Research Article

Influence of Sugar Industry Wastewater on Sugarcane Juice Quality and Soil Health

Ghulam Muhiyuddin Kaloi[1]* and Mehrunisa Memon[2]

[1]National Sugar and Tropical Horticulture Research Institute, PARC, Thatta, Pakistan; [2]Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan.

Abstract | Sugar industry wastewater could be handled positively for agricultural purpose. The wastewater is a nutrient rich plant material well known for its high biological oxygen demand, chemical oxygen demand and soluble salts. Its injudicious use may be hazardous for soil health. Study was conducted to evaluate significance of wastewater in context of sugarcane juice quality and soil health. Wastewater was tested on experimental field of Matiari Sugar Mills in a randomized complete block design with factorial combination of five concentrations of wastewater (0, 5, 10, 15 and 20%) and four rates of inorganic fertilizers (0, 1/3rd, 2/3rd and full) besides additional control (full recommended NPK). A total of 12 irrigations of wastewater were applied after two months of planting up to harvest of sugarcane (CPF-237). Application of 10% wastewater did not show any adverse effect on sugarcane quality and soil health rather improved juice quality and soil fertility. It gave maximum sugar recovery (12.27%) and sugar yield (11.25 t ha^{-1}). Whereas, integration of 10% wastewater × 2/3rd inorganic fertilizers gave 12.30% sugar recovery and 12.70 t ha^{-1} sugar yield. It increased soil N by 50, P 119 and K 243% and organic matter 53%. The SAR and ESP were significantly reduced with a slight increase (0.1-7.5%) in pH, EC, Cl and HCO_3.

Received | October 22, 2020; **Accepted** | August 31, 2021; **Published** | September 22, 2021
***Correspondence** | Ghulam Muhiyuddin Kaloi, National Sugar and Tropical Horticulture Research Institute, PARC, Thatta, Pakistan; **Email:** gmkaloiparc@gmail.com
Citation | Kaloi, G.M. and M. Memon. 2021. Influence of sugar industry wastewater on sugarcane juice quality and soil health. *Pakistan Journal of Agricultural Research,* 34(4): 766-773.
DOI | https://dx.doi.org/10.17582/journal.pjar/2021/34.4.766.773
Keywords | Sugarcane, Sugar-Industry wastewater, Juice quality, Sugar yield, Soil health

Introduction

Sugarcane is a valued cash crop and plays an important role in the economy of Pakistan. The crop accounted 2.9% in value addition of agriculture and 0.5% in GDP during 2018-19 (NFDC, 2019). Maintaining optimum fiber (11-14%) quality is vital (Lingle *et al.*, 2010). High fiber (>14%) reduces sugar extraction, and low fiber (<11%) encourages lodging and cane pests. Brix content defines the total soluble solids, dissolved sugars and salts including sucrose, reducing sugars, glucose and fructose present in the cane juice (Nawi *et al.*, 2014). It is indefinite indicator of sugar content. The pol is to the only parameter which signifies the actual sugar content in cane. Purity of juice is simply the ratio between brix and pol. Sugar recovery indicates the recoverable sucrose content of cane, while sugar yield depends on cane yield and sugar recovery. Ultimately, sugar recovery depends on the quality of juice produced. The sugarcane yield decreased by 1.8% in 2018-19 over the previous year, while the sugar recovery increased by 4.49% in the same years (PSMA, 2019). However, there is potential to increase the recovery further. Disposal problem of cane and payment difficulties also restricted the acreage of sugarcane. In addition, there are issues related to cost and timely availability of fertilizer. Particularly potassium, which plays an important role in juice quality.

Distillery wastewater is a rich source of macro and micro nutrients. The country has 18 alcohol manufacturing distilleries generating 3.48 million tons of wastewater annually (Kaloi *et al*., 2017). The wastewater generated after methanation process, termed as treated wastewater (also spentwash, vinasse, *etc*.) has reduced BOD, COD and salt content than that discharged directly during distillation. The treated wastewater is a rich source of nutrients, particularly potassium, which otherwise is an expensive input for agricultural community. The high salt content (EC 42 dS m^{-1}), BOD (2000 mg L^{-1}), COD (23000 mg L^{-1}) can be reduced by diluting the wastewater to required concentrations (Kaloi *et al*., 2017; Armengol *et al*., 2003). Further, the significant amount of N (2425-4680 mg L^{-1}), P (175-181 mg L^{-1}) and particularly K (8441-23750 mg L^{-1}) has been highlighted (Kaloi *et al*., 2017; Sadiq *et al*., 2018). By discarding the nutritive rich wastewater in the vicinity of Sugar mills, it is polluting the environment, instead it can fertilize the plants and reduce pollution load. Rath *et al*. (2011) reported that application of wastewater in addition to inorganic fertilizers increased the sugar recovery and sugar yield by 13-16%. Armengol *et al*. (2003) reported that K rich diluted wastewater significantly increased sugar recovery in Cuba. The nutrient rich wastewater can be partially supplemented to the expensive input like inorganic fertilizers in a sustainable manner with minimum adverse impacts. The direct use of wastewater showed adverse impact, while diluted wastewater significantly improved crop quality (Jain and Srivastava, 2012; Saini and Pant, 2014).

