Assessing the changes in soil properties and possible ground water pollution with application of primary treated distillery spentwash

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ABSTRACT

To assess the ground water pollution with varied amounts of primary treated distillery spentwash (DSW) application, locally prepared piezometer were installed in the field at various depths (0.5, 1.0 and 1.5 m) and the collected leachate was characterized. Leachate was collected in piezometers upto 0.5 m depth with lower levels of DSW application (<750 m ha⁻¹) and upto 1.0 m depth with >750 m ha⁻¹ after 30 days of DSW application and indicated that increasing quantities of DSW application increased the pH, EC, COD, NO₃⁻, HCO₃⁻, Cl⁻, Ca²⁺, Mg²⁺ and Na⁺ contents in leachate. Leachate collected in piezometers after 60 days of DSW application showed increased leaching of NO₃⁻, HCO₃⁻, Cl⁻ and Na⁺ with increasing depth, while leaching of Ca²⁺and Mg²⁺ decreased with depth. Chemical oxygen demand of percolating water decreased with increasing depth of soil column. However, application of DSW @ 1500 m ha⁻¹ increased all the parameters in leachate indicating its possible contamination over the period to underground water. Further, the effect of percolating DSW on soil was studied by opening the soil vertical profile upto 120 cm depth. The soil reaction and soluble salt content increased with soil depth upto 90 cm and with increased rate of DSW application. Organic carbon, Available primary nutrients viz., N, P, O₃-, K, O, Exchangeable Ca, Mg and Na and DTPA micronutrient content (Fe, Zn, Mn and Cu) increased in surface soil (upto 30 cm) with increased rate of DSW application and while sub surface soil (60-120 cm) content showed insignificant variation. organic carbon in soil surface increased with increasing quantity of DSW application. The spentwash application at the rate below 750 m ha⁻¹ increased soil nutrient content with lower percolating leachate indicating its beneficial use for agriculture purpose. However, the application rate of 1500 m ha⁻¹ may cause detrimental effect on surface soil electrochemical properties and percolating leachate may cause contamination of underground water under higher water table condition.

Key words: COD, Leachate, Organic carbon, Peizometer, Soil profile.

INTRODUCTION

Environmental pollution is one of the undesirable side effects of industrialization but inevitable as it provides materials for basic necessities of life to over growing population. However, if our environment is degraded in this process, the quality of life suffers. Waste generation is associated with most of the industrial sectors during manufacturing of their stream of products. The wastes may be solid, liquid or gaseous in nature. The pollution caused by the wastes may have adverse impact on air, water, land, flora, fauna and socioeconomic environment.

Majority of the industries in India are agro-based and utilize large volume of good water and generate effluent. The unscientific disposal of this wastewater in to soil and water bodies may create serious problems of pollution. Distillery is one such industry, which uses molasses, a byproduct from sugar industry as a raw material and generates large quantities of liquid waste in the form of spentwash (Anil kumar et al., 2003). The molasses based distilleries produce alcohol by fermentation and distillation process. With the increasing demand for alcohol due to its export potential, potable uses, as readily available energy source and as a raw material for the rapidly advancing chemical industry, the number of distilleries in India has increased drastically especially during the last decade. However, the pollution control boards and environmentalists assessed these distilleries as highly polluting units mainly due to generation of foul smelling, dark colored wastewater known as spentwash (Chowdhary et al., 2017).

