EFFECT OF TEXTILE DYEING WASTEWATER ON GROWTH, YIELD AND NUTRITIONAL QUALITIES OF INDIAN SPINACH

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ABSTRACT

The present study was conducted on Indian Spinach irrigated by groundwater (control) and seven different types of textile dyeing wastewater to assess the suitability for further utilization in vegetables cultivation. The impact of dyeing wastewater was assessed regarding the growth, yield and nutritional qualities of Indian Spinach. The different types of dyeing wastewater were analyzed for a wide range of parameters and compared with irrigation water quality standard. The results revealed that pH, biochemical oxygen demand, dissolved oxygen, chloride and color of the mixed wastewater sample (D8) were exceeded the irrigation water quality standards of Department of Environment, Bangladesh while these properties of other wastewater samples were almost within allowable limits. The mixed wastewater was not suitable for irrigation considering the intensity of pollution and yield of Indian Spinach. The average yield of Indian Spinach irrigated with five less polluted wastewater (2 nd wash after scouring and bleaching, enzyme treated wastewater, 2nd wash after dyeing, neutralized wastewater and fixing wastewater) was 58.54 g which was about 28 percent lower than the groundwater irrigated Indian Spinach. However, number of leaves, plant canopy area, stem diameter and plant height did not varied significantly with groundwater treated plant. Nutritional qualities of Indian Spinach irrigated with wastewater were similar to those irrigated by groundwater. The concentration of ascorbic acid in Indian Spinach irrigated with wastewater was found almost identical with groundwater irrigated plants. Chlorophyll a and chlorophyll b of different wastewater treated plants varied from 0.17 to 0.29 mg and 0.05 to 0.08 mg per gm among the treatments respectively while groundwater irrigated Indian Spinach contained in these range. β carotene in wastewater irrigated Indian Spinach was also higher than the groundwater irrigated plant. From overall assessment, selected wastewater of a dyeing factory could be directly reutilized in irrigation purpose of vegetables cultivation.

Key words: wastewater, irrigation, yield and growth, nutritional qualities.

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Introduction

Bangladesh is an agricultural country where industrialization is taking place in a gradually increasing phase. Water pollution by industrial effluent is one of the vital issues of the environmental concern in Bangladesh (Jolly and Islam, 2009). The important industries are textiles, leather tanning, fertilizer, sugar, chemical, pharmaceutical, oil refining etc. Among these industries, the textile dyeing is considered to be one of the world's worst polluters because it uses huge amounts of both chemicals and water which after processing becomes wastewater (Khan et al., 2011). To dye 1 kg of cotton goods with reactive dyes, it requires an average of 70-150 L water, 0.6 kg NaCl, 40 gms reactive dyes, alkalis (NaOH) and other pretreatment and dyeing auxiliaries (Allegre et al., 2006). Due to continuous disposal of wastewater into river bodies, the surface water quality is being polluted gradually in an around the industrial zone because of the mixing of various chemical pollutants of the effluent with water. On the other hand, the continuous withdrawal of groundwater is responsible for the depletion of underground water resource and this continuous lowering of the underground water level is threatening our agriculture and environment. It has been reported that the groundwater level of the country is going down gradually due to its large scale yearly extraction for crops production (Jolly and Islam, 2009). The use of industrial wastewater for irrigation purpose can reduce the water pollution and dependency on agricultural use of groundwater. However, it is not possible to circumvent the industrialization for the contributions of textile sector in the economy of Bangladesh. Under this situation, it has become urgent to think of an alternative way to reutilize the industrial wastewater as irrigation aspect for crops production. Ultimately that would be helpful to reduce the environmental pollution of wastewater as well as effluent treatment cost.

