A review of literature on the past work on several aspects of distillery spentwash and its use in crop production is presented in this chapter. The literature survey compiled focused on:

2.1. Chemical composition of distillery spentwash

2.2. Use of distillery effluent as a source of nutrients and as liquid fertilizer

2.3. Use of distillery effluent as a source of irrigation

2.4. Effect of distillery effluent on growth, yield and quality of crops

2.5. Effect of distillery effluent on soil physico-chemical and biological properties

2.6. Effect of distillery effluent on soil nutrient availability and uptake by crops

2.7. Effect of percolating distillery spentwash and different effluents on soil, properties, crops and ground water quality

2.8. Mineralization of nutrients in soil treated with distillery spentwash

2.9. Studies on the impact of distillery spentwash on irrigation

2.1 CHEMICAL COMPOSITION OF DISTILLERY SPENTWASH

Molasses based distilleries produce huge amount of wastewater is generally called as spentwash, vinasse, potale, stillage, slops, detritus and dunder. It is purely of plant origin containing large quantities of soluble organic matter and plant nutrients. It does not contain any toxic element/compounds, but the only problem is with very high BOD, COD and electrical conductivity. Raw spentwash (RSW) is usually dark brown colored with acidic in nature. The spentwash that leaves biomethanation plant after the anaerobic digestion is referred as primary treated spentwash (PTSW), which is dark brown in color with neutral alkaline pH, and relatively lower BOD and COD values than the raw spentwash. The distillery spentwash is enrich in N, P, K, calcium (Ca), magnesium (Mg), sulfur (S) and micronutrients, which are essential to plants. The evaporated spentwash contain a dry matter of 30.5%, 3.68% N, 1.1% P and 1.1% K. The Ca, Mg and Na contents are 0.45%, 0.50% and 0.0035% respectively.

The spentwash analyzed for its composition and reported as pH - 8.00; EC - 31 dSm⁻¹ and nutrients such as total N - 0.14 %; P - 0.12 %; K - 1.36 %; Ca - 0.01 %; Mg - 0.17 %; and COD - 1300 ppm.
Spentwash solids contained relatively more quantities of arabinose, galactose, glucose and xylose sugars. The spentwash solids contained more inorganic nitrogen and less Unhydrolysable nitrogen than FYM.\(^56\)

The potale had a pH of 3.3 and other constituents; N: 2,080 ppm, P: 700 ppm, K: 1,000 ppm, Mg: 200 ppm and Na: 500 ppm on fresh weight basis.\(^57\)

After analyzing the constituents of distillery effluent reported that it contains 0.08 ppm N, 700 ppm P, 1000 ppm K, 200 ppm Mg and 500 ppm Na on fresh weight basis and whisky spentwash had a BOD of 34,500 ppm and COD of 47,000 ppm and it had the organic and nitrogen content of 26,500 ppm and 3,040 ppm respectively and pH of whisky spentwash was 3.3.\(^58\)

In examined distillery spentwash the total N, P and K were 2\%, 0.28\% and 4.98\% respectively.\(^59\)

The chemical nature of spentwash solids (SWS) and FYMwas studied. SWS contained more ether soluble, alcohol soluble and hot water soluble fractions and further, it also contained appreciable amounts of inorganic nitrogen and less Unhydrolysable nitrogen than FYM. While, it was poor source of total as well as organic and inorganic phosphorus as compared with FYM. However, the total potassium content of SWS (9.9 \%) was about 12 times more than FYM. They reported that SWS had a total N, P and K of about 2.0, 0.3 and 9.9 \%, respectively.\(^60\)

The chemical analysis of vinasse found that, cane vinasse had a pH of 5.4, BOD of 57,400 ppm and COD of 1, 03,000 ppm. The other constituents were; total N 1190 ppm and total P: 120 ppm.\(^61\)

The spentwash is acidic (pH 3.94-4.30) and loaded with organic and inorganic salts, resulting in high EC (30-45 dS/m). Being plant originated, the spentwash also contains considerable amounts of plant nutrients and organic matter. Nitrogen content in spentwash ranges from 1660 to 4200 mg l\(^{-1}\), phosphorus from 225 to 3038mg l\(^{-1}\)and potassium from 9600 to 17475 mg l\(^{-1}\). Calcium, magnesium, sulphate and chloride are also present in appreciable amounts. Thus, it can effectively be used as a source of plant nutrients and as soil amendment. Recently, the presence of appreciable amounts of plant growth promoters \textbf{viz.}, gibberellic acid and indole acetic acid have also been detected which further enhances the nutrient value of spentwash. The high
concentration of calcium (2050 – 7000 mg l⁻¹) in spentwash may have the potential in reclaiming the sodic soils similar to that of gypsum effect.

The spentwash was highly acidic and had a huge organic load and total solids. It contained a large amount of K and higher concentration of chlorides and sulphates. Spentwash was highly viscous and corrosive type of liquid. In addition, they opined spentwash is rich in highly putrifiable organics, the waste water stream decomposes rapidly giving obnoxious odour which makes nuisance unfriendly and environment to the people living near by the distillery.²⁶

Spentwash was major pollutant because of its high organic load. They considered spentwash as dilute liquid organic fertilizer with high K content and further reported that it contained about 90 to 93 % water and 7 to 9 % solids. 75% of solids were organic and 25 % were inorganic. Its N content was mostly in colloidal form which behaves as a slow release fertilizer and it was better than other inorganic N source. The two thirds of P was in organic form and the metabolic availability of which was more than any other important elements such as Ca, S and Mg as well as Cu, Mn and Zn. It contained 29.1 % reducing sugar, 90 % protein, 1.5 % volatile solids, 21.0 % gums, 4.5 % combined lactic acid, 1.5 % combined organic acids, 5.5 % glycerol and 15.0 % wax and phenolic bodies.²³

The brewery sludge was analyzed for different constituents and the values were; total N: 2.59%, total P: 0.64%, total K: 0.11%. The other constituents found in sludge were 16.8 % Ca, 0.37. The reviewed data on characteristics of spentwash found that, it has highly acidic with a pH range of 3.5 to 4.0 and carries a huge organics load BOD :4500 - 55,000 mg l⁻¹, COD:90,000 - 1,10,000 mg l⁻¹and total solids (TS): 80,000 - 90,000 mg l⁻¹, suspended solids (SS): 300 to 500 mg l⁻¹, volatile solids (VS): 55,000 - 67,000 mg l⁻¹, total nitrogen: 1200 - 1400 mg l⁻¹, phosphorus: 800 - 1200 mg l⁻¹, it contains good amount of K (8000 - 13000) and high concentration of chlorides (Cl) (5000 - 6500) and sulphates (SO₄²⁻)( 4000 - 8000 )mg l⁻¹. It also contains Na: 1100 - 1400 mg l⁻¹, Ca: 2100 - 3300 mg l⁻¹, Mg: 2000 - 3300 mg l⁻¹ and iron (Fe) content of 50 - 70 mg l⁻¹. It has high temperature in the range of 90-95°C, reddish brown to dark brown colored and possesses an unpleasant smell of burnt or caramelized sugar. Besides, spentwash is highly viscous and corrosive type of liquid.³⁶ While studying the effect of distillery effluent on seed germination and
seedling growth of rice, the effluent was analyzed for different constituents. The results indicated 18 ppm N, 34,650 ppm BOD, 1, 13,095 ppm COD and a pH of 4.7.64

The vinasse had the highest content of organic N, nutrients and ash while bagasse contained the least. Organic compounds extracted by alkaline reagents were of humic nature and were similar to those in soil except that fulvic acid predominated over humic acid.65

Effluent originating from distilleries known as spentwash leads to extensive water pollution. A study was conducted to know the quality of effluent generated from the distillery, for the purpose of proper treatment and dilution of effluent before discharge in water stream or on land. Physico-chemical characteristics of distillery effluent samples such as colour, odour, Total Solids, Total dissolved solids, Total Suspended Solids, pH, Electrical Conductivity, Total hardness, Calcium, Magnesium, Alkalinity, Chloride, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Ammonical Nitrogen, Total Phosphorus, and Total Potassium were analysed and it was observed that the characteristics of spentwash and PTDE (primary treated distillery effluent) have high load of chemical and organic pollutants. But when PTDE was diluted with 50% and 75% of water, all the values of physicochemical properties were decreased. The decrease in these values show that the toxicity of distillery effluent decreases with increasing dilution. Thus the characteristics of spentwash and PTDE do not allow its discharge into a waterbody, hence it requires treatment and dilution before discharge.66

The distillery spentwash being a plant extract hardly contained any heavy metals and other toxic substances67. But contained many plant nutrients making it a potential substance for irrigation and nutrition68. Presence of sugars (2 - 20%) and proteins (10 - 11%) in the dry spentwash along with mineral component was observed69. One of the agro industrial waste materials in brewery industry is brewery’s spent grains (BSG). While studying agronomic potential of BSG found some of the chemical characteristics of BSG. They were 21% of organic carbon (OC), 5.1% of total N, 0.4% of available P, 3.4% of K, 0.4% of Ca, 0.48% of Mg besides a pH of 4.4 and C: N ratio of 21:570 and also reported the data on chemical composition of the vinasse with pH ratio as 5.19 and BOD as 63 mg l⁻¹.71
The chemical composition of the raw sugar waste water was analyzed and found to have pH of 4.4 and electrical conductivity as 6.834 mhos/cm. The distillery effluent of Ugar Sugar Works Ltd., Ugarhurd was analyzed and reported that; pH of raw spent was acidic (4.03) which increased to 7.62 during lagooning. It also contained large amounts of suspended and dissolved solids having high concentration of BOD and COD. Whereas, the content of Ca, Mg and K was higher than Na. However, BOD and COD of effluent were found to be drastically reduced by lagooning and diluting with Krishna river water.

The distillery effluent had the highest content of organic N, nutrients and ash while bagasse contained the least. It was found that the composition of Doon Valley distillery effluent in Uttar Pradesh, India, were highly acidic pH and had high BOD, COD, TS (Total Solids) and very low DO (Dissolved Oxygen). The chemical composition of PTSW are, pH: 8, electrical conductivity (EC) (dsm-1): 31.0, total N: 1,400 ppm, total P: 1,225 ppm, total K: 13,600 ppm, total Ca: 100 ppm, total Mg: 1,700 ppm and COD: 13,000 ppm.

Spentwash is highly acidic and carries a huge amount of organic load. Different constituent values are total solids: 9000 to 15000 mg l⁻¹, COD 115000 to 120000 mg l⁻¹, total N: 1800 to 2000 mg l⁻¹ and P 2000 to 2100 mg l⁻¹. It had a good amount of SO₄²⁻ and Cl, 3000 to 4000 and 7000 to 8000 mg l⁻¹ respectively.

It was found that the distillery effluent contained large amounts of organic matter, N, P, K, S and Ca and further contained a high salt load, sulfates and chlorides of K, Na and Ca.

Spentwash was highly acidic having a pH range of 3.8 to 4.0. It carried a huge organic load i.e., BOD (45000 to 55000) mg/l), COD (90000 to 110000 mg l⁻¹) and total solids (80000 to 90000 mg l⁻¹).

The distillery effluent contains N, P, K, Ca, Mg and SO₄²⁻ and it is thus a valuable fertilizer when applied to soil through irrigation water. The spentwash after the primary and secondary treatments can be diluted and disposed off on lands.

Spentwash had a very high EC (29.00 dS/m) with neutral in reaction (7.20), sodium adsorption ratio of 4.17, Ca, Mg, K, NO₃⁻, HCO₃⁻, SO₄²⁻, Cl⁻ values were: 58.88, 34.54, 170.87, 28.58, 35.00, 195.25 and 65.50 mol l⁻¹, respectively. It has total N, P and K content of 1200, 900 and 6681 mg/l, respectively. Fe, Mn, Zn and Cu...
contents are 61.26, 4.00, 1.17 and 0.78 mg l$^{-1}$, respectively. Pb$^{2+}$, Cd$^{2+}$ and Ni content of spent was 0.68, 0.04, 0.70 mg/l, respectively. In spentwash higher organic loading is the problem, i.e. high BOD and COD, 2500 mg l$^{-1}$ and 6000 mg/l respectively.$^{82}$

Anaerobically digested effluent from molasses residue had the elemental concentration of total N: 21,300 ppm, P: 4,000 ppm, K: 1, 20, 000 ppm, Ca: 32,000 ppm, Mg: 18,000 ppm and Na: 14,000 ppm.$^{83}$

The data on characteristics of spentwash revealed that it had a neutral reaction (6.9), alkalinity (CaCO$_3$ : 491.3 mg l$^{-1}$), total dissolved solids (1280.0 mg l$^{-1}$), volatile suspended solids (113.0 mg l$^{-1}$) with high COD (2152 mg/l) and BOD at 200C (1002 mg/l). Spentwash contained almost all the elements required by the plants such as SO$_4^-$, Cl, Na, K and Ca with an amount of 46.0, 18.5, 100.0, 91.0 and 438.0 mg l$^{-1}$, respectively.$^{84}$

The reviewed data on characteristics of the cane sugar mill water. It has a neutral reaction (6.9), alkalinity (CaCO$_3$ 491.3 mg l$^{-1}$), total dissolved solids (128.0 mg/l), volatile suspended solids (113.00 mg/l) with high C.O.D (2152 mg l$^{-1}$), soluble C.O.D (1740mg l$^{-1}$) and BOD at 20 C (1002 mg/l). Spentwash contained almost all the elements required by the plants SO$_4^-$, Cl, Na, K and Ca, 46.0, 18.5, 100.0, 91.0 and 438.0 mg l$^{-1}$ respectively.$^{85}$

Potassium salts were mainly responsive for increasing the EC of the pre-treated distillery effluent. It carries a huge organic load i.e., BOD (5600 ppm), COD (45000 ppm) and total solids (81000 ppm). The high COD of the effluent might be due to the presence of large quantity of chemicals.$^{86}$

Analytical data of raw distillery effluent collected from the Coimbatore alcohols and chemicals Ltd. situated on the banks of river Bhavani were reviewed. The parameters were pH (8.57), Electrical conductivity (36075 mhos m$^{-3}$), total suspended solids (9200 ppm), total dissolved solids (10230 ppm), chlorides (6748 ppm), sulphates (80 ppm), Biological oxygen demand (1400 ppm), chemical oxygen demand (1400 pm), Volatile suspended solids (2450 ppm) and potassium (4560 ppm).$^{87}$

Some chemical characteristics of vinasse were analyzed. Vinasse is acidic in nature (4.43) with high electrical conductivity (21.0 dSm$^{-1}$) and organic load.
Total solids 90.0 gl⁻¹, soluble solids 83.0 gl⁻¹, and total C.O.D 100 gl⁻¹, soluble solids 83.0 gl⁻¹, total BOD 39 gl⁻¹. Vinasse contained a good amount of total K (0.6%), total Ca (0.54%), and total Mg (0.27%). Organic carbon content was 3.10%, organic matter (6.2%), Fulvic acid (0.83%) and humic acid (0.32 %) and also had a total N 1204 mg l⁻¹, ammonical nitrogen 87 mg l⁻¹, nitrate nitrogen 182.4 mg l⁻¹ with total P 423 mg/l and soluble P 185 mg l⁻¹ was observed. The characteristics and composition of liquid distillery effluent were analyzed, spentwash which has dark brown color with unpleasant odor and pH of 7.8. Adverse effect of distillery efficient is due to very high EC (20.8 dS/m), total dissolved solids (14635 mg l⁻¹), organic carbon (8%), total suspended solids (3800 mg l⁻¹). Due to high organic load we can expect more BOD and COD value, 4620 and 26000 mg l⁻¹, respectively. N: 0.19%, total P: 6 ppm, total calcium and magnesium, 100 and 200 moles l⁻¹, respectively. It contained a good amount of potassium (5356 ppm) and Fe (38 ppm). Sulphite (SO₃²⁻) 4.2 and chloride 14.40 moles/l, Na, Zn, Cu, Mn, and B content of spentwash were 6.3, 2.0 and 0.4 ppm, respectively. Bicarbonate content was 150 mg l⁻¹ in contradictory to carbonate content, which was nil.

There was a considerable change in chemical composition of untreated and primary treated spentwash with acidic (3.8) and Alkaline (8.0) reaction, respectively. Electrical conductivity of untreated and primary treated spentwash was 30 and 32.50, respectively. Total solids content in untreated and primary treated spentwash samples were 90,000 and 81,000 (mg l⁻¹), respectively. Other compositions are N (mg l⁻¹): 1500 (untreated) and 1740 (primary), P (mg l⁻¹): 260 (untreated) and 260 (primary), potassium (mg l⁻¹): 10000 (untreated) and 11500 (primary), Ca (mg l⁻¹): 7000 (untreated) and 1050 (primary), Mg (mg l⁻¹): 3300 (untreated) and 2200 (primary), Na (mg l⁻¹): 400 (untreated and 510 (primary), chloride (mg l⁻¹): 5000 (untreated) and 11200 (primary) and also sulphate (mg l⁻¹) content of untreated spentwash: 5000 and primary: 2400. Laboratory incubation studies were conducted with various levels of spentwash viz., 55, 110 and 225 ml kg⁻¹ soil over an incubation period of 60 days to evaluate the impact on physico-chemical and biological properties of the sodic soil. A drastic reduction or total inhibition of microbial population was observed in the soil immediately after spentwash application. The experiment also proved that a safe time gap of 40 days is required for the oxidation of organic matter present in spentwash, thus, providing a favorable environment for the multiplication of microbes.
Chemical composition of untreated distillery spentwash and primary treated distillery effluent was studied. There was a considerable change in chemical composition among them i.e., pH : 3.8 and 8.0; EC : 30.0 and 32.5 dSm$^{-1}$. Total solids : 90,000 and 81,000 mg l$^{-1}$, nitrogen : 1500 and 1740 mg l$^{-1}$, phosphorus : 260 and 260 mg l$^{-1}$, potassium : 10000 and 11500 mg l$^{-1}$, calcium : 7000 and 1050 mg l$^{-1}$, magnesium : 3300 and 2200 mg l$^{-1}$, sodium : 400 and 510 mg l$^{-1}$, chloride : 5000 and 11200 mg l$^{-1}$ and sulphate : 5000 and 2400 mg l$^{-1}$ content in untreated and primary treated spentwash, respectively.\(^90\)

Twenty-one samples of winery and distillery effluents were collected from different Spanish winery and distillery industries. Electrical conductivity, pH, redox potential, density, organic charge (chemical oxygen demand, biological oxygen demand, total, volatile and suspended solids, oxidisable OC and polyphenols) and contents of plant nutrients and heavy metals were analyzed. The winery wastewater (WW) and vinasse (V) showed an acidic pH, a high organic load and notable polyphenol, macronutrient, micronutrient and heavy metal contents.\(^91\)

Chemical composition of biocompost prepared from distillery effluent and pressmud was pH 7.7, EC 12.56 dS/m, OC 36.33%, N 1.90%, P 1.85%, K 1.48%, Zn 255.2 ppm, Mn 347.8 ppm, Cu 91.1 ppm and Fe 58.57 ppm.\(^92\) The treatment of raw spentwash changes the composition of the spentwash. The physico-chemical properties such as electrical conductivity, total solids, suspended solids, dissolved solids, BOD, COD, nitrogen and phosphate were found decreased in effluent after 72 h. The pH of the effluent was relatively increased from 3 to 6.7.\(^93\) Distillery effluent is a contaminated stream with high chemical oxygen demand (COD) varying from 45,000 to 75,000 mg l$^{-1}$ and low pH values of between 4.3 and 5.3.\(^94\) The effluent from a Lucknow-based distillery (Mohan Meakin Distillery) was analyzed for physico-chemical and biological parameters of pollution and concentration of potentially toxic heavy metals (Cd, Cr, Ni and Zn) and the effect of the distillery effluent, as such and on 50% dilution with tap water was studied on seed germination and seedling growth of maize (Zea mays L.) and rice (Oryza sativa L.). The effluent was wine red in color and highly acidic (pH ~5.5) and possessed decaying alcoholic smell. The effluent contained high values of different pollution parameters particularly total solids, 3450 mg l$^{-1}$ (soluble plus suspended solids), alkalinity 1500 mg l$^{-1}$, biological oxygen demand (BOD, 1649 mg l$^{-1}$) and chemical oxygen demand (COD, 2036 mg l$^{-1}$). It had
very low values of dissolved oxygen (DO, 0.34 mg l⁻¹). The heavy metals (Cd, Cr, Ni and Zn) content, particularly the nickel concentration (0.029 mg l⁻¹) was high.⁹⁵

2.2. USE OF DISTILLERY EFFLUENT AS A SOURCE OF NUTRIENTS AND AS LIQUID FERTILIZER

The distillery effluent could be as a nitrogen source by obtaining a significantly higher yield in sugarcane with 200 kg N through spentwash application⁹⁶. The manurial value of distillery effluent can profitably be used as supplement to the fertilizer when used along with irrigation water as it contains nutrients such as total N 0.14%; P 0.12 %; K - 1.36 %; Ca - 0.01 %; Mg - 0.17 %;⁵⁵. But higher rates were found detrimental. An increase in ash and K content of raw, clear cane juice and molasses was observed by application of vinasse.⁹⁷

Spentwash is as good source of potassium chloride. The use of this water saved 25 % fertilizer besides solving the problem of disposal. (KCl) as a source of potassium for sorghum. The evaluation of stillage as a source of K for maize (Zea mays L.) in comparison with KCl and potassium sulphate (K₂SO₄).⁹⁸ The use of effluent water has indicated that 25 % of the recommended dose of fertilizer nutrients can be saved in this way which not only solve the problem of disposal but also substitute some quantity of inorganic fertilizers. In sand culture studies, the growth and chemical composition of sugarcane were not adversely affected by spentwash solids applied at 250 ppm.⁹⁹

Pressmud is a solid waste by-product obtained from sugar factory. About three % of pressmud is obtained from the total quantity of cane crushed. Pressmud is a rich source of organic carbon (35-37 %) and supplies N (1.0-1.5 %), P₂O₅ (2.5-3.5 %) and K₂O (0.5 - 0.8 %) besides a good source of secondary and micro-nutrients¹⁰⁰ cash crops are long duration, they require huge quantity of nutrients. If nutrients are supplied through spentwash, the nutrients requirement of the crops can be met besides reducing the use of costly chemical fertilizers. Application of 80 m³ ha⁻¹ vinasse alone considerably improved the yield of cane and sugar per hectare.¹⁰¹ Significant increase in cane yield and recoverable sugar per hectare due to application of spentwash at the rate of 90 to 150 t/ha was observed.¹⁰²
Physical soil characteristics influenced by vinasse application and noticed better soil aggregation and water permeability. The available nutrients were also increased with effluent irrigations, the available N from 276 to 412, available P from 21.0 to 34.0 and available K from 700 to 2400 kg ha\(^{-1}\).\(^{103}\) The evaluation of stillage as a source of K for maize crop in comparison with KCl and K\(_2\)SO\(_4\) Distillery waste could be safely used as fertilizer along with irrigation water.\(^{104}\) Distillery spentwash could be safely used as fertilizer along with irrigation water. There was increase in the 20% nodulation of Cymposis tetragonoloba when irrigated with distillery spentwash at 10% dilution\(^{105}\). The distillery effluent contained an excess of various forms of cations and anions, which are injurious to plant growth. The concentration of these constituents should be reduced to beneficial level by diluting the effluent, which can be used as a substitute for chemical fertilizer. Brewery sludge residuals are approximately equivalent on a dry basis to fertilizer with an analysis of 3: 1: 0 (N: P\(_2\)O\(_5\): K\(_2\)O).\(^{113}\)

Brewery sludge residuals on a dry basis are approximately equivalent to 3:1:10 (N: P\(_2\)O\(_5\): K\(_2\)O). It is estimated that a single application of 5 to 20 dry tonnes per acre will increase overall hay yields over one year period by a factor of at least 5 times as compared to untreated hay fields.\(^{107}\) The mineralization of organic materials and the nutrients present in the effluent were responsible for the increase in the availability of plant nutrients.\(^{108}\) The distillery effluent is used as a supplement to mineral fertilizer in Brazil as the distillery effluent contained N, P, K, Ca, Mg and S and is thus valued as fertilizer\(^{109}\). The distillery effluent contained N, P, K, Ca, Mg and S and thus valued as a fertilizer when applied to soil through irrigation water.\(^{110}\)

It was observed that the levels of vinasse increased cane and sugar yield, but reduced poll content, apparent purity, brix and sugar yield. The stand of leguminous intercrop with cane was reduced by vinasse applied at a very early stage of plant growth\(^{111}\). The increase in sugar yield was 2.07 t ha\(^{-1}\) over control. In laboratory experiments, effects of 9 conc. (range 1-100% v/v) of a mixture of fertilizer factory and distillery effluents on germination and seedling growth of P. radiatus [Vigna radiata] were studied. Germination percentage and speed of germination index increased with increase in the effluent concentration up to 5%. Seedling biomass and pigment contents increased with up to 10% concentration and carotenoid content increased with up to 30% concentration. The effluent mixture with up to 15%
concentration was best for overall plant growth. The use of effluent for irrigation could be used as an additional fertilizer source. It was observed severe damage to wheat crop grown in highly polluted soil and attributed this adverse effect due to the excessive concentrations of various cations, anions and organic pollutants presented in the effluent. Spentwash is classified as dilute liquid organic fertilizer with a high potassium contents and its nitrogen was mostly in colloidal form behaving as a slow release fertilizer better than most chemical nitrogen sources. Further, the availability of phosphorous was more than any chemical sources besides containing large amount of important secondary elements like Ca, S and Mg as well as trace elements such as Cu, Mn and Zn.