Spentwash is generated when molasses is subjected to fermentation process to get rectified sprit or ethanol. This process generates 12-15 L of spentwash per liter of ethanol and 220-230 L of ethanol (95 %) per tonne of molasses (Asha and Dutta,1983). The spentwash so obtained is also known as stillage, slops, vinasse, potale or dunder (Sarayu et al., 2009). Presently there are 285 distilleries in India. Most of these distilleries are concentrated in the states of Maharashtra, Uttarpardesh, Tamilnadu and Karnataka. According to recent estimates the alcohol production in India has reached 2.7 billion litre mark. The raw spentwash so generated will be highly acidic (pH- 3.98 to 4.15) in nature and possess huge salt (14.14-14.69 dS m⁻¹) and organic load...
Preparation of piezometers: The PVC pipes of 90, 140 and 190 cm length and 4.5 inch diameter were taken for the preparation of piezometers. The 90 cm PVC pipes were used to collect the percolating water from 0-0.5 m depth soil. The bottom and top 20 cm of PVC pipe was left undrilled for collection of leachate and to leave above the ground level. For the middle part of the pipe (50 cm), perforations measuring 6 mm diameter was made using driller all around the pipe. Similarly to collect the percolating water from 0.5-1.0 m and 1.0-1.5 m depth of soil, 140 and 190 cm pipes were used respectively. The perforations were made up to 0.5 m from the bottom leaving 20 cm for collecting leachate. The holes were covered using muslin cloth and 2 mm mesh to avoid the entry of soil particles into piezometer. Both the ends were covered using end caps (Plate 1).

Installation of piezometer: Seven plots measuring 5 m X 5 m were prepared and a buffer plot was maintained between each plot to avoid the lateral movement of spentwash. In each plot, holes were made to a depth of 0.7, 1.2 and 1.7 meter using six inch bore well driller. Respective piezometers were placed in drilled holes and compacted tightly with soil. An outer ring was made around piezometer using concrete to avoid direct seepage of spentwash into piezometer through loose soil surrounding it.

Treatment details: The different quantity of spentwash was applied to each plot as described below,

- \( T_1 \): Spentwash applied @ 50 m³ ha⁻¹
- \( T_2 \): Spentwash applied @ 100 m³ ha⁻¹
- \( T_3 \): Spentwash applied @ 250 m³ ha⁻¹
- \( T_4 \): Spentwash applied @ 500 m³ ha⁻¹
- \( T_5 \): Spentwash applied @ 750 m³ ha⁻¹
- \( T_6 \): Spentwash applied @ 1000 m³ ha⁻¹
- \( T_7 \): Spentwash applied @ 1500 m³ ha⁻¹

The varied quantity of spentwash was decided based on the recommendation for one time spentwash application to various agriculture crops (upto forty per cent of crop nitrogen requirement) by University of Agricultural Sciences, Bangalore.

Collection of leachate: Leachate collected in the piezometer after 30 and 60 days of effluent application was extracted by “draw and well” method using rubber tube by sucking and the leachates were analyzed for pH, EC, COD, Ca²⁺, Mg²⁺, Na⁺, HCO₃⁻ and Cl⁻ by using standard procedures as given in the Table 1. After 30 days, fresh water was applied uniformly to all the plots @ 250 m³ ha⁻¹ at weekly interval.

Collection of soil profile samples: One profile was dug in each plot applied with different quantities of spentwash and from the plot where no spentwash was applied (Piezometers were not installed) after two months of application. The representative soil samples were collected at 0-15, 15-30, 30-60, 60-90 and 90-120 cm depth from each profile. The samples were processed and analyzed for pH, EC, OC, major, secondary and micronutrients using standard procedures as described in Table 1. The initial properties of soil (Table 2) indicated the soil was loamy sand in texture with neutral pH and low availability of organic carbon, nitrogen and phosphorus.