The main objective of this research was to assess the potential of Pakistani sugar industry wastewater on sugar recovery and yield and overall effect on soil health.

Materials and Methods

A field study was conducted at farm of Matiari Sugar Mills, Matiari, Sindh Pakistan (25.59° N and 68.44° E). The experiment was conducted in a randomized complete block design (RCBD) with 3 replications. The treatments (20) were a factorial combination of five concentrations (0, 5, 10, 15 and 20%) of treated wastewater and four rates *i.e.* 0 (control), 1/3rd (84 N – 42 P_2O_5 kg ha^{-1}), 2/3rd (167 N- 84 P_2O_5 kg ha^{-1}) and full NP (250 N - 125 P_2O_5 kg ha^{-1}) of inorganic fertilizers besides additional control received full recommended NPK (250 N, 125 P_2O_5 and 150 K_2O kg ha^{-1}). Inorganic fertilizers were applied in the form of urea, diammonium phosphate (DAP) and sulphate of potash (SoP). In each treatment, two budded Setts of CPF-237 variety planted in the plots having 7 m long 5 rows at 0.75 m space. The crop was irrigated with canal water for first two months (4 irrigations), followed by wastewater application (12 irrigations) up to harvest. The wastewater concentrations were separately prepared in plastic barrels and irrigated through siphon outlet. The volume of irrigation was based on 3 acre inch calculated by using irrigator's basic equation Q×T=A×D (Irrigation Slide Chart 1999). Where, Q is discharge of water in cusec, T for time in hours, A for area in acres and D for depth in inches. The cusec was calculated on the bases of flow of water (18 L per minute from 1" faucet).

Soil samples were collected at two depths; surface (0-30 cm) and subsurface (31-60 cm). The collected soil samples were air-dried after removing debris, roots and leaves etc., crushed gently, ground using wooden pestle-mortar, passed through 2 mm nylon sieve and kept in plastic bottle. Samples then were analyzed by using standard procedures. Soil texture by the Bouyoucos hydrometer method, pH (1:5) with pH meter (GmbH-Model 960), EC (1:5) by using EC meter (Hanana-HI 8033), the organic matter by Walkley-Black method (Tahir and Jabbar, 1985), total nitrogen (N) by Kjeldahl's method (Jackson, 1958) and phosphorus (P) and potassium (K) by AB-DTPA method (Ryan *et al*., 2001). Chloride (Cl) and bicarbonate (HCO_3) were determined by the methods given in USSL (1954). Sodium adsorption ratio (SAR) was calculated by using the formula SAR=Na+ / [(Ca2+ +Mg2+ /2)] 1/2 (Chopra and Kanwar 1982) and exchangeable sodium percentage (ESP) by using formula ESP = [100 (-0.0126 + 0.01475 x SAR)] / [1 + (-0.0126 + 0.01475 x SAR)] (Richard, 1954).

The samples of wastewater were collected in poly-carbonyl sterilized air-free containers leaving one fourth empty. The labeled samples were stored, immediately packed into ice boxes, brought to the laboratory and kept at 4 °C in refrigerator. The samples of wastewater were analyzed according to standard procedures (APHA, AWWA and WEF, 1998).

Sugarcane was harvested after 12 months (normal maturity period in Pakistan). Ten canes were selected randomly from each treatment, cleaned, tops were removed and labeled properly. The canes were shredded with Fiberator (Model: NOSCF-L4) and pressed in Hydraulic Press Machine (Model: SCF-HP-06) to obtained juice. The extracted juice was analyzed for brix by Digital Refractometer (Model: PR-101 Japan), pol by Polarimeter (Model AA-5 Series, Optical activity, England), purity by the formula given by Yadava (1993) and fiber content by the method described by Chen and Chou (1993). Sugar recovery was calculated by using commercial cane sugar (CCS) formula [3×P/2 (1-F+5)/100 – B/2 (1-F+3)/100] given by Meade and Chen (1977) and multiplied with factor 0.94 (Faqir *et al*., 2011). Sugar yield was obtained by multiplying CCS% with cane yield (weighed whole plot).

The data was analyzed using two way analysis of variance (ANOVA) and means were separated by least significant difference (LSD) using software program Statistix 8.1 (Analytical Software, 2005).

Results and Discussions

Soil properties

Properties of the experimental soil presented in Table 1 illustrated that sandy clay loam textured soil was slightly alkaline (pH 7.55 and 7.85), non-saline (EC 1.12 and 0.34-dS m^{-1}) and low in Cl (0.86 and 1.25 meq 100^{-1} g soil) and HCO_3 (0.41 and 0.85 meq 100^{-1} g soil) at corresponding soil depths of 0-30 and 31-60 cm. SAR and ESP were in normal range at both soil depths. Organic matter (0.08-0.21%), Kjeldahl's N (0.0045-0.0096%), available P (2.65 mg kg^{-1}) and K (43.33 mg kg^{-1}) were low with exception to later two, which were marginal (5.07 mg kg^{-1}) and K (64.55 mg kg^{-1}) at 0-30 cm soil. Soil properties were categorized according to California Fertilizer Association (1980), Foth (1984), Bohn *et al*. (1985), Soltanpour (1985) and SSDS (1993).

