanol yield in sweet sorghum is based on fresh biomass and brix value [14]. Biomass and brix value was highest in plant irrigated with raw waste water and lowest with municipal water. The amount of heavy metals in sweet sorghum stalk, grain and leaf for the three water qualities are presented in Table 5, 6 and 7. Heavy metals were significantly higher in plants irrigated with raw waste water than the other two water qualities. In raw waste water only the amount of Fe and Pb exceed the EPA standard for the plant (Table 3). Fe and Pb concentration was significantly lower in treated waste water than raw waste water. There was no significant difference between treated waste water and municipal waste water for Fe and Pb. Pb is an additive to transportation fuel and municipal water piping is old and made of ferrous materials.

Total coliform for the soil before planting and the three water qualities were higher than the EPA standard (Table 8). Raw waste water had significantly higher coliform than treated waste water and municipal waste water. Number of total coliform of sweet sorghum stalk, leaf and grain among three irrigation qualities when the surface was not sterilized (Table9) and sterilized (Table10) indicates that even when the surface was not sterilized, the number of total coliform was less than 100 MPN $100mL^{-1}$.

Conclusions

Due to the lack of good quality water, the farmers have to use salinity, industrial or waste waters. Therefore, treated waste water is widely used for irrigation all over the world. Treated waste water is not only available as water source for irrigation but also provide a wide variety of nutrients which enhance crop growth and yield and reduce fertilizer application. Among energy crops which are used as feedstock for bioethanol production, sweet sorghum has the ability to tolerate and survive under adverse soil and climatic conditions. In order to explore the potential using waste water with the least accumulation of heavy metals and E.coli in the soil and plant for production of bioethanol from sweet sorghum, it is suggested to irrigated it with treated waste water.

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