Results and Discussion: Effect of different quantities of spentwash application on chemical composition of leachate: The data on leachate collected from the peizometer after 30 days of DSW application indicate collection of only upto 0.5 m depth with 50-750 m³ ha⁻¹ DSW application while, 1000 and 1500 m³ ha⁻¹ DSW application resulted in collection of leachate upto 1.0 m depth. However, the leachate could not be collected at 1.5 m with any quantities of DSW application (Table 3). Spentwash contains 90 to 93 per cent water and 7 to 9 per
Table 1: Methods followed for estimation of leachate and soil properties.

| Parameters                          | Methods                                                                 | References                   |
|-------------------------------------|-------------------------------------------------------------------------|------------------------------|
| pH                                  | Potentiometric method                                                  | Jackson, 1973                |
| EC (dS m⁻¹)                         | Conductometric method                                                  | Jackson, 1973                |
| Total, dissolved and suspended solids (%) | Gravimetric method                                         | Manivasakam, 1987            |
| COD (mg L⁻¹)                        | Potassium dichromate method                                            | APHA, 1975                   |
| BOD (mg L⁻¹)                        | Iodimetric method                                                      | APHA, 1975                   |
| Carbonates (meq L⁻¹)                | Titration method using standard sulfuric acid and phenolphthalein indicator | Manivasakam, 1987            |
| Bicarbonates (meq L⁻¹)              | Titration method using methyl orange indicator                          | Manivasakam, 1987            |
| Total phosphorus (%)                | Chloromolybdic acid blue colour method                                  | Manivasakam, 1987            |
| Total potassium (%)                 | Flame photometry                                                       | Manivasakam, 1987            |
| Sodium (mg L⁻¹)                     | Flame photometry                                                       | Manivasakam, 1987            |
| Chlorides (mg L⁻¹)                  | Winkler’s method using potassium chromate as indicator                  | Manivasakam, 1987            |
| OC (%)                              | Wet oxidation method                                                   | Walkey and Black, 1934       |
| Avail. N (kg ha⁻¹)                  | Alkaline potassium permanganan method                                  | Subbiah and Asija, 1956      |
| Avail. P₂O₅ (kg ha⁻¹)               | Olsen’s extractant method, Colorimetry                                 | Jackson, 1973                |
| Avail. K₂O (kg ha⁻¹)                | NH₄OAC extractant method, Flame photometry                            | Jackson, 1973                |
| Exch. Ca [cmol (p⁻¹) kg⁻¹]          | Versenate titration method                                              | Jackson, 1973                |
| Exch. Mg [cmol (p⁻¹) kg⁻¹]          | Versenate titration method                                              | Jackson, 1973                |
| Exch. Na [cmol (p⁻¹) kg⁻¹]          | NH₄OAC extractant method, Flame photometry                            | Jackson, 1973                |
| Avail. S (kg ha⁻¹)                  | CaCl₂ extractant method, Turbidimetry                                  | Black, 1965                  |
| Fe, Mn, Zn and Cu (mg kg⁻¹)         | Atomic absorption spectrophotometry                                    | Lindsay and Norvell, 1978    |
cent solids. Therefore, increased rate of application might have increased the wetting front of soil and higher quantity of spentwash application might have percolated to higher depths in soil (Malathi, 2002). The soil texture being loamy sand make the spentwash to leach to deeper depths due to presence of macro pores in surface soil. However, the soil Typic Rhodustalf that contain Argillic horizon in subsurface soil (essential in B horizon) that restrict the percolation of leachate (Spentwash/ water) to deeper layers of soil (Thangaswamy et al., 2005). Further, increasing quantities of DSW application increased the pH, EC, COD, NO$_3^-$, HCO$_3^-$, Cl$^-$, Ca$^{2+}$, Mg$^{2+}$and Na$^+$, in leachate samples. Similar observations were made by Devarajan and Obilasi (1995) and Malathi (2002).

After 60 days, successive application of fresh water at 250 m$^3$ ha$^{-1}$ at weekly interval resulted in collection of leachate upto 1.0 m depth in treatments receiving 50 to 250 m$^3$ ha$^{-1}$ of DSW while, with higher quantities of DSW application could collect the leachate upto 1.5 m (Table 4). This might be due to improved physical properties of soil with DSW application, which enhanced the percolation of water through soil. Racchapl Singh et al., (1980), Mbagwu and Ekwealor (1990), Hati et al., (2005) noticed improved physical properties of soil viz., pore space, water holding capacity, aggregate stability, hydraulic conductivity, penetration resistance with the progressive levels of DSW application.

