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Influence of long-term irrigation with bio-methanated spentwash on physical and biological properties in a vertisol

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Abstract: A field experiment was conducted at the Ugar Sugar Factory premises, Ugar-Khurd, Belgaum district to study the effect of long-term spentwash irrigation on physical and biological properties in a Vertisol under Northern Dry Zone (Zone-III) of Karnataka. The long-term spentwash irrigation for >20 years reduced bulk density (1.43 to 1.22 Mg m^{-3}), dispersion index (8.09 to 7.84) and erosion index (4.15 to 3.93) of the surface soil. The other physical properties like maximum water holding capacity (74.46 %), per cent water stable aggregates (66.16) and infiltration rate (0.79 cm hr^{-1}) was higher in the treatment where spentwash was applied for >20 years. Application of spentwash increased the population of bacteria, actinomycetes and fungi in the soil over control. The highest bacterial population (10.21 cfu $x10^6$) was noticed in treatment that received spentwash for 5 to 10 years of surface soil. The highest fungi population (14.56 cfu $x10^4$) was recorded in the treatment that was irrigated with spentwash for > 20 years. In general, bacteria, fungi and actinomycetes population decreased with depth in all the treatments.

Key wards: Bio-methanated spentwash, Long-term effect, Vertisol, Physical and Chemical properties

Introduction

India is a major producer of sugar and its by-products. It is one of the significant exporters of sugar in the world and contributes substantially to economic development. Molasses is an important by-product from the sugar industries which is formed after the crystallization of sugar. Molasses is a chief source for the production of alcohol in the distilleries by fermentation method. In recent report, the US Department of Agriculture (USDA) has pegged India's ethanol production at 2,170 million tonnes for 2012 (Anon., 2012). Sugarcane based industries are increasing exponentially and many factories adjunct with distillery in order to balance the price of sugar in open market besides enhancing energy security to the country. Wastewater reclamation and reuse is one of the best alternatives for compensating water shortages. In arid and semi-arid regions, waste water reclamation and reuse has become an important element in water resources planning. Application of industrial wastes as fertilizer and soil amendment has become popular in agriculture. Irrigation water quality is believed to have effects on the soil and agricultural crops. As the effluent is mainly a plant extract, rich in organic matter and plant nutrients like potassium, nitrogen, sulphur and calcium, there is a scope for using it advantageously as a source for ferti-irrigation to agricultural crops without any adverse effect on soil fertility and productivity. Raw spentwash has a low pH (3.0-5.4), high EC (5-23.7 dS m^{-1}), high BOD (32,800- 43,200 mg L^{-1}) and high COD (76,000- 1,08,000 mg L^{-1}) (Hati, *et. al.,* 2007) and is not suitable for irrigation directly. The BOD and COD were reduced through the bio-methanation process and then used for irrigation with dilution. This study considered the plots irrigated continuously with bio-methanated spentwash and the effect of such practice on on physical and biological properties in a Vertisol.

Material and Methods

The bio-methanated spentwash (dilution 1:10) was used as irrigation source to sugarcane @ 100 m^3 ha^{-1} $year^{-1}$. The physico-chemical characteristics of the bio-methanated spentwash is given the table-1. The soil of the experimental site was calcareous medium deep Vertisol. The soil was alkaline in nature with pH ranging from 7.84 to 8.11. The experiment was laid-out in 2-factor RCBD. The treatments included bio-methanated spentwash irrigation for varied periods of time (factor-1); P_0: Control, P_1: 5-10 years, P_2: 10-15 years, P_3 :15-20 years and P_4: >20 years at different soil depths (factor-2) ; D_1: 0-20 cm, D_2: 20-40 cm, D_3: 40-60 cm, D_4: 60-80 cm and D_5: > 80 cm. Soil samples were collected from these long-term spentwash irrigated fields for varied periods of time and from different depths to study the effect of such practice on soil organic carbon and nutrient status of soil. Standard procedures were followed for the estimation of bulk density (Black (1965), maximum water holding capacity (Piper, 2002), water stable aggregates (Yoder, 1936), infiltration rate (Marshall and Stirk, 1950), dispersion index (Piper, 2002) and erosion index (Sahi *et al.*,1977). The population of bacteria, fungi and actinomycetes was assessed by serial dilution and plate count method as described by Bunt and Rovira (1955), Martin (1950) and Kuster and Williams (1964), respectively.