Wastewater properties

All the properties (Table 2) i.e. EC (3.2 to 11.7 dSm^{-1}), HCO_3 (49.2 to 248.7 mg L^{-1}), Cl (131.5 to 697.8 mg L^{-1}), TS (2.4 to 12.9 mg L^{-1}), SAR (2.2 to 6.3) BOD (93.9 to 489.6 mg L^{-1}) and COD (2618.0 to 10131.0 mg L^{-1}), organic matter (0.3 to 1.4%), total N (178 to 1075 mg L^{-1}), P (21.7 to 70.3 mg L^{-1}) and K (988 to 5347 mg L^{-1}) of wastewater increased upon increasing concentration from 5-20%.

Table 1: *Properties of experimental soil.*

Parameters		Soil depth (cm)		Categorization Reference
Soil depth (cm)		0-30	30-60	
Particle size (%)	Sand	66.98	69.5	Foth (1984)
	Silt	11.95	11.4	
	Clay	21.07	19.1	
Textural Class		Sandy clay loam		
pH		7.55	7.85	SSDS (1993)
EC (dS m^{-1})		1.12	0.34	Bohan *et al.* (1985)
Cl (meq 100^{-1} g soil)		0.86	0.41	-
HCO3 (meq 100^{-1} g soil)		1.25	0.85	California Fertilizer Association. (1980)
SAR		1.14	1.35	Bohan *et al.* (1985)
ESP		0.42	0.72	Bohan *et al.* (1985)
Organic matter (%)		0.21	0.08	-
Kjeldahl N (%)		0.0096	0.0045	-
AB-DTPA P (mg kg^{-1})		5.07	2.65	Soltanpour (1985)
AB-DTPA K (mg kg^{-1})		64.55	43.33	Soltanpour (1985)

Table 2: *Properties of wastewater used for experiment.*

Parameters	Wastewater concentrations (%)			
	5	10	15	20
pH	8.4	8.3	8.3	8.2
EC (dS m^{-1})	3.2	7.1	9.4	11.7
Cl (mg L^{-1})	131.5	292.5	495.1	697.8
HCO_3 (mg L^{-1})	49.2	108.1	178.5	248.7
SAR	2.2	4.9	5.6	6.3
TS (mg L^{-1})	2.4	5.4	9.1	12.9
BOD (mg L^{-1})	93.9	210.7	350.1	489.6
COD (mg L^{-1})	2618.0	5850.0	7990.0	10131.0
Organic matter (%)	0.3	0.6	1.0	1.4
Total N (mg L^{-1})	178.0	340.0	737.0	1075.0
Total P (mg L^{-1})	21.7	48.7	59.6	70.3
Total K (mg L^{-1})	988.0	2194.0	3770.0	5347.0

Juice quality parameters

The quality of juice in the form of fiber, brix, pol and purity content was significantly influenced by wastewater application (Table 3 and Figure 1). The fiber content increased from 12.33% in control to 13.16% under 20% wastewater with percent increase of 6.71. While, brix, pol and purity, respectively increased from 22.03, 16.42 and 70.84 in control to 23.36%, 17.91% and 76.67% under 10% wastewater, which registered a respective percent increase of 6.01%, 9.08% and

8.23% over no wastewater treatment. Based on juice parameters and cane yield, the sugar recovery and sugar yield also increased significantly by wastewater application. The sugar recovery and sugar yield increased from 9.73 and 6.86 in control to 12.27% and 11.25 t ha^{-1} under 10% wastewater application, with a percent increase of 26.02% and 63.89%, respectively.

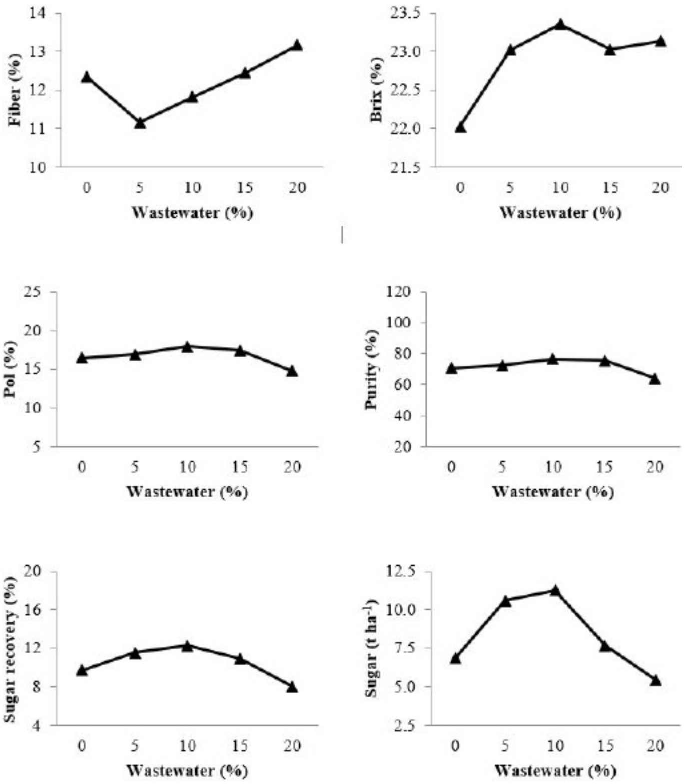

Figure 1: *Effect of wastewater concentrations on quality parameters of sugarcane*.