In general, pH and EC of the percolating water collected at lower depths was increased which might be due to leaching of salts, which increased the pH of leachate. Among the anions, NO$_3^-$ was leached in higher quantities than Cl$^-$ and HCO$_3^-$; In general, anions concentration increased with greater quantity of DSW application and with increase in depths. Among cations Na$^+$ leached was more compared to Ca$^{2+}$ and Mg$^{2+}$ as it is monovalent, retention on exchangeable site is less compared to Ca$^{2+}$ and Mg$^{2+}$ which are being divalent, get strongly adsorbed on clay surface. COD of leachate with increasing depths of soil. Thus, soil acted as filtrate in reducing the COD by rapidly oxidizing the organic carbon present in soil. However, the increasing quantity of DSW application resulted in higher COD in leachate even after 60 days of application. Similar results of increased BOD and salt content in ground water near lagoon sites in most of the distilleries were noticed by Joshi et al., (1994). Husain et al., (2003), Anilkumar et al., (2003) and Malathi (2002) noticed the leaching of anions and cations from soil profile with application of spentwash.

**Effect of different quantities of spentwash application on electro-chemical properties of soil profile:** Soil reaction markedly increased with application of DSW. Increasing the quantity (> 500 m$^3$ ha$^{-1}$) of DSW brought substantial change in soil reaction upto 60 cm depth (Table 5). Increased pH is attributed to accumulation of higher amount of soluble salts. Enhanced accumulation of Ca and Mg on exchangeable site might be due to high application of HCO$_3^-$ through spentwash. Similar findings of increased pH due to DSW application were observed by Machaado-de-Armans et al., (1994). They reported that pH values were strongly

| Parameter                  | Value |
|----------------------------|-------|
| Taxonomic name             | Typic Rhodustalf |
| Coarse sand (%)            | 53.3  |
| Fine sand (%)              | 26.2  |
| Silt (%)                   | 8.2   |
| Clay (%)                   | 12.3  |
| Textural Class             | Loamy sand |
| CEC [c mol (p+) kg$^{-1}$] | 7.4   |
| pH (1:2.5)                 | 7.52  |
| EC (dS m$^{-1}$)           | 0.59  |
| OC (%)                     | 0.38  |
| Available N (kg ha$^{-1}$) | 166.8 |
| Available P$_2$O$_5$ (kg ha$^{-1}$) | 19.54 |
| Available K$_2$O (kg ha$^{-1}$) | 226.5 |
| Exchangeable Ca [c mol (p+) kg$^{-1}$] | 4.43 |
| Exchangeable Mg [c mol (p+) kg$^{-1}$] | 2.87 |
| Exchangeable Na [c mol (p+) kg$^{-1}$] | 0.38 |
| Available S (kg ha$^{-1}$) | 14.5  |
| DTPA-Fe (mg kg$^{-1}$)     | 48.56 |
| DTPA-Mn (mg kg$^{-1}$)     | 23.2  |
| DTPA-Cu (mg kg$^{-1}$)     | 2.50  |
| DTPA-Zn (mg kg$^{-1}$)     | 1.52  |

**Table 3: Chemical composition of leachate collected from piezometers 30 days after application of various amounts of spentwash.**

| DSW (m$^3$ ha$^{-1}$) | Depth of leachate collection (m) | Chemical composition of leachate |
|----------------------|---------------------------------|---------------------------------|
| 50                   | 0.5                             | pH 7.38                         |
| 100                  | 0.5                             | EC 0.79                         |
| 250                  | 0.5                             | COD 142.8                       |
| 500                  | 0.5                             | NO$_3^-$ 8.3                    |
| 750                  | 0.5                             | HCO$_3^-$ 1.52                  |
| 1000                 | 0.5                             | Cl$^-$ 3.68                     |
| 1500                 | 1.0                             | Ca$^{2+}$ 2.28                  |
|                      |                                  | Mg$^{2+}$ 2.21                  |
|                      |                                  | Na$^+$ 4.42                     |
Table 4: Chemical composition of leachate collected from piezometers 60 days after application of various amounts of spentwash.