The application of vinasse at the rate of 120 m$^3$ha$^{-1}$ accelerated cane ripening and increased cane and sugar yield per hectare. Lower concentration of the effluent increased seed germination and early seedling growth in cowpea, rice and sorghum while higher concentrations retarded not only seed germination but also early seedling growth in all four species investigated. In soyabeans percentage germination and early seedling growth were markedly suppressed by increasing concentration of the effluent. Distillery effluent may be used as a liquid fertilizer only for certain crops after proper dilution with water. Application of spentwash found that, spentwash as reliable substitute for muriate of potash on sugarcane and potato.

In Brazil the impact of spentwash application on soil and groundwater was studied. Over 5 samples were collected at depths of 25, 75 and 150 cm. These results showed that the organic material added with spentwash mineralizes rapidly increasing N, P, Ca and S contents and increasing soil fertility. Nutrients reached the groundwater, but not at levels harmful to human health. Plant nutrients viz., N, P, K and S increase because of the incorporation of effluent to the pressmud. Effluent added to pressmud harboured more bacteria, fungi and actinomycetes indicating the more microbial activity. Considering spentwash from the point of view of its organic matter and nutrient content, it could be a valuable source as a fertilizer and source of organic compounds.

The spentwash treated by aerobic composting technology and used as manure. Further, spentwash pressmud compost was superior to other sources in respect of N, P, K, Fe and Zn uptake. The spentwash treated by aerobic composting technology was used as manure. Spentwash solids, farm yard manure and spentwash pressmud
compost were equal in their effect.\textsuperscript{120} The maximum manuring rate was found to be 60 t ha\textsuperscript{-1}, above which earthworms were found affected. It was also observed that the introduction of spentwash compost leachate in water streams enhanced the growth of algae and did not cause any toxic effects on the aquatic fauna. Significantly higher sugarcane yield in CoC. 771 at 50, 40, 30 and 20 times diluted effluent irrigations than irrigated with normal water. The higher dilution could be used for irrigation purpose without adversely affecting soil fertility and crop productivity. The distillery effluent can be considered as liquid manure and controlled application of the treated effluent can increase the productivity of sugarcane and sugar beet.\textsuperscript{121}

About 25\% of the recommended fertilizer can be saved by going for irrigation with distillery waste water along with 75\% of the recommended fertilizer application in onion. The total dry matter and yield obtained was at par with 100\% recommended dose of fertilizer application with normal water irrigation and further percentage utilization of applied N, P and K through fertilizer were more in distillery waste water with 75\% fertilizer dose.\textsuperscript{76}

The distillery effluent can be considered as liquid manure. The effluent irrigations improved the physical and chemical properties of the soil and further increased soil micro-flora and controlled application at the treated effluent can increase the productivity of sugarcane and sugarbeet.\textsuperscript{123} A lower concentration of effluent enhanced both peak value of germination and mean daily germination of Albizia procera whereas the higher effluent concentration inhibited both the parameters progressively.\textsuperscript{75} The highest cane yield of 182.8 tones at irrigation with distillery effluent diluted to 50 times was recorded. However, cane yield and juice quality decreased with increasing concentration of the effluent in irrigation water.\textsuperscript{125}

The best results were obtained when 50 times diluted vinasse was applied at 16 t ha\textsuperscript{-1}, the cane yield (188.1 t ha\textsuperscript{-1}) and commercial cane sugar yield (25.96 t ha\textsuperscript{-1}) were 20\% higher than control (155.9 and 20.94 t ha\textsuperscript{-1}). Juice quality was better than that of control. The cane: brix poll and purity were highest when applied with 32 t ha\textsuperscript{-1} of diluted at 50 fold, while the N: P\textsubscript{2}O\textsubscript{5} ratio was lowest with 32 t ha\textsuperscript{-1} diluted at 75 – fold.\textsuperscript{125} The highest sugarcane yield with 10 times dilution when effluent amended along with the pressmud but the quality parameters in sugarcane were not influenced due to the diluted effluent irrigation.\textsuperscript{126}
The distillery effluent containing large amounts of organic matter. N, P, K, S and Ca and this was used resources in crop production in India as an alternative source of nutrients there by reducing investment on inorganic fertilizers. However, the effluent contained higher salt load, comprising sulfates and chlorides of K, Na and Ca, might result in negative environmental impacts if used continuously and indiscriminately. The application of spentwash diluted at any level increased cane yield and nutrient uptake significantly over irrigation with well water. They also observed increased nutrient availability of P, K and S considerably there by indicating the signs of improvement in some soil physical properties.

A field experiment was conducted between 1998 and 1999 at the EID Parry sugar factory command area, Nellikuppam, Tamil Nadu, India, to assess the optimum dilution with irrigation water of distillery effluent used as an organic nutrient source for growing sugarcane crops in sandy soil. Irrigation with treated distillery effluent at 1:10, 1:20, 1:30, 1:40 and 1:50 dilutions was done every 40 days between 45 days and 6 months after planting. There were no significant differences in the pH and electrical conductivity between soils irrigated with the treated effluents and controls. Levels of organic carbon, macro- and micronutrients, and soil microbial population increases. Similarly increase in the soil available N, P and K content by pre-sowing irrigation with distillery waste was noticed.

Analytical data of distillery waste water are presented which showed it to be a good source of plant nutrients e.g. of K (6-9 gl⁻¹), S (1-3 gl⁻¹), N (2 gl⁻¹) and organic matter. It dried out slowly to a sticky solid mass. Even after its anaerobic digestion, it contained a lot of soluble organics and inorganic nutrients. The digested waste water evaporated at a rate equivalent to that of pure water resulting in a non-hygroscopic solid mass. Thus, it may be concentrated by open field evaporation to recover a potash-rich organic manure. The farmers used spentwash (66-80 P per m³) as source of fertilizer which saved in terms of equivalent chemical fertilizer. The direct use of spentwash liquor has promise in sustainable development of agriculture in developing countries. Application of diluted distillery effluent in 1:10 and 1:20 ratio recorded higher cane yield of 129.5 and 122.3 t per ha, respectively over 1:30, 1:40 and 1:50 dilutions at sugarcane research station, Cuddalore. The distillery effluent contained a considerable amount of plant nutrients There was general buildup of organic carbon, soil available N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu nutrients
including high salt load, sulfates and chlorides of K, Na and Ca. The distillery effluent could be used as soil amendment in sodic soils as it increased both wheat and rice yield grown in sequence and improved the soil physico-chemical properties.85

The pineapple fruit weight and yields increased with increasing vinasse rate (0, 100, 200 or 400 m³ vinasse/ha as K source). Addition of K increased the content of titrable acidity and total soluble solids in fruit.130 Distillery effluent application changes soil properties, microbial population, yield and quality of sugarcane in the treated sandy soils were significantly higher131. Most of the field crops, viz., sugarcane, rice, wheat and mustard showed positive response to biomethanated spentwash application along with irrigation water. Even after the 20th irrigation with spentwash on specific fields, none of the crops showed any toxicity symptoms even up to 30% concentrations. The sugarcane crop receiving 9 irrigations followed by ratoon crop receiving 5 irrigations with 30% concentration showed better yields as compared to normally irrigated crop. The kharif crops like maize and rice responded well to biomethanated spentwash irrigation even up to 40% level. Stress symptoms were visible in case of wheat crop at 40% biomethanated spentwash applied for three years.132

Eco-friendly utilization of distillery effluent in agriculture may serve as one of the nutrient management practices for enhancing crop yields besides reducing the costs of fertilizers. But, it has to be used judiciously and cautiously on a limited scale because of very high organic load. Distillery effluent has excessive BOD (45000 - 55000 mg/l), COD (90000 - 110000 mg/l) and EC (16 - 29 dSm⁻¹). These problems can be overcome either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre-plant application (40 to 60 days before planting) to give sufficient time for the oxidation of organic matter. The untreated distillery spentwash also known as raw spentwash is acidic in nature (pH 3.5 - 4.0) and can be effectively used for the reclamation of non-saline sodic soil. Addition of effluent significantly increased the EC, organic carbon, available N, P, K, Ca and Mg contents as well as micronutrients in soil as reported.133

A pot culture experiment was conducted on rice cultivars Pusa 44 and CSR 10 to study the possible use of postmethanation distillery and paper mill effluents as a nutrient source. The treatments comprised: water (control); 50% paper mill effluent + 50% water; 20% distillery effluent + 80% water; 50% paper mill effluent + 20%
distillery effluent; and 25% paper mill effluent + 20% distillery effluent. CSR 10 treated with 50% paper mill effluent + 20% distillery effluent gave the highest test weight (22.8 g), grain yield (18.0 g/pot) and biomass yield (83.35 g/pot). Similar results were obtained for Pusa 44. The growth and yield of rice improved with the application of effluents (alone or in combination). N and P uptake was enhanced by effluent irrigation. K uptake was inhibited by paper mill effluent irrigation.\textsuperscript{134}

A top trial experiment was conducted to study the effect of different solid industrial bio-resources (pressmud, effluent treatment plant and cynamide sludges @ 2.5 and 5 t ha\textsuperscript{-1}) as a source of organic matter in a heavy black soil using onion as a test crop. The results revealed that sludges were found to increase the pH and electrical conductivity in post–harvest soil. Organic carbon content, available major nutrients (N, P and K), micronutrients (Fe, Zn, Mn and Cu) and heavy metals (Pb, Cd and Ni) were also found to increase with the usage of different sludges. Pressmud treatments were proved to be the best and cynamide treatments were poor in case of nutrient availability. Pressmud showed minimum pollution hazard with less accumulation of heavy metals in soils.\textsuperscript{135}

A 45 m long, 4 m wide and 1 m deep wetland was constructed at Goudini in 2002 to treat distillery and winery effluent. After the plants were fully established, the wastewater with an average COD of 14,000 mg/l\textsuperscript{-1} was introduced to the wetland system at a rate of 4,050 l/day. The experiment consisted of four treatment: clean irrigation water with fertilizer applied (B1); clean irrigation water without fertilizer applied (B2); wastewater irrigation with fertilizer applied (B3); and wastewater irrigation without fertilizer applied (B4). Cabbage was cultivated as a cash crop. The results indicated that cabbage could be irrigated with winery wastewater treated by wetlands. The results indicated that wastewater irrigation improved the nutritional status of the soil.\textsuperscript{136}

The pre-sown application of diluted distillery effluent at 20 m\textsuperscript{3}ha\textsuperscript{-1} was optimum for building up soil fertility and increasing the yield of rice and wheat in sandy loam soil. Nevertheless, the crop performance and yield with distillery effluent alone were overall less than that produced by distillery effluent with chemical fertilizers probably due to failure of the effluent to supply balanced nutrition to the plants for achieving their potential growth capacity.\textsuperscript{137}
Distilleries of sugar industries play a major role in polluting the soil and water. These distilleries discharge a large volume of waste water (Spentwash) every day which poses a major disposal problem. The spentwash is non-toxic, bio degradable, purely of plant origin and contains large amounts of soluble organic matter and plant nutrients. Addition of organic matter is beneficial for improving the soil fertility but the only problem with distillery effluent is its high BOD, COD and salt content. From the references given above, it can be inferred that the distillery spentwash could be judiciously used as a source of nutrients for crops.

2.3 USE OF DISTILLERY EFFLUENT AS A SOURCE OF IRRIGATION

Increased yield was observed in snap bean due to application of spentwash as irrigation water. The potale had a pH of 3.3 and other constituents; N: 2,080 ppm, P: 700 ppm, K: 1,000 ppm, Mg: 200 ppm and Na: 500 ppm on fresh weight basis. Irrigation with distillery effluent at the rates of 83, 166 and 249 m³ ha⁻¹ with regular fertilizers increased the cane yield. Distillery effluent contained an excess of various forms of cations and anions and concentration of these should be reduced to beneficial level by diluting the effluent which can be used for irrigation purpose. Physical soil characteristics influenced by vinasse application and noticed better soil aggregation and water permeability. The available nutrients were also increased with effluent irrigations, the available N from 276 to 412, available P from 21.0 to 34.0 and available K from 700 to 2400 kg ha⁻¹.

Organic matter oxidation brought out by microbial activity was responsible for increased pH when soil was treated with distillery effluent. The electrical conductivity of the soils also increased significantly with effluent irrigation. The organic carbon content of the soils increased significantly with effluent irrigations which might be due to the fact that the effluent contains high organic load. The available N, P, K, Ca, Mg and micronutrient contents of the soils, in both the seasons, were significantly increased due to effluent irrigations.

The effluent from logoon, after dilution can be used successfully to irrigate sugarcane, wheat, barley and elephant grass and the only disadvantage is that it requires enormous water for dilution. The distillery effluent contained N, P, K, Ca, Mg and S and thus valued as a fertilizer when applied to soil through irrigation.
5 to 35% rise in yield of sugarcane with spentwash irrigation was recorded from molasses from distilleries at the application rate of 150 to 600 m$^3$ ha$^{-1}$ in the Tucaman region of Argentina. A study on the effect of distillery effluent on seed germination, seedling growth and chlorophyll content in sunflower (*Helianthus annuus* L.) var EC 68414 revealed decreased seed germination, seedling growth and chlorophyll content with increased effluent concentration but remained safe at low concentration of up to 25%. 

Increased soil pH, available N, P, K, Ca and Mg due to the application of 80 m$^3$ vinasse per hectare. Irrigation to cane field with distillery effluent had a tendency to increase exchangeable calcium. Irrigation to groundnut with raw distillery waste water resulted in a reduction of nodulation and absence of fruit formation of the plant. This inhibitory effect was reduced when raw spentwash was diluted to 50% by tap water.

The digested distillery effluent application increased concentrations of most elements particularly K in soil. The decreasing trend of infiltration rate (IR) was noticed with effluent irrigations. However, the drop in IR was marginal at 50 and 40 times dilutions (33.4 and 31.2 cm/hr) when compared with water (33.8 cm/hr). The infiltration rate of the soils was significantly reduced with effluent irrigations, in both the seasons. The reduction was marginal (5.2%) at 50 times dilution and appreciable (54.5%) at 10 times dilution.

The study revealed that, the distillery spentwash could be safely be used for irrigation purpose at low concentration up to 25%. It was found that, higher sugarcane yield in CoC.771 at 50, 40, 30 and 20 times diluted effluent irrigations than irrigated with normal water.

Cane juice quality parameters such as pol% and purity coefficient, remained unaffected due to irrigation of 500 m$^3$ ha$^{-1}$ distillery effluent. Oil seeds are the important components of agriculture. In India, oilseed production is less than the demand because of their less remunerative nature than other crops. Oil seeds require high amount of sulphur and nitrogen. So, if their requirement is met through spentwash irrigation oil seed production can be made more remunerative.

Twenty five % of the recommended fertilizer can be saved by irrigation with distillery waste water along with 75 % of the recommended fertilizer application in
onion. The total dry matter and yield obtained was on par with 100 % recommended
dose of fertilizer application with normal water irrigation and further, percentage 
utilization of applied N, P and K through fertilizers were more in distillery waste 
water with 75 % fertilizer dose.\textsuperscript{76}

An increase in soil Mg and Na contents in soils due to spentwash application
observed.\textsuperscript{147} At lower concentration, effluent application enhanced both peak value of 
germination and mean daily germination of \textit{Albizia procera} but inhibited at higher 
effluent concentration.\textsuperscript{75} The higher dilution could be used for irrigation purpose
without adversely affecting soil fertility and crop productivity. The effluent irrigations
improved the physical and chemical properties of the soil and further increased soil 
microflora there by producing ideal conditions for cane cultivation\textsuperscript{123}. The effluent
irrigations improved the physical and chemical properties of the soil and further
increased soil microflora there by producing ideal conditions for cane cultivation.
Field experiments were conducted to study the effect of one time application of
treated undiluted distillery spentwash at 25, 50, 125, 250 and 500 t/ha before planting.
Results revealed that all the levels of spentwash addition recorded significantly higher 
cane yield than control. The highest cane yield of 155.80 t ha\textsuperscript{-1} was recorded with the
application of 125 t ha\textsuperscript{-1} followed by 250 t ha\textsuperscript{-1} (148.90 t ha\textsuperscript{-1}).\textsuperscript{123}

The studies on application of distillery waste revealed that there was a positive
influence of distillery waste water on soeghum yield\textsuperscript{76}. A sugarcane variety Co.853
registered significantly higher cane yield by 14.6 and 8.3% at 50 and 40 times
dilutions, respectively when compared with irrigation purely by water. Thus, they
recommended 50 times diluted effluent as suitable for irrigating the crop.\textsuperscript{124}

The investigation recorded the highest cane yield of 182.8 tones at irrigation
with distillery effluent diluted to 50 times. However, cane yield and juice quality
decreased with increasing concentration of the effluent in irrigation water. The
distillery effluent could be used as a source of irrigation at higher dilutions. For
wheat, 50 times dilution proved better but for maize and sugarcane, a lower dilution
of distillery effluent (10 times) proved superior. Further in wheat crop, at 10 times
dilution produced more chaffy and unfilled nature of grains due to excessive nutrients
application particularly nitrogen.\textsuperscript{126}
The irrigation of crops with distillery effluent had no adverse effect on the germination of wheat, maize, sorghum and cowpea, in fact it had beneficial effects as compared to irrigation with fresh well water. Irrigation in standing crop of wheat was done with dilution of the effluent by bringing down the BOD to 500 mg l⁻¹ which was found to be safer for irrigation in wheat.¹⁴⁸

The best results were obtained when 50 times diluted vinasse was applied at 16 t ha⁻¹, the cane yield (188.1 t ha⁻¹) and commercial cane sugar yield (25.96 tha⁻¹) were 20% higher than control (155.9 and 20.94 t ha⁻¹). Juice quality was better than that of control. The cane: brix poll and purity were highest when applied with 32tha⁻¹ of diluted at 50 fold, while the N: P₂O₅ ratio was lowest with 32 t ha⁻¹ diluted at 75 – fold.¹²⁵

Irrigation with treated distillery effluent to sugarcane soil under varying dilutions significantly altered the microbial load in the rhizosphere. The population varied with period under effluent irrigation and the peak was recorded in the fifth month. The microbial population was found to be high in the soil that was irrigated with 50 time’s diluted effluent.¹⁴⁹

The results revealed that as the spentwash does not contain heavy metals may be used as a source of irrigation by going higher dilutions with normal water¹⁵⁰. The usefulness of distillery waste water for irrigation purpose can save fertilizer to the extent of 25% in onion.¹⁵¹

The distillery effluent contains N, P, K, Ca, Mg and SO₄ and it is thus a valuable fertilizer when applied to soil through irrigation water. The spentwash after the primary and secondary treatments can be diluted and disposed off on lands. Field experiments were conducted on sugarcane and ratoon crops at Appakudal, Tamil Nadu to find out the optimum dilution of treated effluent for irrigation of sugarcane varieties Co-8021 and CoC-771. The results revealed that the effluent irrigations significantly increased the pH, EC, organic carbon and available nutrient contents of the soils. Potassium application was withdrawn from fertilizer schedule under effluent irrigation. The CoC-771 registered significantly higher cane yield than Co-8021 in both plant and ratoon crops. The Co-8021 gave higher cane yield at 50 times dilution only, whereas the CoC-771 gave higher cane yields at 50, 40 and 30 times dilution in both present and ratoon crops.⁸¹
The highest cane yield and dry matter yield of 95.03 and 53.67 t ha\(^{-1}\), were observed respectively at 10 times diluted effluent and the increase was 30.58 and 27.51 % over river water irrigated plots which recorded the lowest cane yield of 72.77 t ha\(^{-1}\) and dry matter yield of 42.69 t ha\(^{-1}\). The ratio between canes to dry matter yield was 1.77 and 1.72 in 10 times diluted effluent and river water irrigated treatments. The number of cane tillers, height of millable cane, cane yield and dry matter production were found increased with decrease in effluent diluted irrigation.\(^{152}\)

It was found that, maize crop withstanded irrigation done with five times diluted effluent. This diluted effluent irrigation had positive effect on crop growth and soil productivity. Plants in five times diluted effluent irrigated fields were significantly taller and other growth parameters were also on higher side than higher diluted effluents irrigated plots. They concluded that effluent up to 1000 mg l\(^{-1}\) BOD can be safely used for irrigating maize which left a positive effect on soil fertility.\(^{153}\)

A field survey conducted for assessing groundwater quality and salinity build up in irrigated soils of Sikandarabad area of Bulandshahar district, Uttar Pradesh as influenced by irrigation with mixed industrial effluents of various industries. Samples of effluent from irrigated fields were collected and analyzed for different characteristics. It is inferred that indiscriminate disposal of the effluent aggravated the salinity and sodicity problem in the irrigated soils and shallow surface water resources like ponds. Organic carbon status of surface soils increased two to three times as compared with that of adjacent normal soils.\(^{154}\) In light textured soils, the application of spentwash diluted at any level increased cane yield and nutrient uptake significantly over irrigation with well water. Increase in the soil available N, P and K content by pre-sowing irrigation with distillery waste was noticed.\(^{127}\)

In the areas wherever distillery effluent available, it should be diluted 50 or more than 50 times with irrigation water to increase the rice yield without having any detrimental effect on soil health\(^{84}\). On a reddish yellow latosol of Brazil found that pineapple fruit weight and yields increased with increasing vinasse rate (0, 100, 200 or 400 m\(^3\) vinasse ha\(^{-1}\) as K source)\(^{130}\). It was found that, when digested liquor which was diluted and pumped during the dry season (December to July) to 400 ha of paddy field resulted in a 2-3 fold increase in rice yield.\(^{129}\)
A study revealed that there is possibility of salinity development in the long run with higher levels of effluent application. The treated distillery effluent irrigations resulted in a significant increase in soil pH, EC and organic carbon. There was remarkable addition of 170 and 155 kg of K ha\(^{-1}\) due to the application of effluent 1:10 and 1:20 dilution, respectively. There was an increase in organic carbon (0.14 %), N (48 kg), P (4.4 kg) and K (170 kg) in sugarcane crop receiving 1:10 diluted effluent irrigation. Carbonaceous sugar mill effluent produces adverse effects on soil fertility and chemical constituents of plant if used for irrigation purposes.

Most of the field crops, viz., sugarcane, rice, wheat and mustard showed positive response to biomethanated spentwash application along with irrigation water. Even after the 20\(^{th}\) irrigation with spentwash on specific fields, none of the crops showed any toxicity symptoms even up to 30% concentrations. The sugarcane crop receiving 9 irrigations followed by ratoon crop receiving 5 irrigations with 30% concentration showed better yields as compared to normally irrigated crop. The kharif crops like maize and rice responded well to biomethanated spentwash irrigation even up to 40% level. Stress symptoms were visible in case of wheat crop at 40% biomethanated spentwash applied for three years.

The effects of spentwash as irrigation water on the performance of maize cv. DMH 1 and on soil chemical properties were studied in Karnataka, India, during the winter seasons of 1999-2000 and 2000-2001. The plants were irrigated 10 times during the growth period with spentwash either undiluted or diluted with well water (spentwash and well water ratios of 1:5, 1:10, 1:25 or 1:50). A dilution level of 1:5 resulted in the highest grain yield (7.68 tha\(^{-1}\)), and Zn (0.485 kg ha\(^{-1}\)), Cu (0.172 kg ha\(^{-1}\)), Fe (3.12 kg ha\(^{-1}\)) and Mn (139 kg ha\(^{-1}\)) uptake. Dilution levels of 1:5 and 1:10 recorded the highest N (195.45 and 187.24 kg ha\(^{-1}\)), P (43.26 and 42.04 kg ha\(^{-1}\)) and K (173.70 and 168.52 kg ha\(^{-1}\)) uptake. The undiluted spentwash, which resulted in significantly lower grain yield and nutrient uptake than the control (water without spentwash), gave the highest maize protein (11.69%) and reducing sugar (1.35%) contents, and soil electrical conductivity (1.04) and organic carbon content (0.52%).