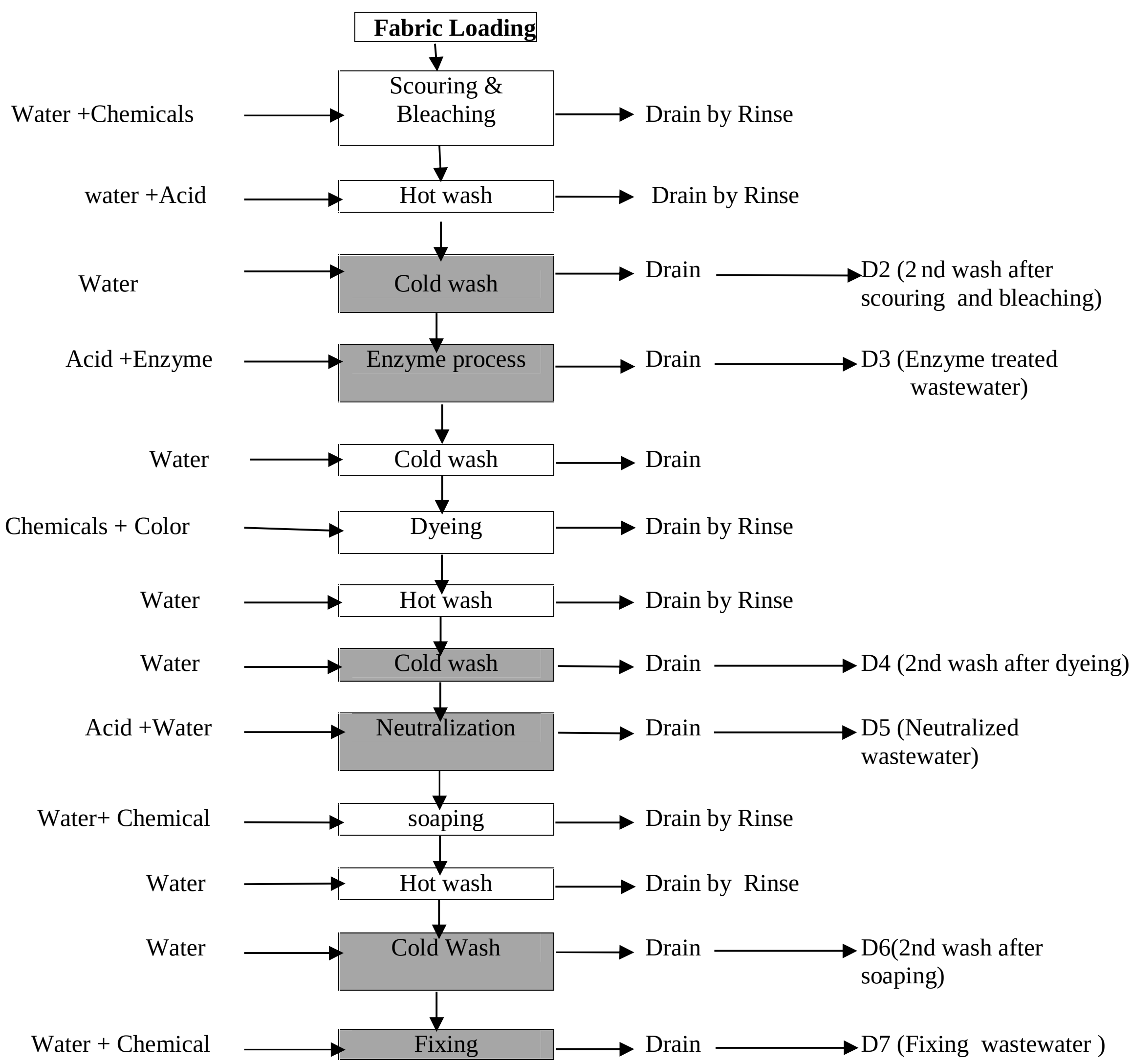
The use of industrial or municipal wastewater in agriculture is a common practice in many parts of the world (Sharma et al., 2007; WHO, 2006). Rough estimates indicate that at least 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater (Hussain et al., 2001) as this effluent contains various micronutrients essential for plant growth. However, several studies were conducted using wastewater as irrigation for crops and vegetable production where treated wastewater can be used safely for this purpose but untreated wastewater were adversely affected both qualitatively and quantitatively.

There are more than 15 steps in knit fabric dyeing process where the wastewaters of all sections are not strongly polluted. In some dyeing process, both chemicals and water are used and some other process only water is used for fabric washing and cleaning after a chemical treatment. Haque (2008) stated that about 50% of wastewater are polluted and needs to be treated and the rest of the water can discharge directly or subjected to very mild treatment. So there is a scope to use such type of wastewater for crops production in Bangladesh. Moreover, as dyeing is a continuous process so it will not hamper to get irrigation water relentlessly. The aim of the present study was to observe the yield, growth and nutritional qualities of Indian Spinach irrigated with less polluted wastewater from the dyeing process comparing with groundwater.