| DSW (m³ ha⁻¹) | Depth of leachate collection (m) | pH | EC (dS m⁻¹) | COD (mg L⁻¹) | NO₃⁻ | HCO₃⁻ | Cl⁻ | Ca²⁺ | Mg²⁺ | Na⁺ |
|----------------|---------------------------------|-----|-------------|--------------|-------|-------|-----|------|------|-----|
| 50             | 0.5                             | 7.28 | 0.36        | 56.8         | 9.4   | 1.08  | 2.94 | 1.95 | 1.51 | 3.62 |
|                | 1.0                             | 7.13 | 0.38        | 43.6         | 9.6   | 0.93  | 3.06 | 1.04 | 0.93 | 3.83 |
| 100            | 0.5                             | 7.26 | 0.35        | 59.3         | 9.1   | 1.05  | 3.05 | 1.69 | 1.73 | 3.56 |
|                | 1.0                             | 7.25 | 0.37        | 53.4         | 9.8   | 1.10  | 2.73 | 1.53 | 1.23 | 4.15 |
| 250            | 0.5                             | 7.48 | 0.38        | 83.8         | 9.6   | 1.25  | 3.15 | 1.85 | 1.57 | 5.33 |
|                | 1.0                             | 7.36 | 0.39        | 80.5         | 9.5   | 1.28  | 3.26 | 1.75 | 1.83 | 5.98 |
| 500            | 0.5                             | 7.52 | 0.45        | 105.6        | 11.3  | 2.06  | 3.83 | 1.96 | 1.69 | 7.56 |
|                | 1.0                             | 7.58 | 0.42        | 86.8         | 15.8  | 1.50  | 3.95 | 1.63 | 1.53 | 6.32 |
|                | 1.5                             | 7.50 | 0.44        | 84.7         | 17.2  | 1.78  | 4.02 | 1.66 | 1.24 | 7.96 |
| 750            | 0.5                             | 7.63 | 0.53        | 138.9        | 20.9  | 1.75  | 4.15 | 2.05 | 1.75 | 6.54 |
|                | 1.0                             | 7.43 | 0.46        | 87.0         | 18.6  | 2.00  | 4.16 | 1.93 | 1.80 | 8.23 |
|                | 1.5                             | 7.68 | 0.48        | 84.7         | 20.0  | 2.15  | 4.04 | 1.51 | 1.13 | 8.51 |
| 1000           | 0.5                             | 7.84 | 0.78        | 248.8        | 20.3  | 2.50  | 4.13 | 2.18 | 2.06 | 8.38 |
|                | 1.0                             | 8.13 | 0.93        | 113.5        | 31.4  | 2.75  | 5.08 | 2.04 | 1.53 | 7.91 |
|                | 1.5                             | 8.16 | 0.98        | 107.4        | 31.5  | 3.03  | 5.23 | 1.93 | 1.24 | 8.56 |
| 1500           | 0.5                             | 7.88 | 0.76        | 315.6        | 24.6  | 2.40  | 5.25 | 2.58 | 1.90 | 8.00 |
|                | 1.0                             | 7.93 | 0.98        | 125.4        | 29.3  | 3.06  | 5.75 | 2.16 | 2.04 | 8.93 |
|                | 1.5                             | 8.33 | 1.81        | 148.8        | 38.9  | 3.53  | 6.03 | 2.09 | 1.53 | 9.21 |

Table 5: Electrochemical properties of soil profile as influenced by various amounts of spentwash application.