Eco-friendly utilization of distillery effluent in agriculture may serve as one of the nutrient management practices for enhancing crop yields besides reducing the costs of fertilizers. But, it has to be used judiciously and cautiously on a limited scale.
because of very high organic load. Distillery effluent has excessive BOD (45000 - 55000 mg/l), COD (90000- 110000 mg/l) and EC (16 - 29 dSm⁻¹). These problems can be overcome either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre-plant application (40 to 60 days before planting) to give sufficient time for the oxidation of organic matter. The untreated distillery spentwash also known as raw spentwash is acidic in nature (pH 3.5 - 4.0) and can be effectively used for the reclamation of non-saline sodic soil. Addition of effluent significantly increased the EC, organic carbon, available N, P, K, Ca and Mg contents as well as micronutrients in soil as reported.¹³³

Experiment conducted at Dharwad (Karnataka) in red soil, it was found that highest wheat grain yield was recorded when it was irrigated with 1:50 diluted spentwash compared to lower dilutions.¹⁵⁸

When primary treated DE is used for fertigation either as a 1-time pre-planting application in sugar cane or rice or used conjunctively with normal irrigation water at a dilution of 1: 20 or 1: 30 in sugar cane, coconut, cashew, and casuarina, addition of K is no longer necessary.⁹⁰

A field study was conducted to determine the effect of distillery effluent as irrigation water on the fertility of soil grown with wheat at a farmer's field beside the Sri Lakshmi Naryana Distillery Unit, Dharwad, Karnataka, India, during two consecutive rabi seasons of 1999-2000 and 2000-2001. The electrical conductivity and organic carbon content of soil increased with an increase in concentration of spentwash in irrigation water. Whereas, the reverse trend was observed with bulk density and reduction in bulk density is favorable trail for the sandy loam soil. However, pH of soil did not show marked change. Availability of N, P, K, Zn, Cu, Fe, and Mn in soil was more in plots irrigated with undiluted effluent which decreased progressively with an increase in dilution levels while, their uptake was more in 1:50 dilution level followed by irrigation with only bore well water as these two treatments produced maximum biomass and economic yield of wheat.¹⁵⁹

Utilization of anaerobically digested distillery effluents (DE) in agriculture represents a means to convert wastes to value added resource as it contains appreciable amounts of N, K and other macro and micronutrients required for crop growth and does not possess any toxic elements.¹⁶⁰ The higher concentration of
effluent was not advisable for irrigation purpose, however, it could be used for irrigation purpose after proper treatment and dilution (one part treated effluent and five parts of available irrigation water), as this dilution level was found to promote growth and yield. The impact of treated and untreated sago industry effluent on seed germination was studied.

From these reviews, it can be inferred that the distillery effluent could be used as a source of nutrient and water, provided good water for dilution is adequately available. Spentwash as a distillery waste is posing disposal problem. Spentwash contains many useful elements and can be profitably re-cycled to improve soil fertility. Spentwash treated optimally can be used as an effective fertilizer as well as irrigation source.

The results revealed that effluent treated by aerobic microorganisms can be effectively used for irrigation. From the above reviewed literature, it can be concluded that, the distillery spentwash could be safely used as a source of irrigation water provided dilution with water. Further, different crops responded to differently diluted distillery spentwash.

**2.4. EFFECT OF DISTILLERY SPENTWASH ON SEED GERMINATION, GROWTH, YIELD AND QUALITY OF PLANTS**

Cereals are long duration crops and require more amount of nitrogen. Nitrogen supply as and when required by the crop through spentwash can meet the crop requirement and also reduce the fertilizer cost. Spentwash contains reasonably good amount of phosphorus and as pulse crops require higher quantity of phosphorus but they are susceptible to salinity so to reduce the salt effect from spentwash ferti-irrigation appears to be good proposal for pulses. Oilseeds are the important component of agriculture. In India, oil seed production is less than the demand because of their less remunerative nature than other crops. Oilseeds require high amount of phosphorus and nitrogen, so if their requirement is met through spentwash in ferti-irrigation which can provide nutrients over a crop growth period, then oil seed production can be made more remunerative. Cash crops are of long duration and also require huge quantity of nutrients over a period of time. If nutrients are applied through spentwash in irrigation water, we can meet the nutrient requirement of the crops and helps to reduce the fertilizer cost and nutrient losses. A review of the past
work on use of spentwash in Cereals, pulses, oil seed crops, cash crops, vegetable plants and other plants in irrigation water is compiled here.

It was noticed that, increased yield uptake of nutrients in snap bean due to application of spentwash. Effluent concentration up to 5% was found beneficial for over all growth of Mung (Phaseolus radiatus), Pigeon pea (Cajanus Cajan) and Chickpea (Cicer arietinum).

The manurial value of distillery effluent can profitably be used as fertilizer when used along with irrigation water. The use of effluent water has indicated that 25% of the recommended dose of fertilizer nutrients can be saved in this way, which not only solve disposal problem but also substitutes some quantity of inorganic fertilizers. An increase in ash and K content of raw and clear cane juice and molasses by application of vinasse.

Pre-treatment of urea and rock phosphate fertilizers with brewery effluent, significantly increased the grain yield of ragi (Eleusine coracana) (34.73 g/pot) over untreated fertilizers (26.25 g/pot). The total annual application of potale (waste product of malt whisky distillery) of more than 100 m³ ha⁻¹ increased the dry matter yield of low land grass and grain yield of barley. Application of 220 m³ ha⁻¹ potale gave higher grain yield (5,000 kg ha⁻¹) over no potale applied plot (2,900 kg ha⁻¹). Number of ears per m² area and 1000 grain weight were also increased (554 and 42.9 g) over control (445 and 39.0 g). Crops of long duration require nutrients over longer period of time and spentwash meet the long-term nutrient requirement of the crops and thus help to reduce the fertilizer cost and nutrient losses. In sand culture studies, growth and chemical composition of sugarcane was not adversely affected by spentwash solids applied at 250 ppm but was detrimental at higher rates.

In a pot culture experiment, per-treatment of urea and rock phosphate with brewery effluent, significantly increased the grain yield of ragi (34.73 g/pot) over untreated fertilizers (26.25 g/pot). It was found that the availability of K from spentwash in different concentration (0, 75, 150, 225 and 300 mg/dm² soil) was similar to that of KCl and K₂SO₄. The less nodulation and no pods were produced in case of groundnut receiving raw distillery effluent. It was found that, application of 80 m³ ha⁻¹ vinasse alone considerably improved the yield of cane and sugar per hectare.
Significant increase in cane yield and recoverable sugar per hectare due to application of spentwash at the rate of 90 - 150 t ha\(^{-1}\) was observed\(^{102}\). The evaluation of stillage as a source of K for maize (Zea mays L.) in comparison with KCl and K\(_2\)SO\(_4\) was investigated\(^{104}\). The studies on irrigation of distillery waste on groundnut reported that, irrigation to groundnut plants with raw distillery waste water resulted in a reduction of nodulation and absence of fruit formation of the plant. This inhibitory effect was reduced when raw waste water was diluted to 50% by tap water\(^{165}\).

It was reported that irrigation of groundnut with raw distillery waste water resulted in the reduction of nodulation and absence of fruit formation of the plant. This inhibitory effect was reduced when raw waste water was diluted to 50% by tap water\(^{165}\). Pressmud compost @ 10 t ha\(^{-1}\) increased the maize and wheat yields by 129.4 and 65.2%, respectively\(^{166}\).

Brewery sludge residuals are approximately equivalent on a dry basis to fertilizer with an analysis of 3: 1: 0 (N: P\(_2\)O\(_5\):K\(_2\)O). It is estimated that a single application of 5 to 20 t/ha will increase overall hay yields over one year period by a factor of at least 5 times as compared to untreated hay fields\(^{107}\). The distillery effluent could be used as a complement to mineral fertilizer to sugarcane in Brazil\(^{109}\). An increased concentration resulted in retarded growth of the crops\(^{167, 112, \text{and} 168, 169}\).

The levels of vinasse increased cane and sugar yield, but reduced poll content, apparent purity, brix and sugar yield. The stand of leguminous intercrop with cane was reduced by vinasse applied at a very early stage of plant growth\(^{111}\). The distillery effluent contained N, P, K, Ca, Mg and S and thus valued as a fertilizer when applied to soil through irrigation water\(^{110}\). The effluent from lagoon, after dilution can be used successfully to irrigate sugarcane, wheat, barley and elephant grass and the only disadvantage is that it requires enormous water for dilution\(^{142}\).

The application of 25 times diluted distillery waste water irrigation was known to increases both fresh weight and dry yield of onion bulbs in clayey soil of Gujarat.

In laboratory experiments, effects of 9 conc. (range 1-100% v/v) of a mixture of fertilizer factory and distillery effluents on germination and seedling growth of P. radiatus [Vigna radiata] were studied. Germination percentage and speed of germination index increased with increase in the effluent concentration up to 5%. Seedling biomass and pigment contents increased with up to 10% concentration and...
carotenoid content increased with up to 30% concentration. The effluent mixture with up to 15% concentration was best for overall plant growth. The adverse effects of distillery effluent on growth parameters of wheat was studied and found a marked decrease in the growth parameter of wheat from non polluted station to the moderately polluted one. No plant could survive at highly polluted station.113

The application of vinasse at the rate of 120 m$^3$ per hectare accelerated cane ripening and increased cane and sugar yield per hectare. The increase in sugar yield was 2.07 tones per hectare over control.114

The application of vinasse at the rate of 120 m$^3$/ha accelerated cane ripening and increased the cane and sugar yield85. Effects of 1-100% concentration of distillery effluent on seed germination and seedling growth of C. Cajan cv. 5-16 were studied. Values for percentage germination, rate of germination, root length and seedling DW were highest in 5% effluent, while shoot length was maximum in 2.5% effluent.169

Lower concentration of the effluent increased seed germination and early seedling growth in cowpea; rice and sorghum while higher concentration retarded not only seed germination but also early seedling growth in all 4 species were observed. In soyabean s % germination and early seedling growth were markedly suppressed by increasing concentration of the effluent.64

In soyabean, the use of distillery effluent at any rate was found detrimental. Cymposistetragonoloba irrigated with 10 % distillery waste showed more nodulation. But higher concentration suppressed the nodulation and growth. The beneficial effect of application of vinasse (25,000-35,000 l ha$^{-1}$) to soil was found to increase the yield of sugar beet, potato and other vegetables by 20%.170

But for cowpea, black gram and mungbean up to 2.5 % concentration was found beneficial.171

The effects of 1, 2.5, 5, 10, 25, 50, 75 and 100% vinasse on the germination of pea, sunflower, Vicia sativa and lentil seeds was tested. Percentage germination and the rate of germination declined as the % of vinasse increased. Germination was non-existent or slight at 50% vinasse and there was no germination at 75 and 100%. The high BOD and the content of cell membrane cations in vinasse were considered responsible for its toxicity. While studying the impact of various concentrations (10, 25, 50, 75 or 100% v /v) of distillery effluent on growth of peas, found that shoot
length, leaf number per plant, leaf area, chlorophyll content and phytomass exhibited a gradual increase up to 25%. However, the effluent at all concentrations inhibited root growth. The number of pods per plant, seeds per pod and seeds per plant in peas increased up to 25% concentration, but seed chlorophyll content was highest (15.73%) with 10% concentration.  

A study on the effect of distillery effluent on seed germination, seedling growth and chlorophyll content in sunflower (Helianthus annuus L.) var. EC 68414 revealed decreased seed germination, seedling growth and chlorophyll content with increased effluent concentration. The application of 2.5% brewers spent grains (BSG) increased the plant height and dry matter of maize from 45.1 cm and 1.77 g/pot in the treatment receiving complete fertilizer (60:15:60:20 ppm of N:P:K:Mg/pot) to 68.3 cm and 5.12 g/pot.

Vinasse alleviates water stress particularly during ratooning and provides K, N, Ca and S. Vinasse application at 120 m$^3$ ha$^{-1}$ to dark red dystrophic latosol increased the cane yield from 57 to 88 t/ha. At another location vinasse increased the cane yield from 98 to 127 t ha$^{-1}$. 

The effect of 0, 22, 44 and 88 g of effluent per pot on growth of Augustine grass (Stenotaphrum secandatum) for 8 months. During the initial 4 months, S. secandatum dry matter yield was 60% higher with the 2 lower application rates than with the higher rate or in the control. At the end of 4 months the highest treatment had caused chlorosis and tissue drying. From all the reviews, it can be concluded that the distillery effluent could be safely used in crop production without any adverse effect on plant growth. Further, use of distillery wastes upto certain level has been found beneficial to growth and yield but indiscriminate use affected crops, soil and ground water.

While testing the possibility of improving the physico-chemical properties of a typical saline, calcareous soil by the application of spentwash, revealed that nutrient supplying status of soil improved considerably as evidenced by the performance of sugarcane grown on this soil.

Spentwash solids, farm yard manure and spentwash pressmud compost were equal in their effect and also found that spentwash pressmud compost was superior to other sources in respect of N, P, K, Fe and Zn uptake. The juice quality parameters
such as poll % and purity coefficient remained unaffected on addition of 500 m³ distillery effluent\textsuperscript{122}. The combination of 10,000 kg ha\textsuperscript{-1} distillery sludge along with recommended dose in finger millet improved the overall growth and registered significantly higher plant height, dry matter and yield (40 q ha\textsuperscript{-1}).\textsuperscript{175}

The moderate application of depottasified concentrated sugar beet vinasse (3-5 tha\textsuperscript{-1}) at sowing would not reduce seedling emergence of rye grass and would provide an effective fertilizer, with lower losses of N then it was applied prior to sowing\textsuperscript{176}. Higher sugarcane yield in CoC. 771 at 50, 40, 30 and 20 times diluted effluent irrigations than irrigated with normal water were registered\textsuperscript{121}. Application of concentrated beet vinasse with added P as organic fertilizer (4 and 9 tha\textsuperscript{-1}) on radish did not impair seedling emergence at either application rates. Further, both application rates increased fresh weight of root yields as compared with inorganic fertilizer treatments containing similar amounts of N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O. Field experiments were conducted to study the effect of one time application of treated undiluted distillery spentwash at 25, 50, 125, 250 and 500 tha\textsuperscript{-1} before planting. Results revealed that all the levels of spentwash addition recorded significantly higher cane yield than control. The highest cane yield of 155.80 tha\textsuperscript{-1} was recorded with the application of 125 t ha\textsuperscript{-1} followed by 250 tha\textsuperscript{-1} (148.90 tha\textsuperscript{-1}).\textsuperscript{123}

The higher dilution could be used for irrigation purpose without adversely affecting soil fertility. The higher dilution of effluent could be used for irrigation purpose without adversely affecting soil fertility and crop productivity. The effluent irrigations improved the physical and chemical properties of soil and increased soil micro-flora thereby ideal conditions for cane cultivation. Besides, the distillery effluent was considered as liquid manure and application resulted in an increased productivity of sugarcane and also sugar beet.\textsuperscript{123}

The results revealed that, 25% of the recommended fertilizer can be saved by going for irrigation with distillery waste water along with 75% of the recommended fertilizer application in onion. The total dry matter and yield obtained with 100% recommended dose of fertilizer application with normal water irrigation and further % utilization of applied N, P and K through fertilizer were more in distillery waste water with 75% fertilizer dose.\textsuperscript{76}
The effects were examined of different concentrations (10, 20, 40, 60, 80, and 100%) of effluent from the Doon Valley distillery in Uttar Pradesh, India, on the germination (percentage germination, germination value, and reduction in germination with respect to control (untreated) seeds) of 3 multipurpose tree species (Acacia catechu, Dalbergia sissoo and Morus alba) which grow abundantly under tropical and subtropical climatic conditions. Germination experiments were carried out in Petri dishes on filter paper moistened with water (control seeds) or with the appropriate concentration of effluent. Low effluent concentration (10%) enhanced the germination of all species relative to control values, but higher effluent concentrations (20-80%) increasingly inhibited germination; 100% effluent totally inhibited germination in all species.75

The effect of liquid effluents from a sugar factory and a distillery in the Seohara region of Uttar Pradesh on germination of Okra was studied. Germination tests were carried out using effluent: tap water ratios of 100:0, 75:25, 50:50, 35:65, 25:75, 15:85, 5:95 and 0:100 (control). Germination percentages increased from 75% with tap water to 90% with 25% effluent then fell markedly to 10% with 50% effluent, and 0% with 100% effluent. Both shoot and root length and FW, together with biomass and root DW were greatest with 25% effluent. Shoot DW was greatest with 50% effluent.177

Sugarcane responded well to compost application increasing cane yield by 126 % over absolute control. Nitrogen supply through urea at the recommended dose remained inferior to bio-compost but, was highly significant when applied in conjunction with biocompost. Also fodder maize yield increased by 12-13 % upon N and P application. However, an increase in fodder yield was much dramatic when it received 20 t ha\(^{-1}\) of bio-compost. On the other hand, application of both compost and nitrogen @ 20 kg ha\(^{-1}\), the response of crop was highly significant and resulted in saving of 100 % P\(_2\)O\(_5\) and K\(_2\)O besides nitrogen.178

Vinasse contains many useful elements and can be profitably recycled to improve soil properties (particularly in reclamation of saline-sodic soils) and increase crop yield while alleviating environmental pollution. Vinasse (2.5-3.5 t ha\(^{-1}\)) increased the yield of sugar beet, potatoes and other vegetables by 20%, but had adverse effect on legumes and no effect on rice.179
The irrigation of crops with distillery effluent had no adverse effect on the germination of wheat, maize, sorghum and cowpea. In fact, it had beneficial effect on the growth of all these crops as compared to irrigation with well water. Irrigation in standing crop of wheat was done with dilution of the effluent by bringing down the BOD to 500 mg per liter which was found to be safer for irrigation in wheat.\textsuperscript{148}

The highest sugarcane yield was with registered 10 times dilution when effluent amended along with the pressmud. But the quality parameters in sugarcane were not influenced due to diluted effluent irrigation. Further higher grain yield in wheat with 50 times and maize 10 times dilution of effluent irrigation. Twelve pre-sowing irrigations with the distillery effluent had no adverse effect on the germination and improved both the growth and yield.\textsuperscript{126}

Rice, Wheat, Black gram [\textit{Vigna mungo}], Green gram [\textit{V. radiata}], Pigeon pea [\textit{Cajanus Cajan}], Lentil, Mustard [\textit{Brassica juncea}], Soyabean, Maize and Chickpea [\textit{Cicer arietinum}] seeds were germinated in 0-100\% distillery effluent from a biogas plant. No seeds germinated in 100\% effluent. Maize, Rice, Mustard, Black gram, Pigeon pea, and Soyabean and Chickpea seeds germinated normally in 20\% effluent, whereas green gram seeds germinated normally in 50\% effluent. Wheat seeds were more sensitive and did not germinate at 50\% effluent. Germination of rice and lentils was greatly reduced at 50\% effluent.\textsuperscript{148}

The distillery effluent effect on \textit{Arachis hypogeal} L. seeds was studied. The effect of effluent on \textit{Arachis hypogeal} L. seedling growth, catalase activity, chlorophyll levels, 8 ALA content were studied. In higher concentrations on the germination as well as the growth of the seedlings was inhibited.\textsuperscript{180}

The application of distillery waste water up to 160 m\textsuperscript{3}ha\textsuperscript{-1} led to increase in dry matter production of Mungbean and further increase in level of distillery waste water led to increasing dry matter production. However, application of 640 m\textsuperscript{3}ha\textsuperscript{-1}, declined the dry matter drastically and was even less than the control.\textsuperscript{181}

Highest cane yield (182.8 tonnes) recorded when irrigated with distillery effluent diluted 50 times. However cane yield and juice quality decreased with an increasing concentration of the effluent in irrigation water.\textsuperscript{124}

Response was significant when 50 times diluted vinasse was applied and cane (188.1 t ha\textsuperscript{-1}) and commercial cane sugar yield (25.96t ha\textsuperscript{-1}) were 20\% higher than
control values (155.9 and 20.94tha⁻¹). Juice quality was better than control. The cane brix pol and purity were highest when applied with 32 t ha⁻¹, while the N: P₂O₅ ratio was lowest with 32 t per hectare.¹²⁵

Field experiments conducted to study the effect of fertilizer and pressmud on yield and quality of plant and ratoon sugarcane. Pressmud alone or in combination with nitrogen improved the cane yield and quality of plant and ratoon crops. Pressmud @ 30 t ha⁻¹ + 120 kg N ha⁻¹ increased the ratoon yield by 32 % over recommended dose (150:60:50 kg NPKha⁻¹). However, total cane production was 5.5 % higher with pressmud @ 30 t ha⁻¹ + 120 kg N ha⁻¹ compared with 150 kg + 60 kg P₂O₅ + 50 kg K₂O ha⁻¹. Sucrose and sugar contents (%) of plant cane were higher in the control plot. However, pressmud @ 30 t ha⁻¹ + 120 kg N ha⁻¹ recorded the highest sucrose and sugar (%) in ratoon crop. The total production of commercial cane sugar was 13.1 % higher when pressmud was applied @ 30 t ha⁻¹ + 120 kg N ha⁻¹ than RDF. A field experiment conducted at Padegaon revealed that the application of pressmud @ 12.5 t ha⁻¹ and 25 t ha⁻¹ to the first crop produced 41 and second crop 49 % more yield than the recommended dose of chemical fertilizers.¹⁴⁸

The comparative study of bi-seasonal crop with farmyard manure indicated that bio-earth was better than FYM in increasing grain yield. 20 % higher rice yield with simultaneous 25 % reduction in recommended doses of fertilizers.¹⁸² Wheat responded significantly to biocompost (pressmud with spent slurry and spentwash) application @ 15 t ha⁻¹ and an increase of 138 % yield was observed over control. Further, an increase in yield by wheat was observed when 50 % NP was added along with 15 tonnes of bio-compost.¹⁸³

It was found that application of the spentwash without dilution did not result in growth deformities or any alternation in plant metabolism. Significant increases in all plant growth attributes were observed. Further they noticed increased total chlorophyll, phenols, pigments, proteins, amino acids, starch and nitrogen contents in the leaves in treated plants.¹⁵⁰

It was found that maize crop tolerated with irrigation of five times dilution effluent. This dilution effluent irrigation had positive effect on crop growth and soil productivity. Plants with five times dilution effluent irrigation plots were significantly taller and other growth parameters were also on higher side than higher
dilution effluent irrigated plots. They concluded that effluent up to 1000 mg l\(^{-1}\) BOD can be safely used for irrigating maize which left a positive effect on soil fertility.\(^{153}\)

Application of diluted spentwash increased cane yield and nutrient uptake significantly over tube well water. They also observed increased P, K and S there by indicating the signs of improvement in soil properties. The application of spentwash diluted at any level resulted in increased sugarcane yield. Less diluted spentwash gave a greater yield of biomass than the more diluted ones\(^{82}\). In a field study, soil amended with diluted post methaned distillery effluent, an increase in the soil available N, P and K by pre-sowing irrigation with distillery was noticed. Further increased wheat and rice yield growing in sequence.\(^{127}\)

It was observed that, the oilseed crops like sesame, groundnut, soyabean and sunflower performed well under effluent irrigations. Higher seed yield of oil seed crops was obtained with effluent irrigation up to 30 times dilution than with normal irrigation. The oil content was not affected by effluent irrigation in sandy loam soil at coimatore.\(^{184}\)

The seedling emergence, plantlet growth and nutrient content of sunflower grown in pots, were not negatively affected by the application of moderate dosage of vinasse (equivalent to 2-3th\(^{-1}\)) at sowing or 30 days before sowing\(^{185}\). Distillery effluent [vinasse] from the sugar industry was found to lower the incidence on cotton [Gossipier hirsute LRA 5166] of two major sap-feeding insects: the plant louse Aphis gossypol, and whitefly Benicia tabaci. The incidence of bollworm [Helicoverpa] was also significantly decreased on cotton crops treated with an insecticide (fenvalerate, ml\(^{-1}\)) in combination with vinasse (2.5 or 5.0 ml\(^{-1}\)); the crop yield of seed cotton was significantly enhanced by this treatment, from 851 to 1270-1360 kg\text{ha}\(^{-1}\). The data suggest that raw vinasse, currently regarded as a serious environmental pollutant, could have significant agricultural potential, both as a fertilizer and as an insecticide.\(^{186}\)

The effects of 0-100% distillery effluent on germination of peas, Cicer arietinum and Phaseolus mungo [Vigna mungo] are tabulated. %age germination increased with up to 75% effluent in C. arietinum and peas and up to 50% effluent in P. mungo. Plumule and radical growth generally increased up to 50 or 75% effluent
concentration and then decreased. Root to shoot ratio decreased with increasing effluent concentration.187

The effect of vinasse application on soil properties and Durum wheat crop was studied. Vinasse was applied in a durum wheat crop by a trailed vinasse sprayer system compacting about 10% of the field. The experiment was carried out in Central Greece, on two soils (a clay and a silty clay loam) with three levels of vinasse rate (one fully covering N requirements of the crop, one covering half the N requirements, the rest covered by chemical fertilizers and a control without vinasse and use only of chemical fertilizers) and three times of application (Summer, Autumn before ploughing and Autumn before drilling). The middle strip of the plots was compacted by three passes of the tractor-trailed vinasse sprayer producing the compacted treatment. In the compacted plots, the yields were generally lower but in the wet years they were also significant. Yields were higher at higher vinasse rates and lower for the application before ploughing in the autumn, indicating an adverse effect of that treatment. Vinasse application significantly increased yields, while an adverse effect was observed for the applications before ploughing188. In a field study, soil amended with diluted post methanation distillery effluent increased the yield of wheat and rice growing sequence85.