Table 3: *F values with significance for juice quality parameters as influenced by wastewater and inorganic fertilizer rates.*

Parameters	F value		
	Wastewater	Inorganic Fertilizer	Wastewater × Inorganic Fertilizer
Fiber (%)	58.75*	0.70	2.79**
Brix (%)	8.45*	1.37	0.50
Pol (%)	22.85*	3.09*	1.23
Purity (%)	17.15*	1.48	0.75
Sugar recovery (%)	38.94**	0.14	0.84
Sugar yield (t ha^{-1})	72.26**	3.54*	4.02**

*ns= Non-significant, * p > 0.05, ** p > 0.01*

On the other side, inorganic fertilizers (NP) resulted in significant increase in pol content only. As for full recommended dose of NPK, the fiber (%), brix (%), pol (%), purity (%), sugar recovery (%) and sugar yield (t ha^{-1}) was 11.95, 22.48, 18.12, 79.20, 12.23 and 10.94, respectively. While, the interaction of wastewater and inorganic fertilizers significantly ($p \leq 0.05$) influenced the fiber content of juice from 12.65 in control to 13.54 under 20% wastewater and 1/3rd NP fertilizers (84 kg N and 42 kg P_2O_5 ha^{-1}). Ultimately, the integration of 10% wastewater and 1/3rd of recommended inorganic fertilizers recovered maximum sugar yield of 12.7 t ha^{-1}.

Soil health

The soils of Pakistan are low in fertility mainly due to macronutrients (N, P and K) and organic matter. The N, P and K are most important nutrients utilized by crops in large amount. The ignorance and unawareness has led to a nutrient imbalance in soil and plant.

Table 4: *F values with significance for soil health as influenced by wastewater and inorganic fertilizers.*

Parameters	Soil depth (cm)	F value		
		Wastewater	Inorganic Fertilizer	Wastewater × Inorganic Fertilizer
Nitrogen	0-30	114.03*	10.94*	0.31 ns
	31-60	28.30*	11.00*	1.10 ns
Phosphorus	0-30	728.68*	113.83*	6.84*
	31-60	1228.11*	624.04*	131.47*
Potassium	0-30	757.26*	1.90 ns	0.56 ns
	31-60	517.22*	2.53 ns	0.32 ns
Organic matter	0-30	289.94*	6.19*	0.72 ns
	31-60	36.32*	2.82 ns	0.66 ns
pH	0-30	135.29*	6.36*	0.90ns
	30-60	1013.49*	21.84*	5.02*
EC	0-30	56.49*	1.14 ns	0.84 ns
	31-60	76.38*	18.00*	6.24*
Cl	0-30	173.14*	0.99 ns	0.13 ns
	31-60	79.37*	2.13 ns	0.17 ns
HCO_3	0-30	1398.68*	0.33 ns	0.59 ns
	31-60	1161.15*	1.23 ns	0.34 ns
SAR	0-30	201.33*	0.20 ns	0.12 ns
	31-60	19.73*	0.08 ns	0.27 ns
ESP	0-30	199.91*	0.19 ns	0.12 ns
	31-60	19.57*	0.08 ns	0.28 ns

*ns= Non-sgnificant, * p > 0.05, ** p > 0.01*

Statistical analysis (Table 4) indicated that effect of wastewater and inorganic fertilizer rates was significant at both soil depths (surface and subsurface), except case of inorganic fertilizers for K at both soil depths and organic matter at subsurface. The integration (wastewater × inorganic fertilizers) was significant only for P.

Data of N, P and K and organic matter is presented in Figure 2a. Nutrient content and organic matter in soil increased with increasing concentration of wastewater. Values of all fertility parameters were higher at surface soil as compared to subsurface. N increased from 0.012 to 0.019%, P 2.98 to 6.48 mg kg^{-1}, K 59.79 to 267.46 mg kg^{-1} and organic matter from 0.19 -0.35% at 20% wastewater in surface soil. Similarly, the respective nutrients (N, P and K) and organic matter was increased from 0.004, 0.44, 41.0 and 0.10 in control to 0.009%, 1.25 mg kg^{-1}, 65.12 mg kg^{-1} and 0.14% at 20% wastewater in subsurface soil. As for inorganic fertilizers application, N and P increased with increasing rate of inorganic fertilizers.