| Parameter | Soil depth (cm) | 0 | 50 | 100 | 250 | 500 | 750 | 1000 | 1500 |
|-----------|----------------|---|----|-----|-----|-----|-----|------|------|
| pH        |                | 7.53 | 7.84 | 8.04 | 8.32 | 8.58 | 8.73 | 8.74 | 8.82 |
| EC (dS m⁻¹) |                | 0.57 | 0.68 | 0.8  | 0.85 | 1.01 | 1.37 | 1.17 | 1.17 |
| OC (%)    |                | 0.38 | 0.47 | 0.56 | 0.6  | 0.88 | 1.14 | 1.17 | 1.41 |

Correlated with rates of distillery effluent application. Ca, Mg and Na were the main cations affecting the soil pH.

Similar trend of results was observed in salt content of soil. Application of DSW markedly increased the EC of soil and with application of 1000 and 1500 m³ ha⁻¹ of DSW, higher salt concentrations were accumulated in 15-30 cm soil layer compared to surface layer (Table 5). However, little changes were observed in subsurface soil layer (30-60 cm) with application of DSW uptil 500 m³ ha⁻¹. Higher quantity of DSW application reached the salt content even upto 60 cm of soil depth. The results are in accordance with the findings of Baskar et al., (2003) who opined increased EC in soil due to application of DSW.

Organic carbon content of soil increased with increasing quantity of DSW application at 0-15 cm depth and appreciable amount of OC was accumulated in subsurface layer with application of higher quantities of DSW (Table 5). The increased OC content of soil may be attributed to higher organic load in DSW, which upon application to soil enhanced the OC content of soil. Also, the increased leaching of OC to sub-surface layer at high levels of DSW application might be due to high dissolved carbon present in DSW which get leached to lower depths of soil (Ramalho et al., 2001 and Baskar et al., 2003).

Effect of different quantities of spentwash application on primary nutrient content in soil profile: The primary nutrients content of soil increased with the application of different quantities of DSW. Among the primary nutrients, accumulation of K was very high in soil profile compared to N and P (Table 6). The N enrichment was observed upto 90
Effect of different quantities of spentwash application on secondary and micronutrient content in soil profile: Distribution of Ca\(^{2+}\) and Mg\(^{2+}\) at different depths of soil profile did not show definite trend. However, application of DSW enhanced the exchangeable Ca\(^{2+}\) and Mg\(^{2+}\) content of surface soil. Application of 1000 and 1500 m\(^3\) ha\(^{-1}\) marginally increased Ca\(^{2+}\) and Mg\(^{2+}\) contents at subsurface layer. The exchangeable Na accumulated in soil profile with application of spentwash application exceeding 100 m\(^3\) ha\(^{-1}\).
Table 8: Micronutrient content (mg kg\(^{-1}\)) of soil profile as influenced by various amounts of spentwash application.