A work on a reddish yellow latosol of Brazil found that pine apple fruit weight and yields increased with an increasing vinasse rate (0,100,200 or 400 m³ vinasse/ha as K source). Addition of K increased titrable acidity and total soluble salts in fruit. Most of the field crops, viz., sugar cane, rice, wheat and mustard showed positive response to biomethanated spentwash application along with irrigation water. Even after 20th irrigation with spentwash on specific fields, none of the crops showed any toxicity symptoms even up to 30 % concentration. The sugarcane crop receiving 9 irrigations followed by ratoon crop receiving 5 irrigations with 30 % concentration gave better yield as compared to normally irrigated crop130.

A 2-3 fold increase in yield observed when digested liquor was diluted and pumped during the dry season (December to July) to 400 ha of paddy field.85,129

Application of 25 tonnes bio-compost to the first crop produced 10.11 % higher cane yield than 100:100:50 N: P₂O₅:K₂O kg ha⁻¹. Later, the residual effect of bio-compost was marked in the first ratoon crop resulting in an increase in the P and
K contents in leaves and higher cane yield as compared with fertilizer alone. In the second ratoon crop, 25 tonnes bio-compost plus 75:50 N: P₂O₅ kg ha⁻¹ produced 36.11% higher cane yield than 150:100 N: P₂O₅ kg ha⁻¹. Application of 25 tonnes of bio-compost thus resulted in saving all K and half N and P with a significant increase in yield over fertilizer treatment.¹⁸⁹

Field experiments were conducted on a calcareous alluvial sandy loam soil to study the effect of sulphitation pressmud (SPM) and nitrogen on yield and quality of sugarcane. The application of SPM and nitrogen increased the yield of sugarcane as well as uptake of NPK and sugar yield significantly. Commercial cane sugar % increased significantly with SPM up to 4 t ha⁻¹ but, decreased non-significantly with increasing levels of nitrogen.¹⁹⁰ An increased yield of groundnut (1702 kg ha⁻¹ average for two seasons) was noticed in treatment receiving 2.5 t bio-compost along with recommended fertilizer in red sandy loam soil of Tamil Nadu during kharif season.¹⁹¹ The response of maize to distillery effluent was studied and found that there was an increase in dry matter production, growth parameters, chlorophyll content, yield and yield attributes as compared to control.¹⁹²

The effect of distillery effluents, applied at 1, 5, 10, 15, 20 and 100%, on Phaseolus aureus [Vigna radiata] and Pennisetum typhoids [Pennisetum glaucum] was studied under laboratory conditions. No germination was observed in seeds irrigated with 100% effluent, while control seeds exhibited 100% seed germination. Irrigation with 1% effluent gave the highest values for germination percentage (77.73 and 100%), shoot length (10.34 and 12.10 cm), root length (2.98 and 7.30 cm), and vigour index (1035 and 1940) for Phaseolus aureus and Pennisetum typhoids, respectively¹⁹³. The effect of Pondicherry distillery effluent on the growth, biochemistry and yield of Vignamungowas studied. All the parameters studied showed an increase over control in 10 and 25% concentrations. The higher concentrations (50, 75 and 100%) were found to reduce growth and yield.¹⁹⁴

The effects of distillery factory effluents (0, 25, 50, 75 and 100%) on the seedling germination and growth of Glycine max cv. PK-472 were determined. Seed germination, hypocotyl length, radical length, epicotyls length, and fresh and dry weight of selected seedlings increased with 25% effluent treatment and decreased with further increase in the effluent concentration. The fresh and dry weight of cotyledons increased with increasing concentrations of effluents.⁸⁶
It was noticed that, the application of spentwash at a rate of 150 tha\(^{-1}\) produced higher grain yield of maize (5.85 tha\(^{-1}\)) and sunflower (2.42 tha\(^{-1}\)) than other higher or lower rates and these yield levels were even significantly higher than recommended dosage of fertilizers.\(^{195}\)

Field experiments were conducted during 1999-2000 in Tamil Nadu, India, to determine the optimum dilution of distillery effluent mixed with irrigation water (1:10, 1:20, 1:30, 1:40 and 1:50) for its direct application to sugarcane. Increases of 5, 8, 13, 17 and 19 t/ha of cane yield were recorded in the dilutions of 1:50, 1:40, 1:30, 1:20 and 1:10, respectively, in sandy loam soil.\(^{131}\)

Application of vinasse to permanent grassland in Romania, at the rate of 4 to 7 t per hectare in a 1:5 water dilution increased yield by 50 to 181 %. Application also improved nutritive value of the fodder by increasing crude protein, potassium, calcium and decreasing crude cellulose, phosphorus and magnesium.\(^{196}\)

Most of the field crops, viz., sugarcane, rice, wheat and mustard showed positive response to biomethanated spentwash application along with irrigation water. Even after the 20\(^{th}\) irrigation with spentwash on specific fields, none of the crops showed any toxicity symptoms even up to 30 concentrations. The sugarcane crop receiving 9 irrigations followed by ratoon crop receiving 5 irrigations with 30% concentration showed better yields as compared to normally irrigated crop. The kharif crops like maize and rice responded well to biomethanated spentwash irrigation even up to 40% level. Stress symptoms were visible in case of wheat crop at 40 % biomethanated spentwash applied for three years.\(^{132}\)

The results indicated that pre-plant application of post-methanated spentwash (PSW) can supplement part of N, P and complete K requirement of Sugarcane\(^{197}\). Irrigating the PSW at 1:30 dilution with well water at 40 days interval increased cane yield, however, decreasing the dilution rate (1:20 and 1:10) had an adverse effect on yield\(^{198}\). Bioassay studies were carried out to assess the toxicity of distillery effluent on seed germination, seedling growth and pigment contents. Higher concentrations of effluent were found to be toxic but however, can be used for irrigational purpose after proper dilution.\(^{199}\)

The effect of different concentrations of raw distillery effluent on root growth, cell division, chromosome structure and nuclear materials in the root meristematic
cells of Allium cepa was studied. The distillery effluent was applied at 0.1, 0.5, 1, 5, 10 and 20%. The rate of root growth per day decreased with increasing distillery effluent concentration. The number of developing roots also decreased as the concentration of the distillery effluent also increased. In the distillery effluent-treated roots, the cells developed deformities in chromosome morphology and irregularities during mitosis.200

Studies were made to assess the impact of distillery effluent on seed germination, and seedling growth (root and plumule length), of Bengal gram, Cicerarietinum Linn, at various concentrations for different days, respectively. There was increment in above parameters at lower concentrations (10%, 20% & 40%) while a decrement was observed at higher concentrations (60%, 80%, and 100%) after exposure.201

Germination studies were conducted in the laboratory to investigate on the growth of Cicerarietinum. Seeds of Cicerarietinum exposed to the concentration of effluent (10 to 50%) and concentration of leachate of flash light factory sludge (5%) of 20% was found to be beneficial for the growth of root and shoot as compared to control. However, the concentration of effluent/leachate 100% was found to be inhibitory202. The effect of distillery spentwash on the physico-chemical characteristic of distillery effluents and the effect of its various concentrations on the seed germination of Helianthus annus Cv Ec 68413 in Western Uttar Pradesh was studied. It was found that the seed germination decreased drastically with the application of distillery waste.203

The fertilizing efficiency of vinasse in a pot on sandy soils in green house was observed and found that the addition of vinasse within all tested rates (0.5%, 1% and 2%) resulted in significant increase in both grain and straw yield as compared to control treatment. However, there was no significant difference in wheat yield between fertilizer and vinasse treatments. Vinasse applied in irrigation water (2%) caused highly significant increase in wheat grain yield (the total amount of irrigation water was 13.5 l/plot along the period of plant growth).78

A field experiment with groundnut as test crop was conducted to evaluate the manurial potential of three distillery effluents: raw spentwash (RSW), biomethanated spentwash (BSW) and lagoon sludge (LS) vis-à-vis recommended fertilizers
(NPK + farm yard manure (FYM)) and a control (no fertilizer or distillery effluent). It was found that all the three distillery effluents increased total chlorophyll content, crop growth rate (CGR), total dry matter, nutrient uptake (N, P and K) and finally seed yield compared to the control but inhibited nodulation and decreased nitrogen fixation. Among the three distillery effluents, BSW produced the highest seed yield (619 Kg/ha) twice that of control (3.10 Kg/ha), followed by RSW (557 Kg/ha) and LS (472 Kg/ha). However, the distillery effluents did not influence protein and oil contents. It was concluded that these distillery effluents because of their high manurial potential could supply nutrients, particularly potassium, nitrogen and sulfur, to the crops and thus reduce the fertilizer requirement of crops. Nevertheless, the crop performance and yield with three distillery effluents were overall less than that produced by recommended NPK + FYM probably on account of failure of the effluents to supply balanced nutrition to the plants for achieving their potential growth capacity.204

A laboratory experiment was conducted to study the effect of different concentrations (0%, 5%, 10%, 15%, 20%, 25%, 50%, 75% and 100%) of distillery effluent (raw spentwash) on seed germination (%), speed of germination, peak value and germination value in some vegetable crops: Tomato, Chills, Bottle gourd, Cucumber and Onion. The distillery effluent did not show any inhibitory effect on seed germination at low concentration except in tomato, but in onion the germination was significantly higher (84%) at 10% concentration as against 63% in the control. Irrespective of the crop species, at highest concentrations (75% and 100%), complete failure of germination was observed. The speed of germination, peak value and germination value also followed a similar trend. We found that a concentration of 5% was critical for seed germination in tomato and bottle gourd, and 25% in the rest of the crops. Based on the tolerance to distillery effluent, the crops studied have been arranged in the following order: Cucumber>Chilli>Onion>Bottle gourd>Tomato. Effect of the distillery effluent is crop-specific and due care should be taken before using the distillery effluent for pre-sowing irrigation purposes.205

The effects of the distillery byproducts vinasse, flegmass and fusel oil on the germination of S. rhombifolia and B. decumbens seeds were studied under laboratory conditions. Byproduct concentrations (12.5, 25.0, 50.0 and 100.0%, v/v) and the control (water with pH and osmolality amended according to byproduct composition...
and levels) were applied directly on plastic boxes filled with 100 seeds of the same species. S. rhombifolia seeds failed to germinate when treated with fusel oil. B. decumbens seeds exhibited reduced seed viability and germination speed index when treated with the highest rate of flegmass and failed to germinate when treated with fusel oil.\(^{206}\)

In two years experiment conducted at Dharwad (Karnataka) in red soil, highest wheat grain yield was recorded when irrigated with 1:50 diluted spentwash compared to lower dilutions, where significantly lower yield (10.6 q ha\(^{-1}\)) was recorded.\(^{88}\)

In two years experiment conducted at Dharwad (Karnataka) in red soil it was found that highest wheat grain yield was recorded when it was irrigated with 1:50 diluted spentwash compared to lower dilutions. Where as significantly lowest grain yield of 10.56 q ha\(^{-1}\) was recorded with undiluted effluent. The effect of dye and distillery effluents on germination of some crops were studied and found that inhibited germination of Solanum melongena, Pisum sativum, S. lycopersicum [Lycopersicon esculentum], Triticum aestivum, Zea mays and Abelmoschus esculentus grown in Panipat, Haryana, India. Sugar mill effluents negatively influenced seedling morphology.\(^{207}\)

A field investigation was carried out in Karnataka, during winter seasons of 1999-2000 and 2000-01 to study the effect of conjunctive use of spentwash and water on maize yield and soil properties. The treatments included six dilutions levels. The results indicated that dilution levels of 1:5 and 1:10 were found optimum to realize significantly higher grain yield of maize (76.82 and 75.01 q/ha, respectively) than other treatments. The effects of graded distillery effluents on wheat (cv. DWR 162) nutrient content, nutrient uptake, yield were investigated during 1999 to 2001 (two rears) in Dharwad with diluted effluent (1:5, 1:10, 1:25 and 1:50), undiluted effluent and pure bore well water.\(^{208}\)

In crop total nutrient uptake and crop yield (52.59 q ha\(^{-1}\)) were highest with 1:50 dilution and undiluted effluent treatment produced the lowest yield. In the field experiment conducted at U.A.S. Dharwad using spentwash in ferti-irrigation where in, 40% of P\(_2\)O\(_5\) requirement of maize crop was applied before sowing through spentwash and remaining 60 % P\(_2\)O\(_5\) was applied in three splits before flowering. It was found that application of recommended P\(_2\)O\(_5\) (1 P) through spentwash recorded
significantly higher yield (51.80 q ha\(^{-1}\)) and it was on par with 1P through fertilizer. Response was observed similarly in experiments at different locations\(^{209}\). Irrigation of primary treated spentwash at 5 cm depth to soyabean and 2.5 cm depth to wheat is optimum from yield salinity and sustainability point of view.\(^{210}\)

In a field experiment conducted during the rainy season in Bhopal revealed that, distillery effluents (biomethanated and raw spentwash) did not affect the oil content (%), crude and true protein contents (%) in groundnut but increased the seed yield. Biomethanated spentwash produced the highest seed yield (619 kg ha\(^{-1}\)) followed by raw spentwash (557 kg ha\(^{-1}\)) and these yield levels were higher than the recommended levels of NPK.\(^{211}\)

In the field experiment conducted at U.A.S Dharwad using spentwash in ferti-irrigation where in, maize receiving 40 % of P\(_2\)O\(_5\) before sowing and remaining 60 % P\(_2\)O\(_5\) was applied in three splits before flowering. It was found that application of recommended P\(_2\)O\(_5\) (1P) through spentwash recorded significantly higher yield (51.8 q ha\(^{-1}\)) and was on par with 1P through fertilizer. A similar response was observed in experiments at different locations.\(^{209}\)

A significant difference was observed among the dilutions with respect to grain yield. A grain yield of 76.8 q per ha was recorded with irrigation by lower dilution 1:5 as compared to remaining dilution levels and an increase of 14.7 % over grain yield at treatment irrigated with good water. A similar effect was observed in terms of number of rows per cob and also test weight and maize yield as a result was significantly higher compared to farmers practice. This was as good as application of chemical fertilizer on the equivalent basis.\(^{212}\)

In a fifteen year old vineyard of Pinot Noir at a density of 5000 vines per hectares, located in the DOC zone Oltrepo Pavese, the influence of growing doses of distillery vinasses on vegetative growth, leaf mineral levels, grape yield and quality was tested in a four year period. Doses of vinasse were computed to apply 0 (test), 50, 100, 150 kg N ha\(^{-1}\). Vinasse doses were factorially combined with three levels of urea (0, 50 and 100 kg N ha\(^{-1}\). In plots without vinasses supply, ureic nitrogen reduced the number of blind buds and increased the potential and actual bud fertility. The application of vinasses nitrogen had a similar result, even if ureic and vinasses nitrogen had no additive effects. The most profitable grape yield was obtained by
application of 50 kg ha\(^{-1}\) of nitrogen either in urea or in vinasses forms. Highest vinasses supply improved the ripening levels of grapes increasing sugars and reducing acidity of juice. Results clearly show the possibility to use vinasses for proper vineyard fertilization.\(^{213}\)

Continuous pre-sowing application or fertigation with 200 m\(^{3}\)ha\(^{-1}\) secondary treated biomethanated spentwash to sugarcane improved the growth and yield, reduced soil pH, and slightly increased soil EC, considerably increased OC, soil available N and K.\(^{214}\) The sugar mill based distillery effluent has become a challenge for environmental protection. It is necessary to deal with this effluent in an eco-friendly and cost-effective way. The sugar mill based distillery effluent was mixed with other fertilizers to form liquid fertilizer, which was applied to sugarcane (Saccharum officinarum). The liquid fertilizer was applied at a rate of 7.5, 15 and 22.5 th\(^{-1}\), which increased the yield of sugarcane by 2.4, 5.915 and 7.543 t ha\(^{-1}\), respectively with a growth rate of 3.29-10.34\%, and increased the yield of sugar by 0.99, 1.165 and 1.368 tha\(^{-1}\), respectively, with growth rate of 10.18-14.07\%. A significant economic benefit of applying the liquid fertilizer was observed.\(^{215}\)

The effects of spentwash, compost, and inorganic fertilizers on the micronutrient contents of turmeric (cv. Erode Local) were studied in Sathyamangalam, Tamil Nadu, India, during 2001-02. The treatments were: 2.5 t Biocompost\(^{\text{ha}^{-1}}\) + 75\% of the recommended NPK rates (T1); 2.5 t Biosuper + 75\% NPK (T2); 2.5 t Biocompost + 100\% NPK + micronutrients (T3); 2.5 t Biosuper\(^{\text{ha}^{-1}}\) + 100\% NPK (T4); untreated control (T5); treated spentwash at 50 kl ha\(^{-1}\) as basal + 2.5 t Biocompost\(^{\text{ha}^{-1}}\) + 75\% NP + micronutrients (T6); and treated spentwash at 50 klha\(^{-1}\) as basal + 2.5 t Biosuper\(^{\text{ha}^{-1}}\) + 75\% NP (T7). The fertilizers significantly enhanced the micronutrient (Zn, Cu, Mn and Fe) contents of the plant. T7 resulted in the highest Zn (29.7 and 19.4 ppm), Cu (7.8 and 4.1 ppm) and Fe (265.7 and 164.7 ppm) contents of vegetative parts and rhizomes; and Mn content of vegetative parts (69.9 ppm). The highest rhizome Mn contents were obtained under T4 (34.2 ppm), T6 (34.1 ppm) and T7 (34.3 ppm).\(^{216}\)

The effects of sugar and distillery wastes, compost, and inorganic fertilizers on the yield and quality of turmeric (cv. Erode Local) were studied in Erode district, Tamil Nadu, India, during 2001-02. The treatments consisted of: 2.5 t Biocompost + 75\% of the recommended NPK rates (125, 60 and 90 kg ha\(^{-1}\), respectively) +
micronutrients \((30 \text{ kg FeSO}_4 \cdot 4\text{ mole} + 15 \text{ kg ZnSO}_4 \cdot 4\text{ mole})\); 2.5 t Biosuper/ha + 75% NPK; 2.5 t Biocompost + 100% NPK + micronutrients; 2.5 t Biosuper/ha + 100% NPK; treated spentwash at 50 klha\(^{-1}\) as basal + 2.5 t Biocompost ha\(^{-1}\) + 75% NP + micronutrients; treated spentwash at 50 klha\(^{-1}\) as basal + 2.5 t Biosuperha\(^{-1}\) + 75% NP; and untreated control. The highest available N content was obtained with the application of treated spentwash + Biocompost + 75% NP + micronutrients. The available P and K contents of soil were highest with treated spentwash + Biosuper + 75% NP (T7). Spentwash, Biocompost and Biosuper significantly enhanced the yield, yield components and quality over the control. T7 resulted in the highest number of mother rhizomes per plant (3.8), number of primary rhizomes per plant (17.3), number of secondary rhizomes/plant (22.5), weight of mother rhizomes (8312.5 kg ha\(^{-1}\)), weight of finger rhizomes (21 202.5 kg ha\(^{-1}\)), rhizome yield (29 515 kg ha\(^{-1}\)), harvest index (74.0%), and cur cumin (4.1%), oleoresin (9.2%) and essential oil (2.6%) contents.\(^{217}\)

The physicochemical parameters of distillery effluent and the effects of various concentrations (25, 50, 75 and 100% v/v) on seed germination, seedling growth and root merited cells of Vigna radiata were investigated. The effluent was alkaline with high BOD and COD contents, total dissolved solids and total suspended solids. The germination in 25% concentration was found to be maximum (100%) as compared to 75 and 100% concentrations of effluent, which were found to be inhibitory (50 and 30%, respectively). Mitotic index increased at lower concentrations of the effluent but the frequency of abnormalities increased with increasing concentrations. The highest frequency of abnormalities was found at 100% effluent concentration (58.2%), and the lowest at 25% effluent concentration (0.8%). The distillery effluent induced various types of chromosomal aberrations, namely stickiness, ring metaphase, multinucleate cells, anaphasic bridge, laggards and multipolar cells. The reduction in seedling growth and mitotic index and increased chromosomal aberrations revealed that constituents of distillery effluent at higher concentrations exhibited deleterious effects on crops. If the effluent is diluted, it can be used as liquid fertilizer for irrigating crops.\(^{218}\)

Petri-dish experiment was conducted to study the effect of different concentrations of distillery effluent on pulses. The higher concentration of the different elements (already present in effluent), BOD and COD affected the seed
germination, seedling growth and ultimately plant growth and yield. The Petri dish experiment, using effluent of one of the distillery of Lucknow region, on seed germination and seedling growth in pea and black gram revealed that potassium content of distillery effluent adversely affected seed germination, seedling growth (radical and plumule size), number of lateral roots, total chlorophyll, total amylase, fresh weight, dry weight, moisture content and water absorption. Therefore, the higher concentration of effluent was found to be toxic, but can be used for irrigation purpose after proper treatment and dilution.219

Incorporation of spentwash treated biocompost alone or in combination with N and P fertilizers markedly improved the growth and yield of maize and wheat. The grain yield of wheat recorded highest when biocompost was applied at the rate of 5 t/ha with 50 % N and P fertilizers. The cob yield of maize was highest when biocompost was applied at the rate of 5 t/ha with 50% N and P fertilizers which was at par with the treatment 2.5 t/ha biocompost with 75% N and P69. To assess the optimum dilution of post-methanation distillery effluent, a rich source of organic potassium nutrient, two sets of fixed plot experiments were conducted for two consecutive years during 2001-03 with rice (Oryza sativa) and wheat (Triticum aestivum) as test crops grown in sequence. Dilutions of distillery effluent with irrigation water significantly affected the grain yield as well as biomass production. The highest yield recorded in plots treated with pre-sown distillery effluent at 20 m³ha⁻¹ along with 60 kg Nha⁻¹ in 2 split doses. The status of electrical conductivity (0.26-0.33 dSm⁻¹), organic carbon (0.27-0.32%), N (138-172 kg ha⁻¹) and K (117-202 kg ha⁻¹) was significantly increased in effluent-treated soils over the control. An experiment was carried out with Indian mustard during the crop season of 2004-05 and 2005-06 in Bagpat, Uttar Pradesh, India, comprising 10 treatments: control, farmyard manure (FYM) at 5 t ha⁻¹, distillery effluent and pressmud compost (DEPC) at 1, 2 and 3 t ha⁻¹, FYM+DEPC at 3 t ha⁻¹, FYM+DEPC at 2 t ha⁻¹, FYM+DEPC at 1 t/ha, and N at 40 and 60 kg ha⁻¹. The DEPC, FYM, combinations of DEPC+FYM and inorganic fertilizer significantly increased the seed yield, biological yield and quality content of Indian mustard. Among the various treatments, application of FYM+DEPC at 3 t ha⁻¹ recorded the highest seed yield, biological yield and all the quality contents (oil, protein, nitrogen and sulfur contents in seeds, and N content in seed and Stover) in both years.220
Pot culture experiment was conducted to study the effect of distillery spentwash (dilutions of 25, 50, 75 and 100 times) on seed germination, seedling growth and yield of Bhendi. The results revealed that application of spentwash diluted at higher level (50 T) has increased germination percentage (74%), growth (47 cm) and fruit yield (264 g/pot) over control. Less diluted spentwash (50 T) gave higher yield (264 g/pot) of fruit than concentrated one (188 g/pot).  

A laboratory work was undertaken to assess the waste water quality parameters of treated distillery effluent and their effect of various concentrations like 0%, 25%, 50%, 75% & 100% on seeds germination, speed of germination, peak value and germination value of three selected seeds i.e. Wheat (Triticum aestivum), Pea (Pisum sativum) and Lady Finger (Abelmoschus esculentus). Germination percentage decreases with increasing concentration of effluent in all the tested seeds, where as the germination speed, peak value and germination value increases from control to 25% and 50% concentration and decreases from 50% to 75% and 100% effluent.