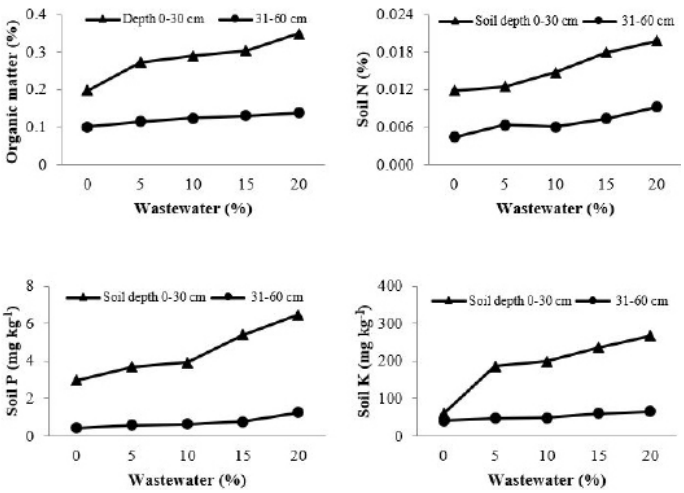

Figure 2a: *Effect of wastewater concentrations on soil health.*

The statistical analysis of soil properties (Table 4) depicted that wastewater had significant effect ($p \leq 0.05$) on pH, electrical conductivity (EC), chlorides (Cl), bicarbonates (HCO_3), sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) at both soil depths (surface and subsurface). The effect of inorganic fertilizers and interaction of both (Wastewater × inorganic fertilizers) was significant ($p \leq 0.05$) only for pH and EC at subsurface.

The data of soil properties (Figure 2b) indicated that the values of EC, Cl and HCO_3 were higher at surface soil, while, pH, SAR and ESP at subsurface soil. Furthermore, that the values of all soil properties increased with increase in wastewater concentration except SAR and ESP. pH, EC (dS m^{-1}), Cl (meq 100 g^{-1}) and HCO_3 (meq 100 g^{-1}) increased from 8.01, 0.98, 0.75 and 1.88 at concentration of 5% to 8.58, 1.40, 1.42 and 3.30 at 20% wastewater, with a percent increase of 7.12, 41.91, 87.92 and 75.22, respectively in surface soil. Similar trend was noted at subsurface soil. Unlike other properties, the SAR and ESP decreased from 2.63 and 2.56 in control to 1.44 and 0.86 with a percent decrease of 45.20 and 66.25, respectively at 20% wastewater in surface soil. Similarly, SAR and ESP were decreased at subsurface soil.