Materials and Methods

Sample Collection

The less polluted wastewater samples were carried in 120 liters plastic container for irrigation of vegetables from dyeing process (D2, D3, D4, D5, D6 and D7) of a knit fabric dyeing factory in Bangladesh (Fig. 1). Mixed effluent sample (D8) was taken from equalization tank of ETP (Effluent treatment plant) and groundwater sample (D1) was collected as control treatment from a tube-well near experimental site. For wastewater characterization, samples were taken in two liters plastic bottles with good stoppers from the plastic container. Bottles were thoroughly washed with 1 (M) HCl and rinsed several times with de-ionized water before sample collection. Sampling was carried out using the grab method except mixed effluent (Stone et al., 2000).



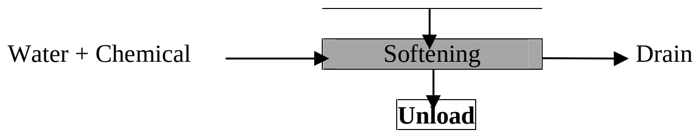


Figure 1: Typical dyeing process and Sample Collection Steps

Laboratory Analysis of Wastewater

The pH, electrical conductivity and temperature were measured on the spot before acidified according to the standard procedures (APHA, 1998). Colour, nitrate (NO_3^-), sulphate (SO_4^{-2}), phosphate (PO_4^-) were carried out in the laboratory using DR-2800™ Spectrophotometer. Electrical conductivity (EC) was determined by conductivity meter (EC150, HACH). Biochemical oxygen demand ($BOD_{5)}$ was measured by dilution method (APHA, 1998). Dissolved oxygen (DO) was measured by chemical method and Chemical oxygen demand (COD) was determined by dichromate digestion method. Chloride was determined by Mohr's method. Total solids (SS) was measured gravimetrically while suspended solids (SS) was obtained by subtracting the TDS from TS. The determinations of heavy metals (nickel, zinc, copper and chromium) were carried out using Atomic Absorption Spectrophotometer (SPECTRA A.A-55B, VARIAN, and Australia) as per standard method.

Cultivation of Indian Spinach

Pot experiment was conducted at the nursery of Horticulture Department at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh on March-May, 2012. 24 pots were arranged according to the RCBD (Randomized Complete Block Design) with three replications for eight wastewater samples including one groundwater irrigated plants. After rising of plants, thinning and wedding were done properly and each pot was irrigated with equal amount (500 ml) of wastewater from respective drum at one alternate day to keep soil moistured. Harvesting was done 70 days after seed sowing because maximum yield and growth of Indian Spinach was obtained in this period (Rashid, 1993). At least five plants were taken randomly from each replication of treatments to analysis the growth and yield of Indian Spinach.

Measurement of Growth and Yield

Total Plant height and shoot length were measured by measuring tape. Leaf length and leaf width were also measured in the similar way. Stem diameter was measured in mm by slide calipers in the three position of a plant. Plant weights were measured by using electronic balance precisely. All measurements were taken 5 randomly selected plants from each replication and average value was calculated. Leaves per plant were counted from 5 plants of each replication and average was calculated. Plant canopy area was measured by using the following formula.

Canopy area= Leaf expansion at the north-south direction X Leaf expansion at the west- east direction.

Nutritional Analysis

Fresh leaves were sampled manually for estimations of chlorophyll and β carotene. Chlorophyll and β carotene pigments were extracted in 80% acetone and estimated according to the methods of Maclachlan and Zalik (1963) and Duxbury and Yentsch (1956), respectively. Ascorbic acid was determined by the methods described by Keller and Schwager (1977).

Statistical Analysis

The data was analyzed using MSTATC statistical software. Analysis of variance (ANOVA) was done according to Gomez and Gomez (1984). The means were compared by Duncan's multiple range test (DMRT) at 5% significance level.

Results and Discussions

Physiochemical Properties of Wastewater and Groundwater

Physicochemical properties of different textile dyeing wastewater and groundwater were compared with irrigation water quality standard suggested by DOE (Department of Environment). The analytical results are shown in Table 1. The highest amount of Colour, TDS, electrical conductivity, sulphate, chloride were detected in mixed effluent (D8) and 2nd wash after bath drop. Chloride, Electrical conductivity of these two samples were exceeded the recommended value of Department of Environment (DOE), Bangladesh.