The industrial effluents, treated distillery and sugar factory mixed effluent was used in Petri dish culture experiments to investigate its effect on seed germination and seedling growth in Wheat, Garden pea, Black gram and Mustard. The seed germination and seedling growth were significantly reduced with increase in concentration of the effluent. The fresh matter was found significantly increased in barley (1.16 g/seedling in 25% dilution level of effluents in comparison to 0.93 in control), while other higher dilution levels reduce it. Wheat, garden pea, black gram and mustard invariably showed inhibition in fresh weight. Dry weight was found consistently reduced or unchanged in different treatments. Total chlorophyll contents in barley were significantly increased in different treatments (2.351 and 2.721 mg/g fresh weight of tissue at 25, 50% dilution levels in comparison to 1.781 of control) while in other crop it was reduced in all the treatments. Based on the data of different crops barley was found to be highly tolerant as the 25 and 50% dilution levels of combined effluents. It showed no change in germination percentage, while seedling growth was increased in lower dilution levels of combined effluent as compared to control. Barley>Garden pea>Wheat>Black gram>Mustard gradually showed increased level of sensitivity respectively. Most detrimental effects were seen in mustard.
A field experiment was conducted during 2001-02 and 2002-03 at Research Station, Vallabh Nagar (Udaipur, Rajasthan), to study the effect of pressmud (0.5, 10, 15 t ha\(^{-1}\) and spentwash (0, 2.5, 5.0, 7.5 lac l ha\(^{-1}\)) with phosphogypsum (0, 25, 50% GR) on wheat productivity. The highest wheat grain yield was recorded with the treatment phosphogypsum at 25% GR alone or with either pressmud (15 t ha\(^{-1}\)) or spentwash (7.5 lac l ha\(^{-1}\)). Incorporation of phosphogypsum beyond 25% GR had no significant effect on grain as well as straw yield of wheat. Incorporation of soil amendment increased the net returns and B:C ratio of wheat crop. The net returns and B: C ratio was under phosphogypsum at 50% and 25% GR, respectively, alone or with either spentwash at 7.5 lac l ha\(^{-1}\) or pressmud at 15tha\(^{-1}\). A field study conducted for two years (2003-05) on sandy-loam soil at New Delhi showed that seed yield (1.80 t ha\(^{-1}\)) of oleiferous rocket salad (Eruca sativa Mill.) obtained with distillery pressmud-distillery effluent compost @ 5 tha\(^{-1}\)+half the recommended dose of NPKS (60 kg N, 13.1 kg P, 25.0 kg K and 20 kg Sha\(^{-1}\)) was on a par with the seed yield (1.69 tha\(^{-1}\)) recorded with the recommended dose of NPKS. The seed yield recorded with former treatment was significantly superior to that with fly ash-distillery effluent mixture (1:1) @ 5 tha\(^{-1}\)+half the recommended dose of NPKS by 30.4% and litter-fall of jatropha (Jatropha curcas) @ 5 tha\(^{-1}\)+half the recommended dose of NPKS by 24.1\%.\(^{223}\)

The effects of various concentrations of distillery effluent (0, 5, 10, 25, 50, 75 or 100 ml/l) on V. mungo (cultivars T-9 and ADT-1) seed germination and seedling growth were studied under laboratory conditions. The number of seeds that germinated in Petri dishes containing the effluent was evaluated daily for seven days at 28±2\(^{\circ}\)C. The values of the germination and growth parameters decreased as the concentration of the effluent increased. In T-9 and ADT-1, the 5% distillery effluent resulted in the highest seed germination percentage (100 and 97%, respectively), speed of germination index (717 and 688), vigor index (1378.15 and 1190.25), tolerance index (0.975 and 0.950), root length (9.14 and 8.36 mm), lateral root length (11.64 and 9.72 mm) and shoot length (10.89 and 10.16 mm).\(^{224}\)

Wheat (Triticum aestivum) seeds were kept in Petri dishes on double layer of filter paper saturated with different concentrations of digested distillery effluent under laboratory conditions. Lower concentrations of effluent were not inhibitory (10 and 20%) to seed germination, while higher concentrations (75 and 100%) of effluent led
to complete failure of seed germination. In another experiment, seeds were soaked in different concentrations of effluent for different time interval and germination was studied on 1% agar plates. % germination and speed of germination increased with increase in soaking time at lower concentrations of effluent but decreased at higher concentrations of effluent when seeds were soaked beyond two hours. In pot house experiment also, lower concentrations of the effluent were not inhibitory to seed germination but higher concentration (50%) of effluent suppressed and delayed germination. The higher concentration of effluent was inhibitory to plant growth when plants were irrigated before germination followed by when always irrigated with effluent after germination. Plant growth was completely suppressed when 50% effluent concentration was used for irrigation throughout the experiment. However, when plants were irrigated after germination at every 20 days interval, maximum plant growth was obtained in 50% effluent concentration (comparable to 100% RDF) followed by 20% effluent concentration (comparable to 75% RDF). Significantly higher plant growth was also obtained when plants were irrigated with 10% effluent concentration always after germination.225

Experimental effects of untreated (Raw) distillery effluent, discharged from a distillery unit (based on fermentation of alcohol from sugarcane molasses), and the post-treatment effluent from the outlet of conventional anaerobic treatment plant (Treated effluent) of the distillery unit were studied in Mung bean (Vigna radiata, L.R. Wilczek). Mung bean is a commonly used legume crop in India and its neighboring countries. Mung bean seeds were presoaked for 6 h and 30 h, respectively, in different concentrations (5–20%, v/v) of each effluent and germination, growth characters, and seedling membrane enzymes and constituents were investigated. Results revealed that the leaching of carbohydrates and proteins (solute efflux) were much higher in case of untreated effluent and were also dependent to the presoaking time. Other germination characters including percentage of germination, speed of germination index, vigor index and length of root and embryonic axis revealed significant concentration-dependent decline in untreated effluent.226

The effluent from a Lucknow-based distillery (Mohan Meakin Distillery) was analyzed for physico-chemical and biological parameters of pollution and concentration of potentially toxic heavy metals (Cd, Cr, Ni and Zn) and the effect of
the distillery effluent, as such and on 50% dilution with tap water was studied on seed germination and seedling growth of maize (Zea mays L.) and rice (Oryza sativa L.). Use of the distillery effluent, even on 1:1 dilution with tap water, inhibited germination and early seedling growth of maize and rice. In both maize and rice, more so in the former, germination % of seeds, length of radical and plumule and the fresh and dry weight of the seedlings were significantly reduced. The emerging leaves of the seedlings also developed visible effects of toxicity, some of which resembled the symptoms of nickel toxicity.95

Experiments were carried out to study the effect of distillery sludge amendments with garden soil (10, 20, 40, 60, 80 and 100%) on seed germination and growth parameters of Phaseolus mungo L. Germination percentage and index values decreased with rise in sludge concentration. Soil amended with 10% (w/w) sludge showed favorable growth while >10% was inhibitory for plant growth. Soil amended with 10% (w/w) distillery sludge induced the growth in root length, shoot length, number of leaves, biomass, photosynthetic pigment, protein and starch while 20% (w/w) sludge amended soil had variable effects on the root, shoot, leaves and nodules of P. mungo L. At concentrations (>40%) reduced all the growth parameters, viz., root length, shoot length, number of leaves, biomass, photosynthetic pigment, protein and starch of P. mungo. Malondialdehyde (MDA) product of lipid peroxidation was also enhanced in both root and leaves of sludge amended soil grown P. mungo at all the sludge amendments and exposure periods. A coordinated increase in cysteine, non-protein thiol and ascorbic acid antioxidants was up to 40 days of growth. After this period a decrease was observed. The N, P, K and Mg accumulation followed the order shoot > leaf > root. Calcium accumulation was highest in the upper part of the plants (including shoot and leaves). Furthermore, heavy metals content were also increased in different parts of P. mungo grown on increasing concentration of sludge amended garden soil with time. Zinc and copper accumulation was maximum versus other heavy metals. Based on these studies, sludge having concentrations <=10% (w/w) can be applied as a fertilizer.227

The impact of treated and untreated sago industry effluent on seed germination was studied. The study of seed germination (maize and green gram) was carried out at 25, 50, 75 and 100% concentrations of treated and untreated effluent using soil sowing method. Shoot length, root length, fresh weight, dry weight and chlorophyll
content showed an increase when treated effluent was tested whereas a decrease of growth was noticed in untreated effluent tested seedlings.\(^{93}\)

Four decades of investigations unequivocally demonstrated that utilization of treated distillery spentwash enhances crop productivity, soil fertility besides saving considerable amount of inorganic fertilizers.

2.5 EFFECT OF DISTILLERY SPENTWASH ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

Vinasse as an industrial waste is a problem for getting it disposed from sugar industries. Vinasse contains many useful elements and can be profitably recycled to improve soil fertility. Spentwash treated optimally can be used as an effective fertilizer as well as irrigation source. This not only benefits farmers by increasing yields, but also removes heavy financial burden on the sugarcane processing companies. Land disposal of spentwash is practiced as an alternative for reducing pollution, as its application in agricultural fields improves almost all factors involved in soil fertility. Regular application of distillery effluent has adverse effect on soil properties viz., infiltration rate, hydraulic conductivity, water retention capacity, electrical conductivity, pH, availability of nutrients in the soil and also results in adverse effect on microbial population and microbial biomass which might alter the soil fertility status. Some of the reviews on these aspects are covered in this section.

Physical properties

Changes observed in hydraulic conductivity, aggregate stability and improvement in infiltration rate by addition of distillery slops to a column of saline-sodic soil.\(^{228}\)

Inorganic forms of soil nitrogen constituted less than 2 % of total N implying that the major portion of nitrogen is bound in organic combination.\(^{229}\)

Reports reveal the effect of organic residue application on nitrate production. It can be generalized from their studies that residue with wide C: N ratio initially immobilizes nitrogen from the soil and releases nitrate later when mineralization sets in. High nitrogen containing residues initially liberate substantial quantities of
nitrogen in available form followed by a lower rate of mineralization with the progress of decomposition.\(^{230}\)

It was observed that, the changes in hydraulic conductivity, aggregate stability and improvement in infiltration rate by addition of distillery slops and molasses to column of saline sodic soil\(^{110a}\). The infiltration rate in soil was reduced due to crust formation on surface layer and restricting the movement of water due to clogging of pores by application of distillery effluent.\(^{231}\)

Application of spentwash increased pH, EC, cations, anions, sodium adsorption ratio (SAR), potassium adsorption ratio (PAR), exchangeable Na and K and exchangeable Ca and Mg. A significant rise in COD of saturated paste extract was observed. The physical properties of soil like water retention, hydraulic conductivity and water stable aggregates were adversely affected with irrigation of distillery effluent. The soil physical properties like water retention, hydraulic conductivity and water stable aggregates were adversely affected with irrigation of distillery effluent\(^{55, 232}\). Increased potassium content in soil was observed when soil was treated with spentwash.\(^{98, 233, 234, 175}\)

FYM or decomposed straw applied at the time of planting did not release as much available N as green leaf manures (Sesbania bispinosa and Ipomea crassicantis) or spent hop (waste from brewerage industry) applied @ 10 t ha\(^{-1}\) at four to five weeks before planting of rice in submerged soil. The waste (spent hop) released more N (65 ppm) than other bulky organic manure. Application of spent hop resulted in increased organic carbon (1.0 %), CEC (15.15 me/100g), P (8.7 kg ha\(^{-1}\)) and K (198 kg ha\(^{-1}\)) than control (0.87 %, 13.89 me/100g, 7.1 kg ha\(^{-1}\) and 193 kg ha\(^{-1}\)), respectively.\(^{235}\)

Addition of spentwash without dilution was very effective in increasing the water intake rate of sodic calcareous soil. Application of spentwash followed by irrigation rather than dilution of spentwash at the time of its application was very effective in reclamation of sodic soil.\(^{236}\)

Increasing levels of spentwash application did not alter total N, organic carbon and exchangeable Na\(^+\) values were not affected, while exchangeable K\(^+\), Ca\(^{++}\), Mg\(^{++}\) and pH were increased. In contrast, exchangeable Al\(^{3+}\) available P and NO\(_3^-\) decreased.\(^{237}\) Nitrogen mineralization is defined as transformation of N from the
organic state into the various inorganic forms. The process is performed through heterotrophic soil organisms by utilizing nitrogen and organic substances as energy source.  

The inorganic N present in most of the soils was in the form of exchangeable and fixed NH$_4^+$–N, and also as NO$_3^-$ -N. All these forms constitute an extremely dynamic system influenced by physical and chemical processes in the soil.  

The incubation studies conducted showed that application of various rates of stillage resulted in substantial but temporary increase in the population of bacteria and fungi. But, actinomycetes were inhibited until population of other microorganism decreased. Application of stillage contributed to soluble nitrogen, which stimulated non-fixing bacteria but inhibited temporary nitrogen fixing Beijerinkia. The population of Beijerinkia increased rapidly following the decline of non-fixing bacteria Azospirillum spp. And nitrogenase activities were also stimulated by stillage application but effect was only in the presence of applied molybdenum.  

Physical soil characteristics influenced by vinasse application and noticed better soil aggregation and water permeability. The available nutrients were also increased with effluent irrigations, the available N from 276 to 412, available P from 21.0 to 34.0 and available K from 700 to 2400 kg ha$^{-1}$.  

Application of fermentation residues @ 200 t ha$^{-1}$ positively influenced the biological activity of soil. Bacteria, actinomycetes and fungi in amended soil sample showed significantly higher colony counts than in the unamended soils. The abundant growth of Calothrix maxchica var. intermedia was noticed in soil, which received the effluent of molasses distillery. The effluent particularly at low concentrations (1-10% v/v) and neutral pH increased the growth of organism. Vinasse applied for 20 years and observed increased pH and higher K, Ca, Mg and CEC. NH$_4^+$–N accumulation was more than NO$_3^-$ –N in sludge amended soil. It was mainly due to inhibition of nitrobacter involved in the nitrification process, which was highly sensitive to metals present in the sludge than heterotrophic microorganisms involved in ammonification process.  

Organic matter oxidation brought out by microbial activity was responsible for increased pH when soil was treated with distillery effluent. The electrical conductivity of the soils also increased significantly with effluent irrigation. The organic carbon
content of the soils increased significantly with effluent irrigations which might be due to the fact that the effluent contains high organic load. The available N, P, K, Ca, Mg and micronutrient contents of the soils, in both the seasons, were significantly increased due to effluent irrigations.\textsuperscript{141}

The application of vinasse for 20 years and found that soil was benefited in terms of pH, increased K, Ca and Mg content and greater CEC. Discharge of untreated spentwash on land lowered soil pH and waste water produced in the distillery carried a high organic load which caused foul smelling of atmosphere.\textsuperscript{142}

And an increase in the total and available contents of NPK in soil by the use of sewage water for irrigation\textsuperscript{243}. The application of spentwash to soil increased the soil nitrate-N availability, EC and interchangeable potassium\textsuperscript{143}. A partial inhibition of acid phosphatase activity in red yellow latosol irrigated with cumulative dose of distillery effluent.\textsuperscript{244}

Application of vinasse to the main crop of cane increased the available K of the surface soil and remained high even after the harvest of first rat\textsuperscript{245}. An increase in soil pH, available N, P, K, Ca and Mg 80 m$^3$ observed vinasse application per ha$^{-1}$. Irrigation to cane filed with distillery effluent increased exchangeable calcium and potassium. Also increased levels of distillery effluent application resulted in increased mean weight diameter water stable aggregates (1.6 to 2.2 mm), moisture retention (17.2 to 20.3 %) as well as available water holding capacity of soil (14.7 to 18.3 %).\textsuperscript{246}

The \textit{Cyanobacterium} grew photoheterotrophically and chemoheterotrophically in the medium supplemented with sucrose and lower concentrations (10\% \textit{v/v}) of neutralized distillery effluent.\textsuperscript{248} The reviewed results revealed increased water holding capacity, pore space and aggregate stability \% of sodic calcareous soil when spentwash was used for reclamation process.\textsuperscript{249}

An experiment was conducted and found that, the progressive levels of distillery effluent from 2.5 to 10\% increased the mean weight diameter of water stable aggregates (1.62 to 2.20 mm), moisture retention (17.17 to 20.25\%) and available water holding capacity of soil (14.7 to 18.3\%). Further, increased soil pH, available N, P, K, Ca and Mg due to the application of 80 m$^3$ vinasse per ha$^{-1}$. Irrigation to cane field with distillery effluent had a tendency to increase exchangeable calcium.\textsuperscript{70}
Annual application of vinasse increased the amylase and cellulase activity but the urease activity was unaffected in the red yellow latosol of Cerroda area in Brazil.\textsuperscript{247} The effect of distillery spentwash and sewage on enzyme activities in different soils and concluded that the cellulase, dehydrogenase and phosphatase activities were increased in soil irrigated with distillery effluent than sewage effluent. He also reported that an increase in enzyme activity was more marked in Palampur acid soil than in neutral soil of IARI, New Delhi.\textsuperscript{250}

Addition of spentwash liquid lead to build up of salinity in clay loam, silty clay soils and from the composition of soil leachates and diluted spentwash would not add soluble salts to the soil provided sufficient provision is made for leaching. However, addition of concentrated spentwash would result in buildup of salinity of both soil and groundwater.

Enzymes are the indicators of microbial activity and may provide an index of total microbial activity in soil\textsuperscript{252} In Brazil the impact of spentwash application on soil and Groundwater was studied. Over 5 samples were collected at depths of 25, 75 and 150 cm. These results showed that the organic material added with spentwash mineralizes rapidly increasing N, P, Ca and S contents and increasing soil fertility. Nutrients reached the groundwater, but not at levels harmful to human health.\textsuperscript{117}

The digested distillery effluent application increased concentrations of most elements particularly K in soil. The decreasing trend of infiltration rate (IR) was noticed with effluent irrigations. However, the drop in IR was marginal at 50 and 40 times dilutions (33.4 and 31.2 cm/hr) when compared with water (33.8 cm/hr). The infiltration rate of the soils was significantly reduced with effluent irrigations, in both the seasons. The reduction was marginal (5.2 \%) at 50 times dilution and appreciable (54.5 \%) at 10 times dilution. The addition of distillery effluent regardless of rate raised the soil pH, owing to increase in soil K, Ca, Mg and Na content. Further, they noticed that digested distillery effluent application increased soil concentrations of most elements.\textsuperscript{146}

The possibility of improving the physico-chemical properties of a typical saline calcareous (Vertisol) soil by the application of spentwash, the potash rich acidic (pH 3.7) byproduct of alcohol distillery, was assessed. Treatments consisted of dilutions of spentwash with water at 1:25, 1:50, 1:75 and 1:100. The treatments were
compared with the use of both canal and well waters. The effect of canal and well waters with equivalent quantity of potash added through two spentwash treatments was also studied. The addition of diluted spentwash improved the physico-chemical properties as indicated by the decreased electrical conductivity. There were significant changes in the exchangeable $K^+$, $Ca^{2+}$ and $Mg^{2+}$. It was found that addition of spentwash decreased the pH and EC of soil. There were significant changes in exchangeable K, Ca and Mg. Further, the DTPA extractable Fe and Mn contents of soil were significantly increased at all stages of crop growth treated with diluted spentwash.174

There was an improvement in stability of aggregates and porosity due to application of spentwash solids and spentwash pressmud compost. It was observed increased EC and available K in soil and saturation paste extract when applied with spentwash solids. Further, available N, P and DTPA extractable Fe, Mn and Zn in the soil at the harvest of sorghum were increased.120

One time application of treated diluted effluent before planting of the crop and ploughed into the soils raised the pH (7.87) slightly to the alkaline range.253

In sugar cane cultivation soils irrigated with distillery effluent found that pH was strongly correlated with Mg$^{2+}$ and Na$^+$ were the main cations affecting soil pH. Available P and exchangeable cations with the exception of Ca were positively and organic matter was negatively correlated with soil pH. Irrigation with distillery effluent increased soil Mg and Na contents.147

The EC, SAR and available nutrient status of soil receiving diluted effluent were higher compared to soils irrigated with only water.73

The effect of effluent changes in fertility status of clay soil of Gujarat, recorded higher values of electrolyte conductivity, organic carbon, available N, P and K with the usage of effluent water than with normal water at the same level of fertilizer application.76

Higher values of electrolyte conductivity, organic carbon, available N, P and K with the usage of effluent water than with normal water at the same level of fertilizer application were recorded. The reduction in the hydraulic conductivity with the application of effluent was due to accumulation of solids at the surface. The distillery waste in irrigation water slightly increased the pH, organic matter and...
conductivity of the soils. A field experiment was conducted on Inceptisol at Sakthi Sugars Limited, Sakthi nagar (Tamil Nadu), during 1992-93 to assess the optimum dilution of effluent irrigations (50, 40, 30, 20 and 10 times dilutions) with mulching (FYM at 12.5 t ha$^{-1}$) and without mulching, pressmud at 12.5 t/ha with composted coir waste mulching, pressmud at 12.5 t/ha with sugar cane trash mulching, pressmud at 12.5 t/ha with Azospirillum at 5 kg ha$^{-1}$. pH, EC, OC content and available nutrient content (N, P, K, Ca, and Mg) and exchangeable Na of soil increased with decreasing dilution levels. The composted coir waste and sugar cane trash mulching recorded significantly higher organic carbon and available nutrient contents than FYM applied soils. The infiltration rate of the soil was significantly reduced with effluent irrigations. The reduction was comparatively less at 50 and 40 times dilutions (2.5 and 7.9, respectively). The composted coir waste mulching and sugarcane trash mulching registered significantly higher infiltration rate (29.6 and 29.2 cm/hr, respectively).

The soil enzymes show an immediate response to any deviation in soil health. An increased microbial biomass and dehydrogenase activity observed due to application of distillery effluent and established a close relationship between the number of micro-organisms and enzyme activity in soil.

It was found that irrigation with diluted distillery spentwash along with gypsum and pressmud reduced the exchangeable Na and increased the available N, P and K and exchangeable Ca and Mg contents. The manorial potential of post methanation effluent at different levels concluded that dilution of 1:10 was best one and it supplied 120, 8, 2,400 and 400 kg ha$^{-1}$ of NPK and sulphates respectively. The use of vinasse (a distillery byproduct) and mineral N with regard to leaching of N from soil and possible pollution of groundwater with NO$_2$, NO$_3$, NH$_4^+$ or other free N compounds which were found in soil samples from depths of 0-2 m.

Irrigation with treated distillery effluent to sugarcane soil under varying dilutions significantly altered the microbial load in the rhizosphere. The population varied with period under effluent irrigation and the peak was recorded in the fifth month. The microbial population was found to be high in the soil that was irrigated with 50 time’s diluted effluent.
Effect of irrigation with tube well water (S₀) as well as with spentwash diluted for 25 (S₂₅), 50 (S₅₀) and 100 (S₁₀₀) times on yield of and nutrient uptake by sugarcane grown on typical chromustert was studied. Results revealed that, application of spentwash diluted at any level increased the nutrient uptake significantly over S₀. The total uptake of all the elements was invariably higher in S₂₅ treatment as compared with rest of the treatments like S₀, S₅₀ and S₁₀₀. There was tendency for slight increase in the soil salinity due to use of spentwash. The post harvest nutrient status of soil with increase in concentration of spentwash revealed that there was significant increase in soil organic carbon, available N, P, S, Fe, Mn, Cu& Ni over control. While the exchangeable Na, Ca & Mg significantly decreased with increase in proportion of spentwash in irrigation water, but Pb and Cd remained unaffected due to spentwash treatments. The soil water held at zero tension differed significantly due to the use of spentwash. In all the cases, it was maximum with tube well water usage and least with the usage of spentwash water at the highest concentration (S₂₅). Decline in the water retention capacity of the soil was due to increase in the organic carbon content of clay soil. Distillery effluent irrigation decreased the rate of infiltration and bulk density of soil, which are favorable traits for sandy soils¹⁵³.

With an increase in effluent an increase in pH, EC, available N, P and K were noticed. Further, found that the pH and electrical conductivity of soil slightly increased. Where as, the soil organic carbon, nitrogen, phosphorus and potassium contents increased significantly with an increase in the number of pre-sowing effluent irrigation¹²⁷. A field survey conducted for assessing groundwater quality and salinity build up in irrigated soils of Sikandarabad area of Bulandshahar district, Uttar Pradesh as influenced by irrigation with mixed industrial effluents of various industries. Samples of effluent from irrigated fields were collected and analyzed for different characteristics. It is inferred that indiscriminate disposal of the effluent aggravated the salinity and sodicity problem in the irrigated soils and shallow surface water resources like ponds. Organic carbon status of surface soils increased two to three times as compared with that of adjacent normal soils¹⁵⁴.