Results and Discussion

Soil physical properties: The data obtained after analyzing the surface soil samples (0-20 cm) for physical properties like bulk density, maximum water holding capacity, water stable aggregates, dispersion index, erosion index and infiltration rate are presented in Table 2. The long-term spentwash application significantly reduced bulk density of the surface soil. Maximum bulk density was observed in control (1.48 Mg m^{-3}). With increased periods of spentwash irrigation, the bulk density significantly decreased. The lowest BD (1.23 Mg m^{-3}) was observed in the plot irrigated with bio-methanated spentwash for >20 years. The reduction in bulk density was due to addition of high organic matter through spentwash. Such reduction in bulk density due to spentwash addition was also reported by Rubina (2013) and Kumar and Chopra (2011) where lower bulk density was observed in spentwash irrigated treatment compared to control. Bose *et al.* (2002) also reported reduced bulk density and increased water holding capacity of a sandy soil due to spentwash application. The maximum water holding capacity was higher in the treatment where spentwash was applied for >20 years (74.46 %). The lowest water holding capacity was recorded in the control (67.84 %) which did not receive spentwash. Per cent water stable aggregates (> 0.25 mm size) were improved significantly by the long-term spentwash application. The data indicated that the treatment that received spentwash for 15-20 years recorded the highest per cent stable aggregates (67.10 %). The per cent stable aggregates were minimum in control treatment (55.13 %). The control treatment recorded the lower infiltration rate (0.61 cm hr^{-1}) which increased due to spentwash application. The higher infiltration rate (0.81 cm hr^{-1}) was noticed due to continuous spentwash irrigation for 15-20 years.

The higher per cent water stable aggregates, maximum water holding capacity and infiltration rate were observed in the treatment that received spentwash for 15 to 20 years. However, long-term spentwash application for >20 years lead to slight reduction in these parameters which might be due to clogging of pores with high particulate organic carbon. The application of spentwash for limited periods increased aggregate stability which might be due to the salts present in the spentwash. The fresh application of effluent might also had stimulated the microbial activity and secretion of microbial polysaccharides, which helped in stabilization of soil aggregates. Higher concentration of Ca in soil solution and on exchange sites in spentwash applied plots might have improved aggregation and its strength. Increase in infiltration rate in spentwash treated plots was ascribed to higher organic matter content and changed distribution of pore sizes of the soil. An increase in maximum water holding capacity can be attributed to increased number of small pores caused by better and fine grade aggregation. Water holding capacity was related to the number and size distribution of soil pores and consequently increased with soil organic matter level. This was in agreement with the findings of Biswas *et al.* (2007) and Kumar and Chopra (2011). Hati *et al*. (2007) reported that the mean weight diameter, saturated hydraulic conductivity, water retention capacity and available water content were significantly higher, while bulk density and penetration resistance of the surface soil were significantly lower in all distillery effluent treated plots.

The data on dispersion index indicated lower values in spentwash irrigated plots compared to control (8.09) which did not receive spentwash (control). The lowest dispersion index of 7.78 was noticed due to 15-20 years spentwash irrigation. Similarly, the control treatment recorded the highest erosion index (4.15) as compared to spentwash irrigated treatments. The lowest erosion index (3.87) was noticed with15-20 years of spentwash irrigation.