Table 1: Physicochemical properties of textile dying wastewater

Parameters	Irrigation std of DOE	**Treatments**							
		D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**
		Tube well	2nd wash after scouring& bleaching	Enzyme Treatment	2nd wash after BD	Neutralization Treatment	2nd wash after Soaping	Fixing Treatment	Mixed Effluent from ETP
pH	6-9	7.2	9.1	6.1	8.2	7.1	7.4	7.3	9.5
DO (mgL^{-1})	4.5-8	6.5	5.85	6.12	4.58	5.0	5.8	4.77	0.58
Color (pt.co- unit)	NA	16	97	67	477	367	171	348	1038
TDS (mgL^{-1})	2100	300	910	650	2070	1840	470	1290	3320
TSS (mgL^{-1})	200	30	40	50	60	66	40	40	310
EC ($\mu s\ cm^{-1}$)	1200	350	850	900	1350	550	480	700	4200
BOD (mgL^{-1})	100	1.5	68	28	23	83	143	203	223

COD (mgL^{-1})	400	4	755	610	98	195	317	393	450
Nitrate(NO_3^-) (mgL^{-1})	10	1.5	0.8	0	0.6	0	0.3	0.8	0.8
Phosphate(PO_4^-) (mgL^{-1})	NA	0.5 2	0.52	0.81	0.23	0.27	0.19	1.06	0.40
Sulphate(SO_4^{-2}) (mgL^{-1})	NA	0	9.0	2.5	38.0	0	5.0	8.0	65
Chloride(Cl^-) (mgL^{-1})	600	31	8	5	2500	58	64	42	2700

Note: n a - not available

The wastewater discharge from 2nd wash after scouring and bleaching (D2) and mixed effluent (D8) were strongly alkaline. Dissolved oxygen was the lowest in D8 which indicates the severity of pollution. Very little amount of nitrate and phosphate were found in different wastewater samples.

Growth and Yield Characteristics of Indian Spinach

Number of Leaves per Plant

There was no significant variation found for the total number of leaves per plant among the wastewater and groundwater treated Indian Spinach. The number of leaves in groundwater irrigated plant was 19.11 while in other wastewater treated plants varied from 14.11 to 16.50 statistically (Table 2).

Leaf Length

The highest leaf length of Indian Spinach was found in D1 (17.83 cm) treated plant while leaf length of different wastewater treated plants ranged from 12.0 to 13.28 cm and statistically similar. Islam et al., (2011) studied that the maximum leaf length was 17.0 cm and minimum leaf length was 10.4 cm in Indian Spinach grown in wastewater irrigated soil which is identical with the present study.

Leaf Width

Leaf width of Indian Spinach was found the highest in groundwater treated plant (10.78 cm). However; leaf width of different wastewater irrigated plant was within the same group ranged from 6.78 to 8.39 cm and has no statistical variation each among.

Plant Canopy Area

There was no significant variation observed in plant canopy area of different wastewater irrigated plants with groundwater irrigated plant. The highest plant canopy area was seen in D3 (745.00 cm^2) while the lowest value was found in D8 (581.30 cm^2) (Table2). Higher Plant canopy area enhances the exchange of gases and photosynthesis process. Iersel and Lee (2008) found that leaves area of plants decreased with the increasing of salinity of soil for irrigation. Salinity not only decreases the area of individual leaves, but also the total leaf area of plants (Brugnoli and Lauteri, 1991; Romero-Ara-nda et al., 2001). The concentration of chloride (Cl^-) in D8 and D4 was the highest. Therefore, the canopy area of those treatments were seems to lower.

Stem Diameter

No significant variation was found in stem diameter among the wastewater and groundwater treated plants. The highest stem diameter was found in D1 (10.47 mm) closely followed by D3 (10.35 mm) and D5 (10. 17 mm). The lowest stem diameter was measured in D8 (8.597 mm).