Nitrogen mineralization of poultry manure, pressmud, sewage sludge and FYM increased with increase in incubation period. The nitrogen mineralization potential (N₀) differed markedly depending upon organic material and soil type. It
ranged from 31.5 to 46.9 mg kg\(^{-1}\) for FYM, from 40.6 to 71.0 mg kg\(^{-1}\) for sewage sludge from 52.2 to 107.0 mg kg\(^{-1}\) for pressmud and from 59.2 to 122.4 mg kg\(^{-1}\) for poultry manure. The nitrogen mineralization rate constant (K) was the highest for poultry manure and the lowest for FYM.\(^{257}\)

The effect of distillery effluent and organic amendments on rice yield and soil fertility status in a field experiment with different dilutions of effluent (10, 25, 50, 75, 100 times) and water alone with amendments like FYM (12.55 t ha\(^{-1}\)), pressmud (12.5 t ha\(^{-1}\)), gypsum (5 t ha\(^{-1}\)) and neem leaves (5 t ha\(^{-1}\)) and control without manure were studied. Results revealed that, pH, EC and organic carbon increased with increase in concentration of the effluent (decrease in dilution). Among the amendments treatment, which received neem leaves and only water, recorded lowest pH, EC, and OC.\(^{84}\)

The application of vinasse on soil properties was studied. Vinasse was applied in a durum wheat crop by a trailed vinasse sprayer system compacting about 10% of the field. The experiment was carried out in Central Greece, on two soils (a clay and a silty clay loam) with three levels of vinasse rate (one fully covering N requirements of the crop, one covering half the N requirements, the rest covered by chemical fertilizers and a control without vinasse and use only of chemical fertilizers) and three times of application (Summer, Autumn before ploughing and Autumn before drilling). The middle strip of the plots was compacted by three passes of the tractor-trailed vinasse sprayer producing the compacted treatment. During the experiment, the physical and chemical properties of the soil were measured. It was found that the compacted plots had higher dry bulk density and soil strength, while vinasse rate and time of application effects were not significant. An increase in N, exchangeable Na\(^+\), K\(^+\) and available Mn was caused by vinasse application.\(^{188}\)

A study revealed that there is possibility of salinity development in the long run with higher levels of effluent application. The treated distillery effluent irrigations resulted in significant increase in soil pH, EC and OC and saturated hydraulic conductivity, bulk density and volumetric water content of soils improved with effluent application.\(^{85}\)
The field experiment on a reddish yellow latosol in tress pontas, Minasgerais, Brazil, with Pineapples crop (CV. Smooth Cayenne) were given with 0, 100, 200, or 400 m$^3$ vinasse ha$^{-1}$ as a K source. Vinasse increased K, Ca and Mg content of soil.

Saturated hydraulic conductivity, bulk density and volumetric water content of soils improved with effluent application. Application of diluted distillery effluent in 1:10 and 1:20 ratio recorded higher cane yield of 129.5 and 122.3 t per ha, respectively over 1:30, 1:40 and 1:50 dilutions at sugarcane research station, Cuddalore. There was general build up of organic carbon, soil available N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu nutrients including the sodium.

A field experiment on pineapple crop (cv. smooth caenne) was conducted on a reddish yellow latosol in trespontas of Brazil. The crop was irrigated with 0, 100, 200 and 400 m$^3$ ha$^{-1}$ vinasse as potassium source. Soil analysis after harvest of crop indicated that vinasse increased K, Ca and Mg contents in soil. A significant increase in the uptake of N, P and K nutrient by the addition of spentwash @ 50 m$^3$ ha$^{-1}$ was observed over control, 12.5 and 37.5 m$^3$ ha$^{-1}$ treatments and also there after decreasing trend was noticed in 75.0 and 87.5 m$^3$ ha$^{-1}$. Significant increase in the uptake of N, P and K nutrients by the addition of spentwash at the rate of 50 m$^3$ ha$^{-1}$was observed under control, 12.5 and 37.5 m$^3$ ha$^{-1}$treatments and also there after decreasing trend was noticed in 75.0 & 87.5 m$^3$ ha$^{-1}$. The pH values of soil were decreased with increased levels of spentwash but EC values were increased with increased levels of spentwash. Depletion of calcium from soil had adverse effect on structure and hydraulic conductivity of soil.

An incubation study was carried out in plastic containers with FYM, biogas slurry and sewage sludge added to sandy clay loam soil @ 5, 10 and 15 t ha$^{-1}$ with without N:P fertilizer. Ammonium N decreased and NO$_3^{-}$ + NO$_2^{-}$ -N increased significantly with increase in incubation period from 1 to 16 weeks in all the organic manures. Highest NH$_4^{+}$-N was observed in sewage sludge followed by biogas slurry and FYM. At higher rate (15 t ha$^{-1}$) all the manures mineralized significantly into more NH$_4^{+}$ and (NO$_3^{-}$ + NO$_2^{-}$) -N fractions.

Impact of periodic watering from germination to maturity with carbonaceous sugar mill effluent on chemical constituents of soil and Hordeum vulgare var IB65 was assessed. Watering with effluent caused alteration in chemical constituents of soil.
and such alteration resulted in reduction in phosphate, potassium, total nitrogen, carbohydrate, crude protein and increase in sodium, calcium, sulphate, chloride, and ash content of root, stem, leaf and seeds of Hordeum vulgare var. IB65. Carbonaceous sugar mill effluent produces adverse effects on soil fertility and chemical constituents of plant if used for irrigation purposes.\textsuperscript{156}

A field experiment was conducted at Theni in Tamil Nadu (India) to study the effects of bio compost (pressmud and distillery effluent) and enriched pressmud on the yield and quality of sugarcane (Cv. 0.8021). Treatments were 50, 75 and 100\% of the recommended NPK; 50 and 75\% NPK combined with biocompost (10 t ha\textsuperscript{-1}) and 50 and 75\% NPK combined with pressmud enriched with either Pleurotus Sp. (10 t ha\textsuperscript{-1}), Trichoderma viride (10 t ha\textsuperscript{-1}) or Acetobacter and phosphobacterium (each at 10 kg ha\textsuperscript{-1}). The soil of the experimental field was low in OC, available N and P, but well supplied with K. The combined application of organic and chemical fertilizers significantly improved soil organic carbon and available NPK without markedly affecting soil pH and exchangeable cations.\textsuperscript{260}

Field experiments were conducted during 1999-2000 in Tamil Nadu, India, to determine the optimum dilution of distillery effluent mixed with irrigation water (1:10, 1:20, 1:30, 1:40 and 1:50) for its direct application to sugarcane. Its effect on soil (Inceptisols and Alfisols) properties was observed. Irrespective of dilution, effluent application significantly increased soil pH from 7.10 to 7.25 in sandy loam and 8.02 to 8.11 in clay soil. Electrical conductivity also increased from 0.29 to 0.36 ds/m and 0.45 to 0.58 ds/m in sandy loam and clay soil, respectively. An increase of 0.30 and 0.35\% in OC content was also observed. There was a gradual increase in available N, P and K, which in turn reflected in the buildup of soil fertility. The exchangeable Ca, Mg and Na contents of the post harvest soil were significantly increased from the initial level. The available micronutrients (Fe, Mn, Zn and Cu) were increased with distillery effluent application and the availability being highest in 1:10 dilution.\textsuperscript{131}

**Biological properties**

Analyzed soil samples treated with sugarcane industrial residues (vinasse and filter cake) and their respective control areas soils of Dos Goytacazes campus, Rio de Janeiro, Brazil for total contents of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn in 1995. The
results revealed that the use of vinasse for more than 15 years in volumes of 300 m³ ha⁻¹ year⁻¹ did not increase the concentrations of the heavy metals above toxicity level. All heavy metals increased significantly with the exceptions of Zn and Mn. Even though the heavy metals concentrations were higher, the sequential extraction showed that these elements were present in non-labile form in the soil.²⁶¹

Immobilization of mineral N with the incorporation of wide C/N ratio crop residue would enhance substantially if incorporated along with fertilizer N. However, re-mineralization would initiate after about 3 week period with a faster immobilization-mineralization turn over. These results suggest that some initial starter N would be needed when wide C/N ratio crop residues are incorporated, whereas, incorporation of narrow C/N ratio crop residues would supply sufficient N to the growing plants. Nitrogen release from organic N source is controlled by the soil environment.²⁶²

Impact of distillery waste on soil properties was studied and found that, high temperature, acidic pH, excessive quantities of inorganic salts, organic matter and total solids in the spentwash caused soil salinity and high osmotic pressure of the soil solution after irrigation.²⁰³

Spentwash with different dilution levels (1:5, 1:10, 1:25 or 1:50). Dilution levels of 1:5 and 1:10 recorded the highest uptake of N, P and K as well as Zn, Cu, Fe & Mn uptake than the undiluted spentwash and control (water without spentwash). The undiluted spentwash resulted in significant lower nutrient uptake than the control.¹⁵⁷

The chemical soil properties of a Camisole under long term sugarcane crop with vinasse application and without slash burning was studied. This study was undertaken in Campos’s dos Goytazes Northern state of Rio de Janeiro, Brazil. Based on soil properties, it is a Vertic Fluventic Eutrocharept, which had been cultivated with sugarcane for several decades. In one situation the crop had been cultivated for 55 years without burning the residues at harvesting. On another sugarcane plantation, harvest residues had been burned with vinasse inputs applied by sprinkle irrigation at a rate of 120 m³ ha⁻¹ year⁻¹ during 35 years. Results indicated that, the application of crop residue on the soil surface and to a lesser extent, the addition of vinasse increased the macro and micronutrients contents, organic carbon contents in the
surface layer (0 – 0.2 cm) 13.13 kg in the burned cane to 22.34 kg in the unburned cane and from 15.71 kg in the vinasse application. The improvement of the chemical soil attributes favored the formation of more polymerized alkaline soluble humic substances.263

A field experiment was conducted during 2000 in red soil with wheat as test crop, employing different effluent dilution levels (1:5, 1:10, 1:25, 1:50) in comparison to undiluted effluent and fresh water. Results indicated that available N, P, K, Zn, Cu, and Mn contents in soil were decreased with increased dilution levels.88

The effect of distillery spentwash on some soil characteristics and water studied. The effluent from Sri Sadilal distillery situated at Mansurpur (Dist: Muzafarnagar) falls into the river Kali. Soil samples were collected very nearer to effluent channel and away from the channel. Comparison of the water and soil characteristics revealed that the spentwash was highly polluted with very high (far more than ISS standards) BOD, COD and dissolved suspended solids which got diluted after mixing with Kali water. As the spentwash along with river water moved down the stream, its organic load reduced substantially. Soil samples collected from effluent fed fields showed higher salinity and organic matter content compared to the soil without being fed with effluent.264

Eco-friendly utilization of distillery effluent in agriculture may serve as one of the nutrient management practices for enhancing crop yields besides reducing the costs of fertilizers. But, it has to be used judiciously and cautiously on a limited scale because of very high organic load. Distillery effluent has excessive BOD (45000 - 55000 mg/l), COD (90000- 110000 mg/l) and EC (16 - 29 dSm⁻¹). These problems can be overcome either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre-plant application (40 to 60 days before planting) to give sufficient time for the oxidation of organic matter. The untreated distillery spentwash also known as raw spentwash is acidic in nature (pH 3.5 - 4.0) and can be effectively used for the reclamation of non-saline sodic soil. Addition of effluent significantly increased the EC, organic carbon, available N, P, K, Ca and Mg contents as well as micronutrients in soil as reported.133

A field investigation was carried out in Karnataka, during winter seasons of 1999-2000 and 2000-01 to study the effect of conjunctive use of spentwash on soil
properties\textsuperscript{120}. The treatments included six dilutions levels. The bulk density of soil was decreased due to conjunctive use indicating favorable trait for sandy loam soil. The EC and OC content of soil increased with increase in concentration of effluent in irrigation water, i.e., lower dilution levels. However, pH of soil remained unchanged\textsuperscript{158}

The investigation reviewed the untreated distillery spentwash lag of 40 days to overcome the depletion of oxygen from the soil environment. The distillery spentwash application is recommended in summer when the ground water table is low. The distillery spentwash alone or in combination with gypsum is effective in spot reclamation of alkali soils for agro forestry in rain fed conditions. The primary treated distillery effluent (PTDE) can be used as source of fertigation either as one time pre plant application or frequent application of diluted (1:20 or 1:30) effluent. The OC and EC of the surface soil increased significantly with application of spentwash, but the soil pH was not affected.

Untreated DE was successfully used for amending and reclaiming non-saline, calcareous, alkali soils. Rice yields in the reclaimed soil increased by 1.0-1.2 t/ha. The use of DE alone or in combination with gypsum was effective for spot reclamation of alkali soils for agro forestry under rain fed conditions\textsuperscript{90}

A top trial experiment was conducted to study the effect of different solid industrial bio-resources (pressmud, effluent treatment plant and cynamide sludges @ 2.5 and 5 t/ha) as a source of organic matter in a heavy black soil using onion as a test crop. The results revealed that sludges were found to increase the pH and electrical conductivity in post–harvest soil. Organic carbon content, available major nutrients (N, P and K), micronutrients (Fe, Zn, Mn and Cu) and heavy metals (Pb, Cd and Ni) were also found to increase with the usage of different sludges. Pressmud treatments were proved to be the best and cynamide treatments were poor in case of nutrient availability. Pressmud showed minimum pollution hazard with less accumulation of heavy metals in soils\textsuperscript{135}.

The % water stable aggregates and water retention at field capacity were significantly high, while penetration resistance of the surface soil was significantly low in all the spentwash treated plots\textsuperscript{265}. 

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Continuous pre-sowing application or fertigation with 200 m$^3$ha$^{-1}$ secondary treated biomethanated spentwash to sugarcane improved the growth and yield, reduced soil pH, slightly increased soil EC, considerably increased OC, soil available N and K.$^{214}$

Irrigation with distillery effluent, besides influencing crop yield, may have considerable impact on physical properties of soil because of its high salt and organic carbon contents. This experimental study was conducted to evaluate the effect of distillery effluent on hydraulic conductivity of a sandy loam alluvial soil. The treatments consisted of 4 sources of K: potassium chloride, potassium sulfate, post methantion distillery effluent (PME) and oxidized PME (PME minus organic carbon) at 4 levels equivalent to 10, 20, 40 and 100% of the K concentration in the PME. Soils, collected from the upper 15 cm of a farm were crushed, passed through a 2-mm sieve and packed in 6.5 cm diameter and 50 cm long columns. Each of the solutions was applied 4 times at the interval of 20 days to the soil column, which were subsequently flushed with distilled water and saturated hydraulic conductivity of soil was measured using the constant head technique. Application of PME and salts increased the hydraulic conductivity of soil to 3 to 4 fold as compared to that of the untreated soil. The oxidized PME, which contained only the inorganic salts present in the PME, had highest hydraulic conductivity at 100% salt level followed by PME and inorganic salts. The exchangeable K content of soil (x) and hydraulic conductivity (y) showed a polynomial relationship ($y=15.28-1.61x+0.05x^2$).$^{266}$

Impact of long term effluent irrigation in the field (10 years) and short term effluent irrigation using different doses of PME in the laboratory (30 days) was studied in combination with three bioamendments i.e. farmyard manure, brassica residues and rice husk. Impact on various soil properties like EC, pH, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), available phosphorus, exchangeable K, Na, Ca, Cl, microbial population and soil enzyme activities were studied. Long term application of PME proved useful in significantly increasing TOC, TKN, K, P and soil enzymatic activities in the soil but tended to build up harmful concentration of Na that could be chelated by bioamendments. In short terms studies, application of 50% PME along with bioamendments proved to be the most useful in improving the properties of sodic soil and also favored successful germination and improved seedling growth of pearl millet.$^{267}$
Soils were incubated to evaluate the effects of soil moisture (50 %, 70 % and 90 % of water holding capacity) and temperature (15, 20, 25°C) on N release from four organic N sources. Differential N release kinetics of the N sources was determined by measuring ammonium and nitrate nitrogen contents periodically over 12 weeks. N released, as a percentage of organic N, was greatest in the order, urea (91 - 96 %) > blood meal (56 – 61 %) > alfalfa pellets (41 – 52 %) > partially composted chicken manure (37 – 45 %).268

The effects of spentwash, compost, and inorganic fertilizers on the micronutrient contents of turmeric (cv. Erode Local) and soil were studied in Sathyamangalam, Tamil Nadu, India, during 2001-02. The treatments were: 2.5 t Biocompost ha\(^{-1}\) + 75% of the recommended NPK rates (T1); 2.5 t Biosuper + 75% NPK (T2); 2.5 t Biocompost + 100% NPK + micronutrients (T3); 2.5 t Biosuper/ha + 100% NPK (T4); untreated control (T5); treated spentwash at 50 k l ha\(^{-1}\) as basal + 2.5 t Biocompostha\(^{-1}\) + 75% NP + micronutrients (T6); and treated spentwash at 50 k l ha\(^{-1}\) as basal + 2.5 t Biosuperha\(^{-1}\) + 75% NP (T7). The fertilizers significantly enhanced the micronutrient (Zn, Cu, Mn and Fe) contents of the soil and plant. T7 resulted in the highest mean soil Zn, Cu, Mn and Fe contents (6.35, 6.85, 18.2 and 13.4 ppm, respectively); Zn (29.7 and 19.4 ppm), Cu (7.8 and 4.1 ppm) and Fe (265.7 and 164.7 ppm) contents of vegetative parts and rhizomes; and Mn content of vegetative parts (69.9 ppm). The highest rhizome Mn contents were obtained under T4 (34.2 ppm), T6 (34.1 ppm) and T7 (34.3 ppm).216

Effect of soil application of vinasse (distillery spentwash, DSW) at a dilutions of 25, 50 and 100% was studied on growth, tillering and biomass production of two commercial sugarcane varieties, viz., CoS 95255 and BO 91.269

A field experiment was conducted during 2001-02 and 2002-03 at Research Station, Vallabhnagar (Udaipur, Rajasthan), to study the effect of pressmud (0.5, 10, 15tha\(^{-1}\)) and spentwash (0, 2.5, 5.0, 7.5 lac lha\(^{-1}\)) with phosphogypsum (0, 25, 50% GR) on wheat productivity. Incorporation of phosphogypsum at 25% GR in integration with either pressmud or spentwash decreased the soil pH, EC and ESP. Incorporation of soil amendment increased the net returns and B: C ratio of wheat crop. The net returns and B: C ratio was under phosphogypsum at 50% and 25% GR, respectively, alone or with either spentwash at 7.5 lac Lha\(^{-1}\) or pressmud at 15 tha\(^{-1}\).270
Field experiments were conducted with sugarcane crop in sandy loam soil to study the long term effect of post bio-methanated sugar distillery effluent (PME) on soil properties and yield of sugarcane during 2001-04. The PME was applied at different dilutions viz., 1: 10T, 1: 20T, 1: 30T, 1: 40T and 1: 50T. The results revealed that the pH of the soil was changed to near neutral and there was no significant change observed on the EC of the soil. The organic carbon and available NPK content of the post-harvest soil had significantly built up over the years in the PME applied plots when compared to the control. The 1:10T dilution treatment recorded the highest built up of 96, 17.5 and 372 kg ha$^{-1}$ available N.\textsuperscript{271}

Experiments were carried out to study the effect of distillery sludge amendments with garden soil (10, 20, 40, 60, 80 and 100%) on seed germination and growth parameters of Phaseolus mungo L. The N, P, K and Mg accumulation followed the order shoot > leaf > root. Ca accumulation was highest in the upper part of the plants (including shoot and leaves). Furthermore, heavy metals content were also increased in different parts of P. mungo grown on increasing concentration of sludge amended garden soil with time. Zn and Cu accumulation was maximum versus other heavy metals. Based on these studies, sludge having concentrations $< or =10\%$ (w/w) can be applied as a fertilizer\textsuperscript{227}.

Spentwash as a distillery waste is posing disposal problem. Spentwash contains many useful elements and can be profitably re-cycled to improve soil fertility. Spentwash treated optimally can be used as an effective fertilizer as well as irrigation source. Regular application of distillery effluent may affect soil physical and chemical properties viz., infiltration rate, hydraulic conductivity, water retention capacity, electrical conductivity, pH, availability of nutrients and also results in adverse effects on microbial biomass and population which might alter the fertility status of the soil.

### 2.6 Effect of Distillery Spentwash on Soil Nutrient Availability and Uptake by Crops

An increased yield and uptake of P, K and Ca by snap bean due to spentwash application. A significantly higher yield of sugarcane and available N was recorded with 200 kg N through spentwash application\textsuperscript{139}
A significantly higher yield of sugarcane and increased available N content of soil was recorded with 200 Kg N through spentwash application, further uptake of K by Jowar was also higher in treated soil (21 mg/40 plants) than in control (9 mg/40 plants).\textsuperscript{96, 272}

In laboratory incubation studies, applied K at 1000 ppm through spentwash. They noticed that at the end of 60 days, the NH\textsubscript{4}OAc extractable K was higher in spentwash applied soil (320 ppm) than in control (160 ppm). Uptake of K by Jowar was also higher in treated soil (21 mg/40 plants) than in control (9 mg/40 plants).\textsuperscript{98}

The decomposed straw applied at the time of planting did not release as much available N as green leaf manure (Sesbani bispinosa and Ipomeas crassicantis) or spent hop (waste from brewery factory) applied at 10 t/ha to four to five weeks before planting of rice in submerged soil. Spent hop released more N (65 ppm) than other bulky organic manure (64 ppm). Application of spent hop resulted in an increase in organic carbon (1.01%), CEC (15.15 m eq/100g), P (8.7 kg ha\textsuperscript{-1}) and K (196 kg ha\textsuperscript{-1}) than over control (0.87% OC, 13.89 m eq/100g CEC, P 7.1 kg ha\textsuperscript{-1} and 193 kg ha\textsuperscript{-1}).\textsuperscript{235}

It was found that the application of rum distillery waste at the rate of 6.2 cm slops, 18.6 cm slops and 31.0 cm slops/ha contributed higher K content of 1.89, 5.66 and 9.44 m eq /100g of soil respectively. The initial salt content was increased by about 23%. After application of 6.1 cm of water, salt content was reduced to two thirds of the total salt content from top 60 cm soil in all treatments.\textsuperscript{233}

Uptake of N, P, K, Ca and Mg were higher by ragi (Eleusinecoracana) when urea and rock phosphate fertilizers are treated with brewery effluent (703.5, 128.8, 467.0, 625.5, and 317.8 mg/pot) than when untreated (446.0, 65.3, 396.0, 550.3, and 90.3 mg/pot).\textsuperscript{162}

The soil treated with 400 m\textsuperscript{3}/ha of residue with addition of N and P, the leaching of nitrate was about 30 ppm less and the leaching of ammonium about 4 ppm more than in no-residue treatment. Increasing levels of spentwash application did not alter total N, organic carbon and exchangeable Na levels but exchangeable K, Ca, Mg and pH were increased, while exchangeable Al, available P and NO\textsubscript{3} were decreased.\textsuperscript{237} Application of 80 m\textsuperscript{3} ha\textsuperscript{-1} vinasse alone considerably improved the yield of cane and sugar per ha-1.\textsuperscript{101}
Exchangeable NH₄ of the soil and leaf N, P, K, Ca and Mg were not affected by the levels of distillery slops. An increase in the K concentration of soil with increased rate of stillage. The application of distillery residues to the soil decreased the nitrate loss from soil²⁷³.

The effect of distillery slops on rice and rice soils were studied. Exchangeable and HNO₃ extractable K increased with increasing levels of slops, from a total of 313 kg ha⁻¹ when no slops were applied to 699 kg ha⁻¹ when 240 hl of slops were applied per ha weekly 12 week to 4 successive rice crops. Exchangeable NH₄⁺ content of the soil and leaf contents of N, P, K, Ca and Mg were not affected by the levels of distillery slops²³⁴.

Effluent concentration up to five % was found beneficial for overall growth of mung (Phaseolus radiatus), pigeon pea (Cajanus cajan) and chickpea (Cicer arietinum). An increased concentration resulted in retarded growth of all these crops. In soybean, the use of distillery effluent at any rate was found detrimental ⁶⁴

An increase in the K concentration of soil with increased rate of stillage application in potato field has been found, there was also increased soil Ca and pH due to application in potato field ¹¹⁶.

Irrigation to groundnut with raw distillery waste water resulted in a reduction of nodulation and absence of fruit formation of the plant. This inhibitory effect was reduced when raw spentwash was diluted to 50 % by tap water.¹⁴⁵

Vinasse (distillery waste) when applied to soil, mineralizes rapidly release nutrients and thus maintains soil fertility. The Ca, S, N and P contents of soil were increased. There was also increase in soil Ca and pH with up to 100 m³ stillage¹¹⁷.

In a pot experiment 30-d-old pea cv. T 16, plants were treated every 15 d with 1 liter each of the different concentrations (10, 25, 50, 75 or 100% v/v) of distillery effluent. In another experiment, 6-month-old C. maxima plants were treated every week with 0.25 liters of concentrations of 10-100% v/v of the distillery effluent. Cystine, Lysine, Histidine and Tyrosine concentrations were higher in pea plants treated with a 25% concentration of the effluent compared with the untreated control, whereas the aspartic acid, glutamic acid and alanine concentrations were greater in the control than in the treated plants. In the treated maxima plants, the concentration of most of the amino acids was lower than in the control. Aspartic acid, glycine,
glutamic acid and tryptophan concentrations were distinctly higher in the control than the treated plants. However, proline concentration was highest in the plants treated with 10% effluent concentration. Protein content of pea seeds from plants treated with 10% effluent concentration was 15.73% compared with 15.11% in the controls, but as the effluent concentration increased, the protein content decreased below the control level.