Table-1: Characteristics of distillery bio-methanated spentwash

Parameter	Value
Colour	Light brown
Odour	Tolerable
pH	7.37
Electrical conductivity (dS m^{-1})	17.32
Biological oxygen demand (mg L^{-1})	7,200
Chemical oxygen demand (mg L^{-1})	18,032
Bicarbonates (mg L^{-1})	3.9
Carbonates (mg L^{-1})	Trace
Chlorides (mg L^{-1})	3266
Sodium (mg L^{-1})	234
Potassium (mg L^{-1})	6213.12
Calcium (mg L^{-1})	521
Magnesium(mg L^{-1})	233
Total nitrogen (mg L^{-1})	748
Total phosphates (mg L^{-1})	112.35
Zinc (mg L^{-1})	8.34
Iron (mg L^{-1})	21.25
Manganese (mg L^{-1})	4.35
Copper(mg L^{-1})	6.55

(Source: Personal communication, Ugar Sugar Factory, Belgaum, Karnataka)

Table-2: Effect of different periods of spentwash application on soil physical properties

Treatment	Bulk density (mg m^{-3})	MWHC (%)	% water stable aggregates (> 0.25 mm)	Infiltration rate (cm hr^{-1})	Dispersion index	Erosion index
P_0 (control)	1.43	67.48	55.13	0.62	8.09	4.15
P_1	1.42	70.84	58.36	0.67	8.03	3.95
P_2	1.33	71.98	62.47	0.76	7.89	3.89
P_3	1.25	73.34	67.10	0.81	7.78	3.87
P_5	1.22	74.46	66.16	0.79	7.84	3.93
S.Em.±	0.02	0.44	0.92	-	0.22	0.08
CD(P=0.05)	0.073	1.32	2.75	-	0.67	0.25

P_0- Control. P_1, P_2 and P_3- correspond to periods of spentwash application; P_1-5 to 10 years, P_2-10 to 15 years and P_3- 15 to 20 years

Soil biological properties: Application of spentwash significantly increased the population of bacteria (Table 3) in the soil over control. However, bacterial population significantly reduced in plots irrigated with spentwash for > 20 years. The highest bacterial population (10.21 cfu x10^6) was noticed due to spentwash irrigation for 5 to 10 years and the lowest was found in control (7.36 cfu x10^6) treatment. In general, bacterial population decreased with depth in all the treatments. Among different depths, the surface soil (0-20 cm) recorded the higher population of bacteria (13.47 cfu x10^6) and lower population of bacteria was noticed in > 80 cm depth (6.23 cfu x10^6). The highest fungi population (14.56 cfu x10^4) was recorded in the treatment that was irrigated with spentwash for > 20 years and the lowest (8.55 cfu x10^4) in control. In general, the fungi population decreased with soil depth. The surface soil (0-20 cm) recorded the higher population of fungi (23.10 cfu x10^4) and lower population was noticed in > 80 cm depth (6.41 cfu x10^4).

Long-term spentwash irrigation for 10 to 15 years recorded higher actinomycetes population (18.88 cfu x10^3) while, the lowest in control (13.28 cfu x10^3). In general, the population of actinomycetes

Table-3: Effect of different periods of spentwash application on total bacteria and fungi