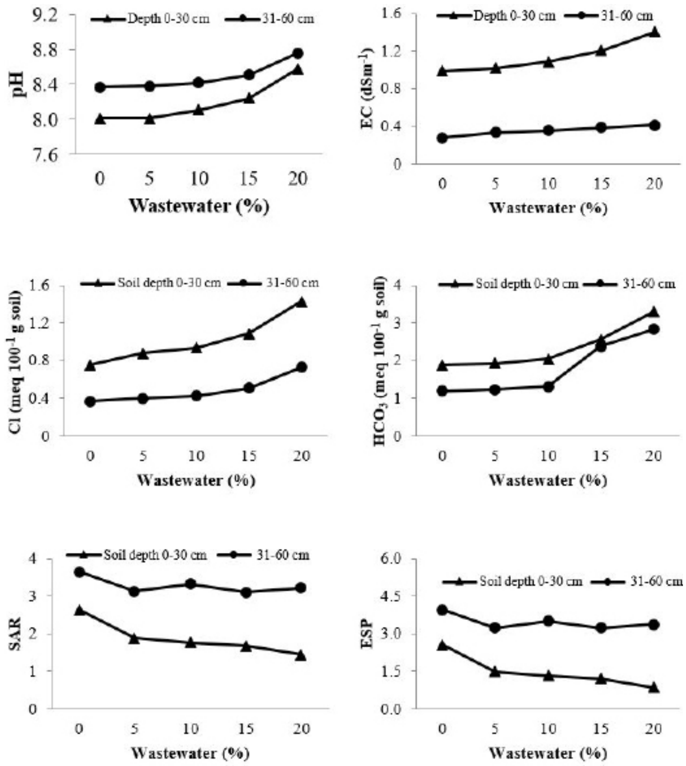

Figure 2b: *Effect of wastewater concentrations on soil health.*

The soil under experiment was low in fertility (Table 1). All properties (EC, Cl, HCO_3, SAR, TS, BOD, COD, N, P, K and organic matter) of wastewater increased with concentration except pH (Table 2). The results were supported by various workers who analyzed wastewater at various concentrations (Kumar and Chopra, 2013; Adhikary, 2014; Ali *et al*., 2015). Application of wastewater increased juice quality and sugar yield up to 15% concentration. The concentrated wastewater (20%) reduced same parameters except the fiber. Highest increase was noted at 10% wastewater which increased brix, pol, purity and sugar recovery by 6.01, 9.08, 8.23 and 26.02%, respectively and ultimately the sugar yield by 63.89% over control (0% wastewater). The fiber was in optimal range (11-14%) at all wastewater concentrations (5 to 20%). The fiber is only a parameter needed in an optimal range and either low or high affects the juice quality. In case of inorganic fertilizers rates, the fiber was improved at full rate, while brix and pol at 2/3rd rate. The purity and sugar recovery was better at full rate of inorganic fertilizers. The interactions (wastewater × inorganic fertilizers) of 5 and 10% × 0, 1/3rd, 2/3rd & Full inorganic fertilizers and 15% × 0 & 1/3rd inorganic fertilizers increased sugar recovery between 25-53%, however the difference was statistically non-significant. As for sugar yield, interaction of 10% wastewater × 2/3rd inorganic fertilizer gave an increase of 139.62%. The improvement in quality parameters and sugar yield at 10% wastewater might be due to low salt contents and reduced BOD and COD of wastewater. The initial nutrient requirement for growth was fulfilled by inorganic fertilizers and latterly by wastewater throughout growing period. The concentrated wastewater (15 and 20%) might have high level of salts, BOD and COD that caused salt accumulations and osmotic pressure within the root zone. Concentrated wastewater affected vegetative growth and sucrose formation in plant (Ramana *et al*., 2001; Rathore *et al*., 2000). The results were supported by Pujar (1995) and Silvaloganathan *et al*. (2013) who reported that 10% wastewater significantly improved brix, pol, purity and sugar recovery. However, Matibiri (1996) reported 61.33% increase in sugar yield at 2% wastewater. In contrast, Ashutosh (2014) during three year study reported that sugar yield was better at 75% wastewater × 25% inorganic fertilizer which increased sugar yield by 31.86, 24.72 and 27.64% at first, second and third year crops, respectively.

Soil physico-chemical properties (pH, EC, Cl, HCO_3, SAR and ESP) and nutrients (N, P and K) were increased with wastewater concentration except SAR and ESP. The effect of wastewater (5-20%) application was minor on soil pH. It increased between 0.01-7.12%. Armengol *et al*. (2003) reported 0.65% increase in pH at 5% wastewater. While, Patil and Patil (2013) reported 9.9% increase in pH during one time application of 100% wastewater. The application of 5 and 10% wastewater increased EC by 3.29 and 9.61%, respectively as compared to 20% wastewater which increased EC by 41.91% at surface soil. It might be due to salts like Ca, Mg, Na, Cl and K present in the wastewater. The K might be the major contributor of increase in EC. Sivaloganathan *et al*. 2013 reported that wastewater contained large amount of soluble salts which increased EC in soil. Similarly, Cl and HCO_3 increased between 9 to 90%. Patil and Patil (2013) reported 14% increase in Cl by one time surface application of concentrated wastewater. While, Adhikary (2014) recorded 129% increase in Cl and 215% in HCO_3. Unlike other parameters, the SAR and ESP reduced regardless of concentration at both soil surfaces. It reduced between 28 to 65%. Various workers reported reclamation quality of wastewater in sodic soils (Valliapan *et al*., 2001; Mahendra *et al*., 2010). It might be due to leaching of Na by Ca and S present in wastewater (Rath *et al*., 2010). As for soil fertility, the wastewater significantly improved soil organic matter at surface soil. It increased by 38.94, 47.43, 54.19 and 77.53% at 5, 10, 15 and 20% wastewater, respectively. The N, P and K were increased by 5.93, 24.19 and 214% at 5%, 24.58, 31.64 and 232% at 10%, 51.69, 80.41 and 295% at 15% and 67.80, 117.48 and 347 at 20% wastewater, respectively. This might be due to high organic matter and N, P and K content in available form. Chopra *et al*. (2013) and Patil and Patil (2013) reported that wastewater significantly enriched the soil fertility. It contains large quantities of organic matter (Selvamurugan *et al*., 2013; Kamble *et al*. 2016) and N, P and K (Shenbagavalli *et al*., 2011).

Conclusions and Recommendations

Study concludes that the integrated use of 10% wastewater with 2/3rd of inorganic fertilizers gave more sugar recovery (12.3%) and sugar yield (12.70 t ha^{-1}). Application of 10% wastewater supplemented Urea (N) and DAP (P) fertilizers by 33% and SoP (K) by 100%. Hence, input cost against the fertilizers reduced by 62.82%. This treatment combination improved soil organic matter by 53%, Kjeldahl's by 50%, AB-DTPA P and N by 119% and 243%. It may be the partial substitution of costly inorganic fertilizers, potassium (K) in particular. It was therefore concluded that the application of sugar industry wastewater at 10% along with 2/3rd dose of nitrogen and phosphorus was recommended for sugarcane.

Acknowledgment

The authors are grateful to management of Matiari Sugar Mills for their support in providing wastewater (distillery) and related material to conduct experiment on their field.

Novelty Statement

Sugarcane based wastewater, rich in nutrients can be better utilized to fertilize the crop itself, rather than polluting the environment.