Plant Height

Statistically there was no significant difference observed in the plant height of Indian Spinach. The maximum plant height was recorded from D1 (60.34 cm) while it was the minimum in D6 (35.76 cm).The height of other treatments (D2, D3, D4, D5, D7 and D8) were varied from 38.23 to 51.51 cm (Table 2). As D2, D4, D7 and D8 wastewater contained higher amount of nitrate (NO_3^-) therefore, it seems that the plant height was also higher than the other wastewater treated plants. Rop et al., (2012) stated that the height of a plant depends on plant vigor and growth habit. Indian Spinach is a vigorous growing plant and nitrogen had a significant effect on the length of stem. Nitrogen is essential for plant cell division especially during early vegetative growth in plant (Salisbury and Ross, 1986). This implies that timing and application of nitrogen levels is crucial in production of leafy vegetables.

Table 2: Growth and Yield of Indian Spinach Irrigated by Textile Dyeing Wastewater

Treatments	Number of leaves per plant*	Leaf length (cm)	Leaf width (cm)	Plant Canopy area (cm^2)*	Stem Diameter (mm)*	Plant height (cm)	Plant weight (g) (Yield)
D1	19.11a	17.83a	10.78a	654.00a	10.47a	60.34a	81.33a
D2	16.50a	13.28ab	8.39ab	740.00a	9.28a	45.28a	60.67ab
D3	15.55a	12.83b	7.22b	745.00a	10.35a	42.26a	58.00ab
D4	14.67a	12.00b	7.97b	602.00a	9.80a	40.38a	49.00ab
D5	15.44a	13.22ab	7.44b	631.30a	10.17a	38.23a	57.33ab
D6	14.11a	12.22b	6.78b	617.30a	9.16a	35.76a	45.33b
D7	15.56a	12.78b	7.22b	619.00a	9.13a	51.51a	67.67ab
D8	14.89a	12.56b	7.11b	581.30 a	8.60a	45.07a	45.33b
CV%	21.48	19.57	19.44	27.36	20.54	39.85	31.65
LSD value	5.92	4.57	2.67	312.00	3.46	31.30	31.98

* In the same column followed by common letters are not significantly different from each other at 5% level of probability by DMRT.

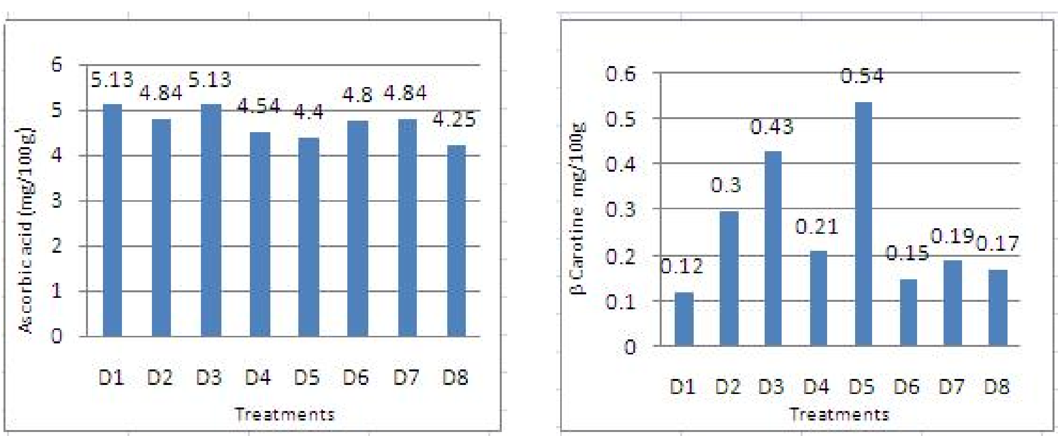
Plant Weight (Yield)

The yield (fresh weight) of groundwater irrigated Indian Spinach was 81.33 g while the yield varied from 45.33 to 67.67 g in different wastewater irrigated plants. According to the MSTAT-C software analysis, the yield of D2, D3, D4, D5 and D7 were within the same group and the average yield was 58.54 g. The yield of D6 and D8 were significantly varied with groundwater (D1) irrigated plat. Solaimalai and Saravanakumar (2004) stated that excess TDS within the plant root zone has a deleterious effect on plant growth primarily because; it increases the energy that must be expended to acquire water from the soil of the root zone and to make biochemical adjustments necessary to survive under stress. In this Study, mixed wastewater (D8) contained the huge amount of TDS (3320 mg L^{-1}) which may be hampered the yield of D8 wastewater treated plant.