| Parameter | Soil depth cm | 0 | 50 | 100 | 250 | 500 | 750 | 1000 | 1500 |
|-----------|--------------|---|----|-----|-----|-----|-----|------|------|
| DTPA-Fe   |              |   |    |     |     |     |     |      |      |
| 0 – 15    | 47.17        | 52.27 | 56.32 | 60.36 | 63.49 | 69.68 | 73.59 | 74.01 |
| 15 – 30   | 19.32        | 23.84 | 24.82 | 37.67 | 37.17 | 34.36 | 31.50 | 38.04 |
| 30 – 60   | 19.24        | 20.52 | 23.25 | 26.95 | 28.68 | 31.36 | 28.86 | 29.01 |
| 60 – 90   | 18.34        | 21.03 | 14.91 | 14.55 | 27.85 | 31.43 | 22.36 | 26.29 |
| 90 – 120  | 13.88        | 17.05 | 14.40 | 13.87 | 23.13 | 21.62 | 19.08 | 24.20 |
| DTPA-Mn   |              |   |    |     |     |     |     |      |      |
| 0 – 15    | 23.57        | 24.41 | 28.40 | 31.91 | 35.73 | 38.08 | 46.45 | 54.00 |
| 15 – 30   | 19.06        | 21.33 | 22.81 | 28.35 | 25.24 | 27.30 | 23.00 | 28.20 |
| 30 – 60   | 17.10        | 16.17 | 18.20 | 18.80 | 23.56 | 22.50 | 27.99 | 29.02 |
| 60 – 90   | 15.93        | 19.10 | 14.79 | 15.42 | 15.96 | 17.08 | 15.58 | 18.40 |
| 90 – 120  | 11.79        | 15.40 | 15.22 | 10.61 | 11.15 | 11.30 | 12.28 | 13.24 |
| DTPA-Zn   |              |   |    |     |     |     |     |      |      |
| 0 – 15    | 2.47         | 2.95  | 3.18  | 3.53  | 3.61  | 4.07  | 4.53  | 5.96  |
| 15 – 30   | 1.58         | 1.57  | 1.62  | 1.68  | 2.10  | 1.67  | 1.90  | 1.97  |
| 30 – 60   | 1.02         | 1.24  | 1.46  | 1.53  | 1.10  | 1.81  | 2.01  | 1.90  |
| 60 – 90   | 0.54         | 0.65  | 0.60  | 0.64  | 0.63  | 0.58  | 0.88  | 0.63  |
| 90 – 120  | 0.31         | 0.30  | 0.38  | 0.35  | 0.35  | 0.27  | 0.42  | 0.29  |
| DTPA-Cu   |              |   |    |     |     |     |     |      |      |
| 0 – 15    | 1.61         | 1.80  | 2.09  | 2.87  | 2.91  | 3.02  | 3.49  | 3.82  |
| 15 – 30   | 1.31         | 1.31  | 1.25  | 1.77  | 1.54  | 1.62  | 1.97  | 1.61  |
| 30 – 60   | 1.15         | 1.28  | 1.15  | 1.13  | 1.52  | 1.17  | 1.56  | 1.36  |
| 60 – 90   | 1.08         | 1.17  | 1.00  | 1.04  | 1.10  | 1.09  | 0.65  | 1.02  |
| 90 – 120  | 0.68         | 0.78  | 0.71  | 0.64  | 0.65  | 0.71  | 0.67  | 0.65  |

of DSW was not noteworthy. Increased applications of DSW brought marginal increase in exchangeable Na but were well below the threshold level (Table 7). The results were in conformity with the findings of Anil Kumar (1995) and Murugaragavan (2002), they noticed marginal increase in exchangeable Na but were well below the threshold levels, suggesting even at higher rates, spentwash is unlikely to cause any sodicity problem.

Substantial increase in DTPA-Fe and Mn content of soil was observed following DSWS application (Table 8) and increasing levels of DSWS application increased the DTPA-Fe and Mn upto 60 cm soil depth. But, DTPA-Zn and Cu did not vary much with application of varied quantities of DSW being poor source of Zn and Cu, thus their increase in soil was marginal. The surface soil (0-30 cm) recorded relatively higher quantity of micronutrients than subsurface soil and increasing the rate of DSWS application increased their surface concentration while, subsurface content did not vary indicating less possible chance of heavy metal contamination by spentwash to underground water (Radha and Srivastava, 2012).

**CONCLUSION**

The present investigation states that the primary treated distillery spentwash applied at the rate below 750 m\(^3\)ha\(^{-1}\) increases soil nutrient status with lower percolating leachate. Thus, based on the needs of the crop the spentwash can be applied to soil for cultivating crops upto 750 m\(^3\)ha\(^{-1}\) without adverse effect on soil properties and with very lower probability of groundwater pollution. However, spentwash application at the rate 1500 m\(^3\)ha\(^{-1}\) has shown adverse impact on soil electro-chemical properties of surface soil and increased leaching of salts in leachate.

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