Application of distillery waste anaerobic digester effluent to soil at any rate significantly increased K, Ca, Mg and Na concentrations (65, 1780, 1460, 545 and 116 ppm) than in control (14, 40, 800, 133 and 13 ppm).

The possibility of improving the physico-chemical properties of a typical saline calcareous (Vertisol) soil by the application of spentwash, the potash rich acidic (pH 3.7) byproduct of alcohol distillery, was assessed. Treatments consisted of dilutions of spentwash with water at 1:25, 1:50, 1:75 and 1:100. The addition of diluted spentwash improved the physico-chemical properties as indicated by the decreased electrical conductivity. There were significant changes in the exchangeable K\(^+\), Ca\(^{2+}\) and Mg\(^{2+}\). The nutrient supplying status of the experimental soil improved considerably as evidenced by the performance of sugarcane grown on this soil in a pot-culture experiment.

Spentwash solids, farm yard manure and spentwash pressmud compost were equal in their effect. Further, they also found that spentwash pressmud compost was superior to other sources in respect of N, P, K, Fe and Zn uptake. A field experiment was conducted on Inceptisol at Sakthi Sugars Limited, Sakthi nagar (Tamil Nadu), during 1992-93 to assess the optimum dilution of effluent irrigations (50, 40, 30, 20 and 10 times dilutions) with mulching (FYM at 12.5tha\(^{-1}\)) and without mulching, pressmud at 12.5tha\(^{-1}\) with composted coir waste mulching, pressmud at 12.5tha\(^{-1}\) with sugar cane trash mulching, pressmud at 12.5tha\(^{-1}\) with Azospirillum at 5 Kg/ha. pH, EC, organic carbon content and available nutrient content (N, P, K Ca, and Mg) and exchangeable Na of soil increased with decreasing dilution levels.

The application of distillery waste water up to 160 m\(^3\)/ha led to increase in dry matter production of mungbean and increase in both N and P uptake. Whereas, increase in the level of distillery waste water led to decrease in both dry matter production and N and P uptake. The dilution of distillery effluent increased the uptake
of Zn, Cu, Fe and Mn in maize and wheat as compared to control and the highest total uptake of these were found at lower dilution levels than at higher dilution levels\textsuperscript{126}.

When soils irrigated with diluted effluent for different periods had higher available N, P and K than soils irrigated with only Krishna river water and un-irrigated soils even they also found higher uptake of N, P and K in lesser diluted treatments\textsuperscript{275}.

The application of distillery waste water (upto 169 m\textsuperscript{3} ha\textsuperscript{-1}) increased dry matter of mung bean and increased both N and P uptake. Whereas, further increase in the level of distillery waste water led to decrease in both dry matter production and N and P uptake.\textsuperscript{181}

The irrigation of crops with distillery effluent had no adverse effect on germination of wheat, maize, sorghum and cowpea. In fact, it had beneficial effects compared to irrigation with well water. Irrigation in standing crop of wheat was done with dilution of the effluent by bringing down the BOD to 500 mg per litre which was found to be safer for irrigation in wheat.\textsuperscript{148}

Field experiments were conducted on sugarcane and ratoon crops at Appakudal, Tamil Nadu to find out the optimum dilution of treated effluent for irrigation of sugarcane varieties Co-8021 and CoC-771. The results revealed that the effluent irrigations significantly increased the pH, EC, organic carbon and available nutrient contents of the soils. Potassium application was withdrawn from fertilizer schedule under effluent irrigation. The CoC-771 registered significantly higher cane yield than Co-8021 in both plant and ratoon crops. The Co-8021 gave higher cane yield at 50 times dilution only, whereas the CoC-771 gave higher cane yields at 50, 40 and 30 times dilution in both present and ratoon crops.\textsuperscript{81}

Application of spentwash diluted at any level increased cane yield and nutrient uptake significantly over irrigation with tube well water. They also observed increased nutrient availability of P, K and S considerably there by indicating the signs of improvement in some soil physical properties\textsuperscript{82}.

The application of distillery residues decreased the nitrate loss from soil. The soil treated with 400 m\textsuperscript{3} per ha of residue with addition of N and P, leaching of nitrate was about 30 ppm less and the leaching of ammonium about 4 ppm more than in no
residue treatment. An increase in soil available N, P and K by pre-sowing irrigation with distillery waste was reported\textsuperscript{128}

The effect of distillery effluent and organic amendments on rice yield and soil fertility status in a field experiment with different dilutions of effluent (10, 25, 50, 75, 100 times) and water alone with amendments like FYM (12.55 tha\textsuperscript{-1}), pressmud (12.5 tha\textsuperscript{-1}), gypsum (5 tha\textsuperscript{-1}) and neem leaves (5.25 tha\textsuperscript{-1}) and control without manure were studied. Results revealed that, pH, EC and organic carbon increased with increase in concentration of the effluent (decrease in dilution).

A study revealed that there is possibility of salinity development in the long run with higher levels of effluent application. The treated distillery effluent irrigations resulted in significant increase in soil pH, EC and OC\textsuperscript{85}.

Significant increase in the uptake of N, P and K nutrients by maize observed due to the addition of spentwash at the rate of 50 m\textsuperscript{3} ha\textsuperscript{-1} was observed under control, 12.5 and 37.5 m\textsuperscript{3} ha\textsuperscript{-1} treatments and also there after decreasing trend was noticed in 75.0 & 87.5 m\textsuperscript{3} ha\textsuperscript{-1}. The pH values of soil were decreased with increased levels of spentwash but EC values were increased with increased levels of spentwash. Depletion of calcium from soil resulting in the increased EC values, also adverse effect on structure and hydraulic conductivity of soil were noticed\textsuperscript{258}.

Soil samples treated with sugarcane industrial residues (vinasse and filter cake) and their respective control areas at campus dos Goytacazes, Rio de Janeiro, Brazil for total contents of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn in 1995 was studied. The results showed that, the use of vinasse for more than 15 years in volumes of 300 m\textsuperscript{3}/ha/year did not increase the concentrations of the heavy metals in the Entisols and Inceptisols. The Incept soils that received filter cake had the concentration of all heavy metals increased significantly with the exceptions of Zn and Mn. Even though the heavy metals concentrations were higher in this treatment the sequential extraction showed that these elements were present in nonlabile form in the soil\textsuperscript{261}.

Field experiments were conducted during 1999-2000 in Tamil Nadu, India, to determine the optimum dilution of distillery effluent mixed with irrigation water (1:10, 1:20, 1:30, 1:40 and 1:50) for its direct application to sugarcane. Its effect on soil (Inceptisols and Alfisols) properties was observed. An increase of 0.30 and 0.35% in organic carbon content was observed. There was a gradual increase in available N,
P and K, which in turn reflected in the buildup of soil fertility. The exchangeable Ca, Mg and Na contents of the post harvest soil were significantly increased from the initial level. The available micronutrients (Fe, Mn, Zn and Cu) were increased with distillery effluent application and the availability being highest in 1:10 dilution\textsuperscript{131}.

Pulse crops require higher quantity of phosphorus but they are highly susceptible to salinity. Spentwash contains reasonably good amount of phosphorus with high salinity.\textsuperscript{78}

As cash crops are long duration, they require huge quantity of nutrients. If nutrients are supplied through spentwash, the nutrients requirement of the crops can be met besides reducing the use of costly chemical fertilizers. Field crops, \textit{viz.}, sugarcane, rice, wheat and mustard showed positive response to bio-methanated spentwash application along with irrigation water. Even after 20\textsuperscript{th} irrigation (30 % concentrations) with spentwash on specific fields, none of the crops showed any toxicity symptoms. The sugarcane crop receiving nine irrigations and ratoon crop receiving five irrigations with 30 % concentrated spentwash showed better yields compared to normal irrigated crop. The \textit{kharif} crops like maize and rice responded well to biomethanated spentwash irrigation even up to 40 % level. Stress symptoms were visible in case of wheat crop at 40 % bio-methanated spentwash applied for three years\textsuperscript{132}.

Eco-friendly utilization of distillery effluent in Agriculture may serves as one of the nutrient management practices for enhancing crop yields besides reducing the cost involved on fertilizers. But it has to be utilized judiciously and cautiously because of very high organic load. Distillery effluent has excessive biological oxygen demand, chemical oxygen demand and electrical conductivity. These can be overcome either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre plant dilution (40 to 60 days before planting) to give sufficient time for the natural oxidation of organic mater. The untreated distillery spentwash is acidic in nature (pH 3.5– 4.0) which can be effectively used for the reclamation of non saline-sodic soil. Addition of effluent significantly increased the EC, OC, available N, P, K, Ca and Mg also micronutrient status of the soil as reported\textsuperscript{133}.
A field experiment was conducted during 2000 in red soil with wheat as test crop, employing different effluent dilution levels (1:5, 1:10, 1:25, 1:50) in comparison to undiluted effluent and fresh water. Results indicated that available N, P, K, Zn, Cu, and Mn contents in soil were decreased with increased dilution levels.

A field investigation was carried out in Karnataka, during winter seasons of 1999-2000 and 2000-01 to study the effect of conjunctive use of spentwash and water on maize yield and soil properties. It was found that, the nutrient availability, viz., N, P, K, Zn, Cu, Fe and Mn contents in soil was significantly higher in plots irrigated with undiluted effluent than those irrigated with the other treatments. The use of distillery effluent (liquid or solid) as N source and its effect on nutrient uptake and soil nutrient status in wheat production were investigated during 1999-2000 and 2000-01 in Dharwad, Karnataka, India. The treatments included substitution of N with 100% solid or liquid effluent; 50% solid + 50% liquid effluent; 25% solid + 75% liquid effluent; 25% liquid + 75% solid effluent; 25 or 50% effluent as liquid or solid + 75 or 50% inorganic sources, respectively; and 100% inorganic sources. Results indicated that substituting N with 50% solid effluent + 50% inorganic source produced the highest yield, followed by 100% inorganic source. Application of 50% solid effluent + 50% inorganic source also produced the highest nitrogen content and total N uptake. The lowest N uptake and content were obtained under 25% N as solid effluent + 75% N through liquid effluent. Soil available N content was lowest under 25% solid effluent + 75% liquid effluent due to low N uptake by the crop. Soil micronutrient status did not change significantly with N substitution levels. The effects of spentwash, compost, and inorganic fertilizers on the micronutrient contents of Turmeric (cv. Erode Local) and soil were studied in Sathyamangalam, Tamil Nadu, India, during 2001-02. The treatments were: 2.5 t Biocompost ha⁻¹ + 75% of the recommended NPK rates (T1); 2.5 t Biosuper + 75% NPK (T2); 2.5 t Bio compost + 100% NPK + micronutrients (T3); 2.5 t Biosuper/ha + 100% NPK (T4); untreated control (T5); treated spentwash at 50 k l ha⁻¹ as basal + 2.5 t Bio compost ha⁻¹ + 75% NP + micronutrients (T6); and treated spentwash at 50 k l ha⁻¹ as basal + 2.5 t Biosuperha⁻¹+ 75% NP (T7). The fertilizers significantly enhanced the micronutrient (Zn, Cu, Mn and Fe) contents of the soil and plant. T7 resulted in the highest mean soil Zn, Cu, Mn and Fe contents (6.35, 6.85, 18.2 and 13.4 ppm, respectively); Zn (29.7 and 19.4 ppm), Cu (7.8 and 4.1 ppm) and Fe (265.7 and 164.7 ppm) contents of
vegetative parts and rhizomes; and Mn content of vegetative parts (69.9 ppm). The highest rhizome Mn contents were obtained under T4 (34.2 ppm), T6 (34.1 ppm) and T7 (34.3 ppm)\textsuperscript{216}.

The study was conducted to evaluate leachate quality from soils that received different vinasse doses and subjected to various incubation times. In twenty-seven 20x110 cm (diameter x height) PVC columns, three soils, classified as Haplic Nitisol, Yellow Argisol and Carbic Spodosol, were reproduced with horizons, thickness and densities similar to original. The soils were treated with vinasse in doses equivalent to 0 (control), 350 and 700 m\textsuperscript{3}/ha and submitted to incubation time of 30 and 60 days. Collected effluents were analyzed for K, Ca, Mg and Na contents, and data evaluated by multivariate statistical analysis, at 5\% level. The results pointed out significant effect for K, Ca, Mg and Na with regard to soil, dose and incubation time, except for Na in relation to soil. The lowest values for cation concentrations in the leachate were obtained for Nitosol which presented the highest clay fraction, followed by Spodosol due to the spodic horizon. When compared to vinasse, leachate cation concentrations were significantly reduced indicating high retention power of the soils\textsuperscript{220}. A field study conducted for 2 years (2003-05) on sandy-loam soil at New Delhi showed that, on an average, pressmud-distillery effluent compost @ 5 tha\textsuperscript{-1} + half the recommended dose of NPKS recorded perceptible increase in the available NPK status of the soil recorded after oleiferous rocket salad harvest compared with the initial fertility status. Available nutrient status of this treatment was also higher when compared with the recommended dose of NPKS and other treatments. Application of pressmud-distillery effluent compost @ 5 tha\textsuperscript{-1} alone recorded significantly higher residual fertility after oleiferous rocket salad harvest\textsuperscript{223}.

Oil seeds are the important components of agriculture. In India, oilseed production is less than the demand because of their less remunerative nature than other crops. Oil seeds require high amount of sulphur and nitrogen. So, if their requirement is met through spentwash irrigation oil seed production can be made more remunerative.
2.7. EFFECT OF PERCOLATING DISTILLERY SPENTWASH ON SOIL PROPERTIES AND GROUND WATER QUALITY

Dumping of large quantity of spentwash can harm the environment, causing water pollution and Stalinization. The quality of river water and ground water affected by the irregular and unscientific application of distillery spentwash and pollution due to high BOD and COD. Ecofriendly utilization of distillery spentwash is a must to facilitate reduction in pollution load terrestrial and aquatic eco-system.

Working on pulp mill effluents found that when sodium adsorption ratio of paper mill effluents exceeded 9.0, infiltration rate of soil was retarded. This was attributed to the sodium replacing calcium and magnesium from the exchange complex of soils resulting in the dispersion of soil aggregates276.

Soil properties were not affected during the eight year period of irrigation with paper mill effluents without dilution277. Sulphite waste liquor derived from paper mill effluent increased the general microbial activity, humus content, sorption capacity and N contents of the soil. Significant increase in the uptake of total Mn, P, K and Mg by oats over three cuttings was reported278 with increasing rates of application of paper mill effluent. They attributed it to the presence of readily decomposable sugars in the liquor which enhanced N and Mn uptake. Increased P and Mg uptake was ascribed to lignin and tannin content279.Studies indicated that paper mill effluent was useful for fine sandy loam soil and did not cause any detrimental effects to soil properties280.

With addition of sulphite spent liquor, NH4 became immobilized in the early stages due to N assimilation by micro-organism, which rapidly consumed carbohydrates and organic acids present in sulphite spent liquor. Solubility of Fe-P increased in flooded soil due to addition of sulphite spent liquor. Sulphonic acid from sulphite spent liquor was not converted into sulphide in flooded soil281

A highly acidic, rich in N with high BOD, sulphite waste liquor was adjusted to neutral pH and used for irrigation in paddy crop. The early crop growth was good but declined during later stages. But, continuous irrigation with this effluent decreased paddy growth. Yield was found to increase with increasing BOD of the water upto 50 ppm (COD 200 ppm) but above 50 ppm, yield levels were decreased because of creation of reduced conditions and decreased pH in the soil which promoted the leaching of inorganic elements like Fe, Ca and Mg282.
When effluent applied to soil through irrigation undergoes a variety of physical, chemical and biological transformations. Some contaminants become fixed in soil, others are held on exchangeable complex where plants can utilize them, while others may leach to the water table below\textsuperscript{283}. Effluent solids play significant role (waste waters of high and low carbon contents of simulated septic tank and simulated extended aeration) in increasing the pore clogging in low permeable clayey soils\textsuperscript{284}. The application of beef feet slot effluent did not affect the concentration of Ca, Mg, Na and K in the forage sorghum\textsuperscript{285}.

Asparagus yield was adversely affected by the application of high rates of (19 mm/day) vegetable processing waste water with higher COD value (7144 mg/l\textsuperscript{-1})\textsuperscript{286}. The undiluted effluents from M/s Seshasayee paper and Board Ltd., and Venkatesh paper mills Ltd., Tamil Nadu caused an increase in pH, organic matter and available nutrient contents of red and black soils. The percentage pore space in both the soils got reduced and water holding capacity of black soil increased due to effluents, where as decreased in red soil\textsuperscript{287}. Reduction in yield due to irrigation with paper factory effluent as compared to river water was reported in soybean and in finger millet\textsuperscript{288,289}.

The raw distillery spentwash is acidic in nature and rich in Ca and SO\textsubscript{4}\textsuperscript{2-}. Therefore, this could be better utilized as an amendment for reclamation of sodic soils similar to gypsum conducted laboratory studies in soil columns to find out the effectiveness of spentwash in the reclamation of a calcareous saline sodic soil. indicated that the application of spentwash increased the rate of water uptake of the soil. The pH was lowered and the salt content was reduced to safer limits after leaching\textsuperscript{236}.

Diluted effluents however showed a favourable effect on seedling growth. Mixing of pulp mill waste water with chlorination and hypochlorite waste water in 7:1, 4:1 and 3:1 proportions reduced the SAR from 18.8 to 11.1, 6, 6 and 5.3, respectively without any appreciable change in total dissolved salts. Further soils of loamy sand, sandy loam, sandy clay loam and loam texture with good drainage may not exhibit salinity problem as the water having electrical conductivity of 2,000 to 3,000 dSm\textsuperscript{-1} has been used successfully in many places\textsuperscript{290}.
The dry matter and yield of ground nut enhanced considerably due to application of Fe or Zn under effluent irrigation. The uptake of Na and Mg were reduced on addition of amendments under effluent irrigation while no significant increase was obtained with K and P. the Ca uptake was also enhanced.

Addition of undiluted spentwash would result in increased salinity of both soil and ground water where there was not sufficient surface leaching of soil solution.

Impact of spentwash on ground water quality was studied. The nitrate pollution in the ground water was assessed. It was observed, nitrate in the ground water, not at levels harmful to human health.

The effluents of a paper factory, a automobile industry, a textile industry and food and paper industry were alkaline in nature and contained variable amounts of plant nutrients such as Ca, Mg, B, Fe and Cu. The raw effluents altered physico-chemical properties of treated soil and they were responsible for reduction in the rate of germination of seeds.

Zinc smelter effluent was used in a pot culture study with various dilutions and amendments to raise maize, sorghum, wheat and barley the dry matter production for maize, sorghum and barley significantly decreased when undiluted effluent was used. However, when effluent was diluted with water and used for irrigation, it increased dry matter yield of maize and barley and lowered the levels of available Fe, Mn and Zn build up in soil. The Bhadhrachalam paper board industry effluent (Andra Pradesh) could be safely used for irrigation to rice and cotton on alluvial soil having loamy to sandy loam texture. Whereas, for tobacco and chilli with this effluent water led to poor quality produce and reduced crop yield.

Impact of sugar mill and distillery effluent on water quality of River Gelabil, in Assam, during the operational period of the mill and also after its clouser has been studied during the year 1990-91. Water samples from wells were collected fortnightly during November 1990 to April 1991 and monthly from May to October 1991 from various points on the course of the river. D1 is the point where the mill discharges its untreated effluents into the stream and D2 is another point on the course of the stream about 8 kilometers away. The effluent added high concentration of organic matter responsible for the deterioration of the river water quality with respect to pH, total suspended solids, DO, BOD and COD along with NH4+, NO3− and phosphate. During
the period when the mill remained opened, addition of organic matter was less and this was evidenced from the reduction in BOD and COD values\textsuperscript{294}.

The use of vinasse and mineral N with regard to leaching of N from soil and it is possible to pollute the ground water. NO\textsubscript{2}, NH\textsubscript{4}\textsuperscript{+}, NO\textsubscript{3}\textsuperscript{-} or other free N compounds were found in soil samples from depths of 0-2 m presumably because the N in the soil was fixed microbiologically. Ground water contamination by effluent with high BOD and salt content near the lagoon sites in most of the distilleries was noticed\textsuperscript{295}. Effluents discharged from Eshasayee paper and Board Ltd., (Pallipalyan) used for irrigating sugarcane crop on ‘Typic Hapustalf’ for 15 years showed that pH, EC, Organic Carbon, CEC, exchangeable cations, available P.K, micronutrients and enzyme activities were more and there was practically no significant change in most of soil properties\textsuperscript{296}.

According to the studies, diluted spentwash will not add soluble salts to the soil provided there was sufficient leaching of soil solution. However, addition of concentrated spentwash would result in increased salinity of both soil and ground water. Pollution of the Faren stream by six sugar factories, of which two distilleries discharge waste into a stream with no proper treatment making the water unfit for drinking, bathing or irrigation. Analytical results of samples and distillery effluents are significantly higher with respect to infiltration rate (29.6 and 29.2 cm/hr, respectively)\textsuperscript{124}.

Generally the spentwash is discharged into the water bodies. The effluent is therefore, a major course of water pollution. That’s why distilleries have been included in the red category list by the Central Pollution Control Board, India. The chemical composition of spentwash has been studied extensively and it is well understood that each cubic meter of spentwash carries N, P, K, Ca, Mg, S, and organic matter to the tune of 1.8, 4, 11.5, 1, 2.2, 2.5 and 30 kg, respectively\textsuperscript{297}. The effects of have been reported\textsuperscript{298,93}

The use of vinasse (a distillery byproduct) and mineral N with regard to leaching of N from soil and possible pollution of groundwater with NO\textsubscript{2}, NO\textsubscript{3}, NH\textsubscript{4}\textsuperscript{+} or other free N compounds which were found in soil samples from depths of 0-2 m NO\textsubscript{2}, NO\textsubscript{3}\textsuperscript{-} pollution due to vinasse application was observed. The analytical results of bore well samples collected from the spentwash irrigated fields (for more than 3
years) indicated that there was no percolation of effluent to the ground water even though it was used continuously.\textsuperscript{256}

The use and impact of sugar alcohol residues vinasse and filter cake on sugarcane production in Brazil were studied. Vinasse has been used primarily on ratoon cane and filter cake on plant cane. Increased sugarcane yield can be expected from the application of either vinasse or filter cake without detrimental effects on cane quality or environment. World wide, the interest in using sugarcane byproducts is growing, largely to decrease in production cost and environmental liabilities\textsuperscript{299}.

Growth, yield and again quality parameters of triticale cultivation were studied with the use of treated oil refinery effluent. The performance of crop was better under treated oil refinery effluent compared with that underground water. Further, it was found three irrigations with tannery effluent proved superior to four irrigation with treated oil refinery effluent for almost all the characteristics studied\textsuperscript{300}. No pollution on ground water samples collected from open wells near the spentwash applied farmer’s field in Theni district, Tamil Nadu as all the quality parameters were below the critical limits.\textsuperscript{301}

The alcohol distilleries associated with sugar industry, produce 15 to 16 liters of spentwash for every liter of alcohol. The spentwash is highly loaded with BOD and COD and could create the environmental problems and danger to human health, if it is allowed to interact with soil or water bodies\textsuperscript{303,304}. One time land application of spentwash at 150 mg kg\textsuperscript{-1} soil could be a viable technology for reclamation of non-saline sodic soils.\textsuperscript{305} The percentage of germination and the seedling growth of groundnut increased from one to ten % concentrations of the fertilizer factory effluent and the other higher concentrations decreased the germination percentage and seedling growth. Whereas, in control the seedling showed highest fresh and dry weight than the effluent treated plants.\textsuperscript{306} The spentwash may percolate the sub soil and affect the ground water.\textsuperscript{307}

Water samples from 18 dug wells in the shallow basaltic aquifer were analyzed and the results obtained showed spatial as well as temporal changes in the chemical properties of ground water. The temporal changes were attributed to climatic factors, whereas variations in the geo-chemical characteristics of ground water appeared related to pollution by effluents from the M/S Mula Sugar Factory (India)
released into the stream flowing through the area\textsuperscript{226}. Leaching experiment was conducted and showed that large amounts of soluble cations were leached from soil amended with spentwash. Increase in the spentwash application had markedly enhanced the leaching of cations. Calcium was the dominant cation leached from calcareous vertisol, whereas, greater amount of sodium was found leached from high pH sodic soil\textsuperscript{227}. The effect of distillery spentwash on some soil characteristics and water was studied. The effluent of Sir Sadial distillery situated at Mansurpur, (Dist. Muzafarnagar) falls into the river Kali. Soil samples were collected very nearer to effluent channel and away from the channel. Comparison of the water and soil characteristics revealed that the effluent water (spentwash) is highly polluted with very high (far more than ISI standards) BOD, COD and dissolved/suspended solids contents which got diluted after mixing with the Kali water. The spentwash along with river water moved down, its organic load reduced substantially and the river water on upstream side was least polluted owing to non-availability of effluent from any industry. Soil samples collected from effluent fed field showed higher sand content and organic matter compared to the soil without being fed with effluent\textsuperscript{264}.