Nutritional Qualities of Indian Spinach

Ascorbic Acid

There was no significant variation observed in ascorbic acid (vitamin C) of Indian Spinach among the treatments irrigated with wastewater comparing with groundwater. Ascorbic acid was varied from 4.25 to 5.13 mg in Indian Spinach per 100 g while groundwater irrigated plants contained 5.13 mg (Figure 2 a).



(a) Ascorbic Acid (b) β carotene

Figure 2: (a) Ascorbic Acid and (b) β carotene in Indian Spinach

β Carotene

The highest amount of ß carotene in Indian Spinach was found in D5 followed by D3 and D2 with the amount of 0.54, 0.43 and 0.30 mg per 100 g respectively (Figure 2 b). These amounts of ß carotene were much higher than the groundwater irrigated plant.

Chlorophyll a and Chlorophyll b

The amount of chlorophyll a and chlorophyll b of different wastewater treated plants were very close with the amount of groundwater (D1) treated Indian Spinach. Chlorophyll a and chlorophyll b was varied from 0.17 to 0.29 mg and 0.05 to 0.08 mg per gm among the treatments respectively while groundwater irrigated Indian Spinach contained in these range (Figure 3).

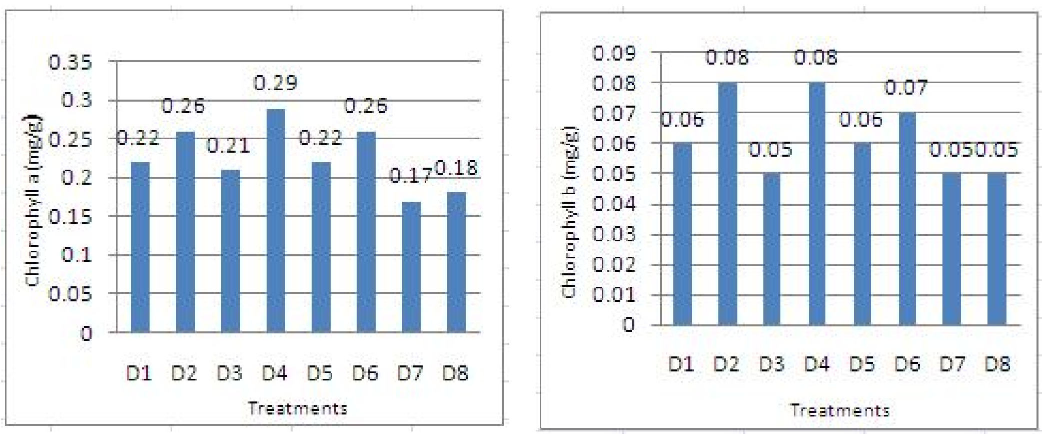


Figure 3: Chlorophyll a and Chlorophyll b Indian Spinach

Conclusion

The physicochemical properties of studied dyeing wastewater were not uniform and mixed wastewater were strongly polluted considering pH, DO, TDS, TSS, BOD and COD according to the water quality standard of DOE (Department of Environment) for using in irrigation. Therefore, the mixed wastewater was not suitable for irrigation considering the intensity of pollution. The average yield of Indian Spinach irrigated with five less polluted wastewater (D2, D3, D4, D5 and D7) was 58.54 g and this amount was about 28 percent lower than the groundwater irrigated Indian Spinach. However, number of leaves, plant canopy area, stem diameter and plant height did not varied significantly with groundwater treated plant. Moreover, nutritional qualities of this vegetable were not affected for irrigation with these less polluted dyeing wastewater. There was no significant variation was observed in the concentration of ascorbic acid, ß carotene chlorophyll a and chlorophyll b of Indian Spinach cultivated with dyeing wastewater irrigation comparing with groundwater. From the overall aspects of the study, Selected these five less polluted dyeing wastewater (without treated) can be considered as suitable alternate for irrigation of vegetables where groundwater is not available on the condition of monitoring the long-term effect on soils which can reduce the effluent treatment cost, groundwater dependency for irrigation, ultimately save the environment.

Acknowledgements

Authors are grateful to the higher education and qualities enhancement project (HEQEP) of University Grant Commission of Bangladesh for financial grant and Tex Euro Bd ltd. for giving permission to collect wastewater samples for the present investigation. The authors also thankful to the Dhaka University of Engineering &Technology (DUET), Gazipur, and Bangabandu Sheikh Mujibur Rahman Agricultural University (BSMAU), Gazipur for providing lab facilities.

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