Author's Contribution

Ghulam Muhiyuddin Kaloi: Conducted physical experiments, collected data, laboratory analysis, statistical analysis and prepared manuscript.
Mehrunisa Memon: Conceived the idea of this research, developed methodology, lab testing of wastewater, reviewed the manuscript, gave technical input thought.

Conflict of interest

The authors whose names are listed certify that they have no any "conflict of interest" in the subject matter or materials discussed in this manuscript.

References

Adhikary, S.P. 2014. Soil amendment with sugar industry effluent and its response on growth parameters of tomato plant (*Lycopersicon esculentum*). Int. J. Curr. Microbiol. App. Sci. 3(6): 555-563.

Ali, N., S. Ayub and J. Ahmad. 2015. A study on economic treatment of distillery effluent. Int. J. Cur. Res. Rev. 7(11): 8-12.

Analytical Software. 2005. Statistix 8.1 User's manual. Tallahassee, (FL): Analytical Software.

APHA, AWWA and WEF. 1998. Standard Methods for Examination of Water and Wastewater 20th ed), Washington, American Public Health Association.

Armengol, J.E., R. Lorenzo and N. Fernandez. 2003. Use of vinasse dilutions in water as an alternative for improving chemical properties of sugarcane planted vertisols. Cultivors Tropicales. 24(3): 73-76.

Ashutosh, S. 2014. Effect of spentwash and chemical fertilizer on yield and nutrient uptake by sugarcane. Ann. Plant Soil Res. 16(1): 32-34.

Bohn, H.L., B.L. McNeal and G.A. O'Connor. 1985. Soil Chemistry, 2nd Ed. John Wiley and Sons, New York.

California Fertilizer Association. 1980. Western Fertilizer Hand Book. 6th (Ed.), Interstate Printers and Publishers. Danville. ILL, USA.

Chopra, A.K., S. Srivastava, V. Kumar and C. Pathak. 2013. Agro-potentiality of distillery effluent on soil and agronomical characteristics of *Abelmoschus esculentus* L. (Okra). Environ. Monit. Assess. 185: 6635-6644. https://doi.org/10.1007/s10661-012-3052-8

Chen, J.C.P. and C.C. Chou. 1993. Cane Sugar Handbook. A Manual of Cane Sugar Manufactures and their Chemists. 12th edition. New Yark. John Wiley & Sons.Inc.

Chopra and Kanwar. 1982. Analytical Agricultural Chemistry, Kalyani Publishers, New Delhi.

CTPSS. 2009. Cleaner technology project for sugar sector. URL: www.pisd-pak.org and www.cpi.org.pk

Faqir, H. M.A. Sarwar, S. Ahmad, M.A. Ali, N. Fiaz and A.A. Chattha. 2011. Effect of stale and fresh cane setts (seed) on yield and quality of sugarcane (*Saccharum officinarum* L.). Int. J. Agric. Appl. Sci. 3(1): 35-37.

Foth, H.D. 1984. Fundamentals of Soil Sience. 7th Ed. New York: John Wiley and Sons.

Irrigation Slide Chart. 1999. The University of Arizona, Cooperative Extension, Pub. az1135, Arizona water series: Number 21. (English/Spanish).

Jackson, M.L. 1985. Nitrogen determination for soils and plant tissue. Soil chemical analysis. Constable & Co. Ltd. London, UK. p. 183-204.

Jain, R. and S. Srivastava. 2012. Nutrient composition of spentwash and its impact on sugarcane growth and biochemical attributes. Physio. Mol. Biol. Plants. 18(1): 95-99. https://doi.org/10.1007/s12298-011-0087-1

Kaloi, G.M, M. Memon, S. Ahmad, S.A. Sheikh and G.M. Jamro. 2017. Effect of sugar industry spentwash (diluted) on the characteristics of soil and sugarcane (*Saccharum officinarum* L.) growth in the subtropical environment of Sindh, Pakistan. Environ. Monit. Assess. 189(3): 127. https://doi.org/10.1007/s10661-017-5861-2

Kamble, S.M., M. Hebbara, M.V. Manjunatha, G.S. Dasog and G.M. Veerendra Patel. 2016. Long-term effect of bio-methanated spentwash irrigation on soil organic carbon and nutrient status in a vertisol. Res. Environ. Life Sci. 9(1): 35-38.

Kumar, V. and A.K. Chopra. 2013. Enrichment and translocation of heavy metals in soil and plant of Vicia faba L. (Faba bean) after fertigation with distillery effluent. Int. J. Agri. Poli. Res. 1(5): 131-141.

Lingle, S.E., R.M. Johnson, T.L. Tew and R.P. Viator. 2010. Changes in juice quality and sugarcane yield with recurrent selection for sucrose. Field Crops Res. 118: 152-157. https://doi.org/10.1016/j.fcr.2010.05.002

Mahendra, A.C., B.I. Bidari, H.R. Umesh, H. Yogeeshappa, M.N. Kumari, H.P. Ravikumar and A. Kumar. 2010. Efficacy of spentwash for reclamation of sodic soils. Int. J. appl. Environ. Sci. 5: 3-6.