Soil depth (cm)	Total bacteria (cfu x10^6)						Total fungi (cfu x10^4)					
	Control (P_0)	Periods of spentwash application (years) 5-10 (P_1)	10-15 (P_2)	15-20 (P_3)	>20 (P_4)	Mean	Control (P_0)	Periods of spentwash application (years) 5-10 (P_1)	10-15 (P_2)	15-20 (P_3)	>20 (P_4)	Mean
0-20 (D_1)	10.31	15.43	15.34	14.24	12.03	13.47	15.67	24.19	26.38	25.96	23.28	23.10
20-40 (D_2)	8.29	12.99	12.73	12.15	9.78	11.19	9.31	15.90	15.89	17.07	18.11	15.26
40-60 (D_3)	6.86	8.64	8.90	9.57	8.56	8.50	7.52	10.76	11.76	12.43	13.04	11.10
60-80 (D_4)	6.32	7.45	6.97	7.58	7.13	7.09	5.78	7.68	7.60	8.30	10.09	7.89
>80 (D_5)	5.02	6.55	6.44	6.76	6.37	6.23	4.45	5.79	6.42	7.10	8.29	6.41
Mean	7.36	10.21	10.08	10.06	8.77		8.55	12.86	13.61	14.17	14.56	
	S.Em.±			CD (P=0.05)			S.Em.±			CD (P=0.05)		
P	0.12			0.35			0.21			0.58		
D	0.12			0.35			0.21			0.58		
PXD	0.28			0.78			0.46			1.30		

P_0: Control. P_1, P_2, P_3 and P_4- correspond to periods of spentwash application; P_1:5 to 10 years, P_2:10 to 15 years, P_3: 15 to 20 years and P_4:>20years D_1, D_2, D_3, D_4 and D_5- correspond to soil depth; D_1: 0-20 cm, D_2: 20-40 cm, D_3: 40-60 cm, D_4: 60-80 cm and D_5: >80 cm.

Table-4: Effect of different periods of spentwash application on total actinomycetes (cfu x10^3)

Soil depth (cm)	Control (P_0)	Periods of spentwash application (years) 5-10 (P_1)	10-15 (P_2)	15-20 (P_3)	>20 (P_4)	Mean
0-20 (D_1)	22.60	32.00	31.40	31.20	29.00	29.24
20-40 (D_2)	17.80	21.00	24.60	22.60	18.40	20.88
40-60 (D_3)	11.60	16.40	15.80	16.40	16.00	15.24
60-80 (D_4)	8.00	10.00	12.60	12.40	13.40	11.28
>80 (D_5)	6.40	7.60	10.00	10.40	11.40	9.16
Mean	13.28	17.40	18.88	18.60	17.64	
	S.Em.±			CD (P=0.05)		
P	0.22			0.62		
D	0.22			0.62		
PXD	0.49			1.38		

P_0: Control; P_1, P_2, P_3 and P_4-correspond to periods of spentwash application; P_1:5 to 10 years; P_2:10 to 15 years; P_3: 15 to 20 years; P_4: >20years; D_1, D_2, D_3, D_4 and D_5-correspond to soil depth; D_1: 0-20 cm; D_2: 20-40 cm; D_3: 40-60 cm; D_4: 60-80 cm and D_5: >80 cm

decreased with depth. The surface soil (0-20 cm) recorded the higher population of actinomycetes (29.24 cfu x10^3) and lower population was noticed in >80 cm depth (9.16 cfu x10^3). The population of bacteria, fungi and actinomycetes was higher in the spentwash irrigated fields compared to control. This is attributed to higher organic load present in the spentwash, which might serve as source of energy for the growth and multiplication of microorganisms and also for various enzyme activities in soil. Batch *et al.* (1993) observed that the spentwash application (@ 250 m^3 ha^{-1}) stimulated the soil microorganisms and increased the dehydrogenase activity of the soil. The marginal reduction in the population of bacteria, fungi and actinomycetes in plots irrigated with spentwash for > 20 years could be attributed to the buildup of salinity and chloride. The results were in agreement with results reported by Altman and Lawlor (2008).

The long-term irrigation with bio-methanated spentwash progressively reduced bulk density, dispersion index and erosion index. The lower bulk density, dispersion index and erosion index was observed in the treatment that received spentwash for > 20 years. The higher value of per cent water stable aggregates, maximum water holding capacity and infiltration rate were observed in the treatment that received spentwash for 15 to 20 years. However, long-term spentwash application for >20 years lead to slight reduction in these parameters. The population of bacteria, fungi and actinomycetes was higher in the spentwash irrigated fields compared to control.

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