Matibiri. 1996. The effects of stillage (vinasse) on nine ratoon crops of NCO-376 receiving full irrigation in the south-east lowveld of Zimbabwe. Proc. S. Afr. Sug. Technol. Ass. 70, 63-66.

Meade, G.P. and J.C.P. Chen. 1977. Cane sugar hand book, 10th Edition, John Wiley & Sons. Inc. New York, USA. 947 p.

Nawi, N.M., G. Chen and T. Jensen. 2014. Prediction of sugarcane quality from juice samples using portable Spectroscope. J. Mech. Eng. Sci. 7: 1219-1226. https://doi.org/10.15282/jmes.7.2014.21.0119

NFDC. 2019. Fertilizer Review Report (2018-19). NFDC Publication No. 1/2019. Government of Pakistan, Ministry of National Food Security and Research, NFDC, Islamabad.

Patil, A.B. and A.D. Patil. 2013. Red soil quality improved by using the spentwash. Online Inter. Interdisciplinary Res. J. 3(4): 278-281.

PSMA. 2019. Pakistan Sugar Mills Association, Annual Report. p. 18.

Pujar, S.S. 1995. Effect of distillery effluent irrigation on growth, yield and quality of crops. M.Sc. (Agri.) Thesis (unpublished), Univ. Agric. Sci. Dharwad.

Ramana, S., A.K. Biswas, S. Kundu, J.K. Saha and R.B.R. Yadava. 2001. Effect of distillery effluent on seed germination in some vegetable crops. Bio-resource Technol., 82(3): 273-275.

Rath, P., G. Pradhan and M.K. Misra. 2010. Effect of sugar factory distillery spentwash (DSW) on the growth pattern of sugar cane (*Saccharum officinarum* L.) crops. J. Phyto. 2 (5): 33-39.

Rath, P., G. Pradhan and M.K. Misra. 2011. Effect of distillery spentwash (DSW) and fertilizer on growth and chlorophyll content of sugarcane (*Saccharum officinarum* L.) plant. Rec. Res. Sci. Tech. 3:169-176.

Rathore, N.P., K.S. Pawar and S.A. Iqbal. 2000. Effect of sugar industry effluents on productivity and nutrient uptake by various Soybean crops. Orie. J. Chem. 16(12): 323-326.

Richard, L.A. 1954. Diagnosis and improvement of saline and alkali soils. United States Department of Agriculture, Washington DC.

Ryan, J., Estefan, G. and Rashid, A. 2001. Soil and Plant Analysis Laboratory Manual. International Center for Agricultural Research in the Dry Areas (ICARDA). Islamabad, Pakistan. 172 p.

Sadiq. N., A. Rehim, M. Imran, M.F. Anwar and S. Hussain. 2018. Effect of distillery spentwash fertigation on crop growth, yield, and accumulation of potentially toxic elements in rice. Environ. Sci. Pollut. Res.

Saini, S. and S. Pant. 2014. Physico-chemical analysis of Sugar mill Effluent and their Impact on changes of growth of wheat (*Triticum aestivum*) and maize (*Zea mays* L.). J. Environ. Sci. Toxicol. Food Technol. 8(4): 57-61. https://doi.org/10.9790/2402-08415761

Selvamurugan, M., V.R. Ramkumar, P. Doraisamy and M. Maheswari. 2013. Effect of biomethanated distillery spentwash and biocompost application on soil quality and crop productivity. Asian J. Sci. Tech. 4(10): 124-129.

Shenbagavalli, S., S. Mahimairaja and P. Kalaiselvi. 2011. Impact of biomethanated distillery spentwash application on soil and water quality: A field appraisal. Int. J. Environ. Sci. 1(7): 1753-1759.

Sivaloganathan, P., B. Murugaiyan, S. Appavou and L. Dharmaraj. 2013. Effect of dilution of treated distillery effluent (TDE) on soil properties and yield of sugarcane. Am. J. Plant Sci. 4: 1811-1814. https://doi.org/10.4236/ajps.2013.49222

Soltanpour, N. 1985. Use of NH_4HCO_3-DTPA soil test to evaluate elemental availability and toxicity. Communication in Soil Science and Plant Analysis. 16: 323-338. https://doi.org/10.1080/00103628509367607

Soil Survey Division Staff. 1993. Soil Survey Manual. USDA Handbook No. 18, US Government Printing Office, Washington DC.

Tahir, H. and A. Jabbar. 1985. Soil and Plant Analysis Manual-3. 32-35 p. & 43-45 p.

USSL. 1954. Diagnosis and improvement of saline and alkali soils. Handbook, 60. USDA.147 p.

Valliapan, K. 2001. Use of poor quality water and sugar industrial effluents in agriculture. In: Proceeding, National Seminar. February 5th, AC and RI, Trichy, India. 73 p.

Yadava, R.L. 1993. Agronomy of Sugarcane. Principles and Practices. 1st Edition. International Book Distributing Company. Charbagh Lucknow. 305 p.