Eco-friendly utilization of distillery effluent in agriculture may serve as one of the nutrient management practices for enhancing crop yields besides reducing the cost involved on fertilizers. But it has to be utilized judiciously and cautiously because of very high organic load. Distillery effluent has excessive biological oxygen demand, chemical oxygen demand and electrical conductivity. These can be over come either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre plant dilution (40 to 60 days before planting) to give sufficient time for the natural oxidation of organic matter. The untreated distillery spentwash is acidic in nature (pH 3.5-4.0), which can be effectively used for the reclamation of non saline-sodic soil. Addition of effluent significantly increased the EC, OC, available N, P, K, Ca and Mg also micronutrient status of the soil\textsuperscript{133}.

A stationary field experiment was carried out for 5 years at the Enrique Varona Agro industrial Complex, in Cuba, to evaluate the cumulative and residual effect of applying different vinasse dilutions in water (1:2.5, 1:5, 1:10 and 1:20) on the chemical properties of Vertisols and sugarcane yields. It was observed that vinasse dilutions increased the content of calcium and other cations, as well as the base exchange capacity. Results proved that treatments using vinasse with water improved
soil inter-cationic balance increased the base-exchange capacity and prolonged the useful life period of the strain.\textsuperscript{308}

Irrigation water continues to be the single most important factors dictating the success of crop productivity in arid and semi-arid agro-climatic zones. In the past five decades, the water availability has reduced to half and further reduction is fast approaching. This necessitates using every drop of water that can be recycled back to the crop production. Sugarcane-based industries are increasing exponentially and many factories adjunct with distilleries in order to balance the price of sugar in the open market besides enhancing energy security of the country. In the distillery industry, for every litre of alcohol produced, about 15 litres of spentwash is released as waste water. Different terminologies are used for this type of effluent in different countries viz., stillage, vinasse, slop, dunder, still residue etc. There are 319 distilleries in India with an installed capacity of 3.25 billion litres of alcohol, generating 48 billion litres of raw distillery spentwash annually.\textsuperscript{309}

The distillery effluent is rich in organic and inorganic ions, which may leach down and pollute the groundwater. An on-farm experiment was conducted to assess the impact of long-term irrigation with post-methanation distillery effluent (PMDE) on nitrate, sulphate, chloride, sodium, potassium, and magnesium contents in the groundwater of two sites in northwest India. Electrical conductivity (EC), pH, total dissolved solids (TDS), sodium adsorption ratio (SAR) and color were also determined to assess the chemical load in the groundwater. Nitrate content in the groundwater samples ranged from 16.95 mg/l in the unamended fields to 59.81 mg/l in the PMDE-amended fields during the 2-year study (2001-2002). Concentrations of TDS in water samples from tube well of the amended field were higher by 40.4% over the tube well water of the unamended field. Color of the water samples of the amended fields was also darker than that of the unamended fields. The organic and inorganic ions added through the effluent could pose a serious threat to the groundwater quality if applied without proper monitoring. The long-term indiscriminate use of PMDSW could lead to significant leaching of inorganic salts. Although leaching of salts has the potential to affect the quality of groundwater, the actual impact will depend on the rate of recharge of groundwater and initial status of groundwater quality.\textsuperscript{310}
Sugar industry effluents contain high biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH) and total dissolved salts (TDS) and affect the seed germination, soil and irrigated lands.\textsuperscript{215,311}

Usually stillage presents high concentrations of nitrate, potassium and organic matter. Its utilization may change the characteristics of soil and modify its chemical properties, increasing the availability of some elements for plants. On the other hand, stillage may also promote change in physical properties of soil in two different ways: these changes can improve soil aggregation, increasing soil water infiltration capacity and, consequently, increasing leaching of ions, in such a way to contaminate the groundwater when at high concentrations, as well as to promote dispersion of soil particles, contributing for a decrease in its infiltration rate and an increase of runoff, with possible contamination of surface water. Due to the fact that there are different types of soil and stillage composition, the results obtained were very variable; however, agreement exists that its application must be made according to the cation exchange capacity of soil. Groundwater quality of Jagdishpur block, Dist. Banka (Bihar, India) was evaluated to assess the impact of distillery unit. Several parameters viz. temperature, pH, conductivity, turbidity, BOD, COD, total hardness, chloride, Na, K, Ca, Mg, nitrate and phosphate were analyzed. It was found that BOD, COD etc. were substantially high and not fit for human consumption.\textsuperscript{312}

The potential value and the problems associated with the usage of spentwash in Rampur District were studied and also their environmental impacts were discussed. The studies revealed that, though at higher doses (>250 m\textsuperscript{3} ha\textsuperscript{-1}) spentwash application is found detrimental to crop growth and soil fertility, its use at lower doses (125 m\textsuperscript{3} ha\textsuperscript{-1}) remarkably improves germination, growth and yield of dry land crops. Large amounts of soluble salts have been found to be leached from calcareous and high pH sodic soils amended with spentwash. Notably, application of spentwash has resulted in leaching of high amounts of sodium from high pH sodic soils reflecting its potential in ameliorating these soils. However, exceptionally high loading of the leachate with organic and inorganic contaminants may pose potential risk for groundwater contamination.\textsuperscript{313}

Distillery spentwash is the unwanted residual liquid waste generated during alcohol production and pollution caused by it is one of the most critical environmental issue. Despite standards imposed on effluent quality, untreated or partially treated
effluent very often finds access to watercourses. The distillery wastewater with its characteristic unpleasant odor poses a serious threat to the water quality in several regions around the globe.\textsuperscript{314}

The discharge of untreated liquid effluents above the National Environmental Quality Standards (NEQS) for industrial effluents may affect quality of soil, groundwater and receiving water bodies. The toxic materials may enter the food chain and cause problem, the effluents of the sugar industry on the water bodies for human health\textsuperscript{315,316} Though several piezometric studies have reported that application of treated spentwash at the rate of 100 m\textsuperscript{3} ha\textsuperscript{-1} did not contribute for groundwater pollution, it is not advisable to apply PMDSW continuously even at doses < 80 m\textsuperscript{3}ha\textsuperscript{-1} as there is a possibility of groundwater contamination due to continuous application of PMDSW.\textsuperscript{317}

In India, a large amount of spentwash generated from distillery industries is discharged either on land or into the running water. The spentwash is dark brown in colour having unpleasant odour with high COD, BOD and electrical conductivity besides appreciable quantities of plant nutrients. Its disposal without treatment would cause pollution of soil, water and air.

Ethanol distillery throws 11880m\textsuperscript{3}/day spentwash highly loaded with salts, oxygen demanding wastes and nutrients into evaporation ponds, which percolate into groundwater and affects its quality. The groundwater around the evaporation ponds is used as drinking water and irrigation. Thirty-five representative water samples (3 spentwash, 2 drainage water and 30 groundwater) were collected and analyzed for 15 different parameters; pH, electrical conductivity, total dissolved solids (TDS), total hardness, chlorides, phosphates, alkalinity, nitrates, sulphates, chemical oxygen demand (COD), Na, K, Ca and Mg. The spentwash indicates a high concentration which is above the permissible limits of National Environmental Quality standard (NEQS) for industrial effluents. Groundwater samples collected near the evaporation ponds indicate high concentrations of nitrate and COD indicating contamination of groundwater. Coefficient of correlation among the parameters, contamination index and sodium absorption ratios were calculated to correlate the sources of contamination and suitability of water for drinking and irrigation purposes. Fourteen groundwater samples indicate the contamination index of more than 3 and are considered as highly contaminated.\textsuperscript{318}
Post-methanated distillery spentwash (PMDSW) is a by-product of sugar industry often used as a source of nutrients for a wide array of crops. In the past four decades, PMDSW has been extensively studied in various crop production systems that brought out benefits and concerns associated with this industrial waste water. PMDSW changes in soil physical, chemical and biological characteristics shift in ground water quality, long-term effects and responses of crops. The spentwash applications has resulted in the changes of soil properties such as impeded hydraulic conductivity, build up of salinity and restricted biological activity transiently as a secondary consequence of intense salt stress. Despite these ill-effects, PMDSW carries macro and micronutrients that facilitate better growth and yield performance in almost all crops that have been experimented. One of the potential hazards associated with PMDSW is the interference with groundwater which is rarely reported or critically analyzed in the context of seasonal and temporal shifts. Overall, this suggests that the PMDSW can be exploited as a source of nutrients to sustain the crop production with a rider that excessive or continuous use need to be circumvented.\(^{319}\)

2.8. MINERALIZATION OF NUTRIENTS IN SOIL TREATED WITH SPENTWASH

The amount of nutrients present in distillery spentwash that become available to plant following its application is to be assessed in order to apply the spentwash to fulfill the nutrient requirement of crops. Availability of nutrients from effluent includes the amount of plant available nutrients already present in spentwash plus the amount that is mineralized to plant available form. Some of the literatures are presented.

The organic matter oxidation brought out by microbial activity was responsible for increased pH of the soil treated with distillery effluent.\(^{55,320,141}\)

A laboratory experiment was conducted to study in soil columns to find out the effectiveness of spentwash in the reclamation of a calcareous saline sodic soil. They observed that the application of spentwash increased the rate of water uptake of the soil. The pH was lowered and the salt content was reduced to safer limits after leaching. The application of spentwash in air dried soil followed by irrigation had greater effect than that of spentwash diluted at the time of application itself in
reducing the soil pH and ESP. Exchangeable sodium percentage was reduced from 100 to 2 in the top 15cm when spentwash applied equivalent to 100% gypsum requirement. The untreated spentwash has an acidic pH and contains substantial quantity of beneficial divalent cations viz., calcium and magnesium.\textsuperscript{236}

The reduction in hydraulic conductivity by distillery effluent irrigation was due to accumulation of solids at the soil surface.\textsuperscript{239}

Increasing levels of spentwash application did not alter total N, organic carbon and exchangeable Na levels but exchangeable K, Ca, Mg and pH were increased, while exchangeable Al, available P and NO\textsubscript{3}\textsuperscript{-} were decreased. Mineralization of organic material as well as nutrients present in the effluent was responsible for increased availability of plant nutrients.\textsuperscript{108}

**Effects of spentwash on soil fertility**

Every cubic meter of distillery spentwash contains 1kg of nitrogen, 0.2kg of phosphorus oxide and 10kg of potassium oxide. Most of these nutrients are soluble forms and are easily available to plants.

Spentwash was classified as dilute liquid organic fertilizer with high K content.\textsuperscript{63} They observed that N was mostly in colloid form behaving as a slow release fertilizer better than most inorganic N sources. Macro and micronutrients Several workers have reported that there was an increase in N status of soil under spentwash application.\textsuperscript{32,180,317}

Increasing amount of K in the exchangeable phase of soil decreased hydraulic conductivity of soils.\textsuperscript{322}

**Effect of spentwash on soil properties**

The spentwash, being loaded with organic and substances could bring drastic changes in the physical, chemical and biological properties of soil. Soil physical properties Soil permeability and porosity are the important parameters to be considered when planning for liquid waste disposal to agricultural land. In soils, heavy dose of organic carbon compound due to distillery waste disposal may cause high oxygen demand by bacterial activity under anaerobic condition, which will in turn cause a decrease in infiltration rate and a reduction in hydraulic conductivity due to accumulation of solids.\textsuperscript{146}
Soil biological properties

The distillery effluent being rich in nutrients and organic matter was found to improve the soil microbial populations. But observations recorded soon after the application of spentwashon soils showed an initial setback in the microbial populations and enzyme activities observed that the spentwash @ 250 m³ha⁻¹ stimulated the soil microorganisms and increased the dehydrogenase activity of the soil.³²³,³²⁴

An improvement in saturated hydraulic conductivity and reduction in bulk density of the soil with effluent amendment over the control.⁷⁹ The spentwash application reduced the pH and ESP (Exchangeable Sodium Percentage) to safer limits. However, an increase in pH of the soils observed in the post harvest soils might be due to leaching of soluble salts and the oxidation of organic matter.⁸⁰

Further, the application of treated spentwash also increased the activities of these soil enzymes.³²⁵

The distillery spentwash (treated or untreated) should be applied before planting to give sufficient time for natural oxidation of organic materials, which in turn enhances the soil available nutrients.³²⁶, 198

The availability of Cu, Zn, Fe and Mn was increased in the sodic soil amended with spentwash. The increased micronutrient availability might be due to direct contribution from the spentwash as well as solubilisation and chelation effect of organic matter.³²⁷,³²⁸ The spentwash has a high amendment value and comparable to any chemical amendment recommended for alkali soil reclamation.³⁰²

The effect of spentwash on soil fertility in laboratory incubation was studied. The result indicated that the soil pH values decreased while EC values increased with increasing level of spentwash application. The highest value of organic carbon was found in 87.5 m³ha⁻¹ spentwash level. The available N, P and K increased with an increase in spentwash levels.²⁵⁸

A field experiment was conducted between 1998 and 1999 at the EID Parry sugar factory command area, Nellikuppam, Tamil Nadu, India, to assess the optimum dilution with irrigation water of distillery effluent used as an organic nutrient source for growing sugarcane crops in sandy soil. Irrigation with treated distillery effluent at 1:10, 1:20, 1:30, 1:40 and 1:50 dilutions was done every 40 days between 45 days and
6 months after planting. Levels of OC, macro- and micronutrients, and soil microbial population were significantly higher in the treated soils. The distillery effluent at 1:10 dilution is the optimum for building up soil fertility and increasing sugarcane yield in sandy soil.\textsuperscript{131}

Field experiments were conducted during 1999-2000 in Tamil Nadu, India, to determine the optimum dilution of distillery effluent mixed with irrigation water (1:10, 1:20, 1:30, 1:40 and 1:50) for its direct application to sugarcane. Its effect on soil (Inceptisols and Alfisols) properties was observed. There was a gradual increase in available N, P and K, which in turn reflected in the buildup of soil fertility. The exchangeable Ca, Mg and Na contents of the post harvest soil were significantly increased from the initial level. The available micronutrients (Fe, Mn, Zn and Cu) were increased with distillery effluent application and the availability being highest in 1:10 dilution.\textsuperscript{131}

The available N, P, K and micronutrients such as Fe, Mn, Zn and Cu were increased due to the spentwash application as reported\textsuperscript{131, 329, 330} The amount of microbial biomass C in spentwash amended soil increased significantly with the increasing rates of application and reached maximum peak after 30 days of application. The EC and OC of soil increased with increasing levels of spentwash application, but did not affect soil pH. Further, the effect on mungbean showed that the application of spentwash up to 100 m\textsuperscript{3}/ ha led to an increase in dry matter production and N, P and K uptake. But spentwash @ 500 m\textsuperscript{3}ha\textsuperscript{-1}or above drastically reduced the dry matter yield.\textsuperscript{331}

A significant increase in the pH of the post harvest soil due to the application of graded doses of primary treated distillery effluent. However, the increase was only by 0.2 units which fall within neutral reactions even at higher dose of distillery effluent (6.25 lakhs l ha\textsuperscript{-1}).\textsuperscript{197} The addition of raw spentwash at 125 m\textsuperscript{3} ha\textsuperscript{-1} in dry land soils increased the activity of soil enzymes, viz., the phosphatase, dehydrogenase and urease.\textsuperscript{332}

The applicability of Langmuir and Freundlich adsorption isotherms on potassium adsorption by the addition of spentwash in Vertisols, Inceptisols and Entisols was studied. The higher adsorption of potassium was observed in Inceptisols followed by Vertisol and Entisol. The superiority of Freundlich model over Langmuir
model of adsorption was observed in all the types of soil by the addition of K through spentwash.333

The bulk density of the soil was decreased and the particle density remained unchanged in the spentwash applied soils.334

A laboratory incubation study on clay loam Typical Haplustert soil to measure the oxidative loss of carbon from the soil treated with six levels (0, 0.38, 0.76, 1.14, 1.52 and 1.90 m³) of spentwash was conducted. The study revealed that quantitatively, 37.03 to 16.02% of the applied C were lost as CO₂ after 8 weeks of incubation. At low level of added C, higher percentage of loss was obtained compared to high level of application. They concluded that it would take 11.95 to 31.5 weeks to allow 50 % of added C to be lost as CO₂ through microbial respiration following the spentwash application.335

A laboratory experiment on black (Vertisol), alluvial (Inceptosol) and red (Alfisol) soils to study the effect of soil application of untreated spentwash on the changes of NO₃-N in soil was studied. Extractable nitrate content in all the three soils decreased markedly with increase in the levels of spentwash application. Further they opined that the high BOD and COD values might have decreased the redox potential of the soil solution below threshold Eh value for nitrate reduction and probably reduced the extractable nitrate drastically in soil. In contrast, the NH₄-N content increased with increase in the levels of spentwash application.336

The annual treated distillery spentwash obtained in India can supply 16,800 t N, 6,300 tonnes P and 1, 26,000 tonnes K and by this it is estimated that Indian distilleries could contribute about 10,000 million rupees annually. Moreover, experiments conducted to reveal the application of distillery spentwash increases the soil hydraulic conductivity. Soil chemical properties The multifaceted characteristics of spentwash bring about significant changes in the chemical properties of soil.266

A study was conducted in Hungary to investigate the advantages and potential disadvantages of using vinasse as a soil amendment. A total of 10,000 kg vinasse/ha was applied on an alluvial soil cultivated with potatoes. The treatment was carried out in 100 m² plots in four repetitions. K content was higher in the deeper layers of the vinasse-treated soil. Results also indicated that Na content was much higher in every layer of the vinasse-treated soil. There was a marked difference between the
compaction pattern of the control (untreated) and the vinasse-treated soil. The average compaction of the upper layer in both fields was \( \sim 2 \) MPa. The compaction increased gradually and reached \( \sim 4 \) MPa, but the values were a little higher in the vinasse-treated soil.\(^{337}\)

Reclamation of sodic soils the raw distillery spentwash is acidic in nature and rich in Ca and SO\(_4\)^{2-}. Therefore, this could be better utilized as an amendment for reclamation of sodic soils similar to gypsum.

The effect of sugar mill effluent on plant growth and biochemical constituents of Raphanus sativus L. var. Pusha Chetki was studied in a pot culture experiment. The experiment was conducted at Botanical Garden, Department of Botany, Annamalai University, Tamil Nadu, during the period of January to March 2008. In the pot culture experiment, radish plants were grown up to 60 days, in the soil irrigated with different concentrations of sugar mill effluent (viz, 0, 20%, 40%, 60%, 80% & 100%v/v). The inner surface of pots was lined with a polythene sheet. Each pot containing 5kg of air dried soil. Six seeds were sown in each pot. All pots were irrigated (500ml) with respective concentration of test solutions daily. Plants were thinned to a maximum of three per pots, after a week of germination. The higher sugar mill effluent concentrations (above 40%) were found to affect plant growth and decreased chlorophyll-a, chlorophyll-b and total chlorophyll, caroteinoids, total sugar, amino acids and protein contents, but diluted effluent (up to 40%) favoured the plant growth and biochemical contents.\(^{338}\)

Distillery spentwash contains all nutrients and organic matter and used in agriculture as a source of plant nutrients and irrigation water. Besides all the nutrients, spentwash contains appreciable amount of nitrogen also. The effect of different levels and methods of spentwash application on soil nitrogen dynamics was examined through a field experiment. The field experiment was conducted using Groundnut (Arachis hypogea L.) as a test crop. At all stages of groundnut growth, the amounts of NH\(_4^+\)-N and NO\(_3^-\)-N were greater in soil that received 120 m\(^3\) of spentwash with the recommended dose of NP fertilizers. Results shown that the spentwash not only adds mineral N (NH\(_4^+\)-N and NO\(_3^-\)-N) to soil, but also promotes the mineralization of soil organic N, thus resulting in large amounts of NH\(_4^+\)-N and NO\(_3^-\)-N in soil. The present study was, therefore, undertaken to study the nitrogen dynamics in soil under spentwash application and its impact on soil, crop and environmental quality.\(^{339}\)
An eco-environmental and geochemical investigation was carried out on the concentration of heavy metals (cadmium, lead) and micro nutrients (copper, manganese, and zinc) in the surface water and sediments of the River Gadilam, that receives the sugar industry treated effluent. The main objective of this study is to assess the environmental situation and evaluate the transferring of heavy metals and micro nutrients from the sugar industry into the river environment. To study the magnitude of heavy metal pollution in the Gadilam River, water samples and sediments were collected in replicates and analyzed using Atomic Absorption Spectrometer during the five consecutive seasons. The industrial effluents analyses results were compared with the Tolerance Limits for Industrial Effluence discharge (Indian Standard: 2490, Part-I-1981) and river water samples with Indian drinking water standards to determine the heavy metal contamination in the river. Some indices such as “Contamination degree”, and “Geo-accumulation index”, were used to assess environmental quality of river water and sediments samples. Spatial pattern of heavy metals indicated that heavy metals in water and sediments showed lower concentration in the upstream, moderate concentration in the sugar industrial area and higher concentration in the downstream where it receives the domestic sewage and other chemical industrial effluents from SIPCOT industrial area. ANOVA results showed that the seasonal and spatial variations of heavy metal and micro nutrients contamination in the water and sediments of Gadilam River were highly significant. Correlation between the Cd, Pb, Zn, and Mn concentration in water and sediments showed a linear positive correlation; however, no correlation was seen in Cu. The ranking pattern of average values of heavy metals and micro nutrients concentration in the water and sediments were Zn>Mn>Pb>Cu>Cd during the five seasons, indicating among the heavy metals Zn was present at highest concentration while Cd was in least concentration. Cluster analysis applied to the five various heavy metals and four sampling sites of water and sediment of the river, have grouped them based on the water quality similarities. Overall the results of the present study suggest the need for a regular monitoring program, which will help to improve the quality of Gadilam River.

Nutrient composition of crude and digested spentwash and effect of their application on sugarcane growth and biochemical attributes were studied. Higher concentrations of essential nutrients (P, S, Fe, Mn, Zn, and Cu) and heavy metals (Cd,
Cr, Ni and Pb) were present in crude spentwash (CSW) as compared to the digested spentwash (DSW); sulphur content was the highest (765 $\mu$g ml$^{-1}$ in DSW and 1,609 $\mu$g ml$^{-1}$ in CSW) among all nutrients analyzed. Sugarcane (Saccharum spp. hybrid cultivar CoLk 8102) sets grown in soil pot culture conditions with different rates of crude spentwash (5, 10, 20 and 100 ml kg$^{-1}$ soil) along with digested spentwash (100 ml kg$^{-1}$ soil) showed improvement in bud sprouting (10.5 %), settling height (40 %), root number (9.4 %), root length (13.2 %), chlorophyll a (52.9 %) and b (55.3 %) contents and activity of catalase (98 %) enzyme over control at low rate of crude spentwash (5 ml kg$^{-1}$ soil). Whereas, higher doses of spentwash (20 and 100 ml kg$^{-1}$ soil) decreased these parameters markedly except peroxidase which was found higher at all the levels of both CSW and DSW. Findings indicated stimulatory effect of low rate of crude spentwash (5 ml kg$^{-1}$ soil) on root and shoot growth and inhibitory effect of higher dose (100 ml kg$^{-1}$ soil) of both crude and digested spentwash, therefore, judicious application of spentwash will improve crop productivity and alleviate environmental pollution problems.\cite{341}

Distillery spentwash is a rich source of organic matter and nutrients like nitrogen, phosphorus, potassium, calcium and sulfur. In addition, it contains sufficient amount of micro-nutrients such as iron, zinc, copper, manganese, boron, and molybdenum. A field experiment was conducted with different dilutions of distillery spentwash using sugar cane (Saccharum officinarum) variety Co1274 as test crop. The experiment was formulated with four treatments (25%, 50%, 75% and 100%) with three replicates, with a set of control for comparison. The growth parameters like height of the plant, length of the leaves, breadth of the leaves, girth of the stem, leaf area index, number of leaves per plant, no. of tillers per plant etc of the plant enhanced with increase in concentration of distillery spentwash up-to 75%. But in 100% concentration of distillery spentwash all the growth parameters showing a declining trend from the control. This increase in the parameters is statistically significant.\cite{342}

Molasses-based distilleries are one of the most polluting industries generating large volumes of high strength wastewater. Different processes covering anaerobic, aerobic as well as physico-chemical methods have been employed to treat this effluent. Anaerobic treatment is the most attractive primary treatment due to over 80% BOD removal combined with energy recovery in the form of biogas. Further
treatment to reduce residual organic load and color includes various: (i) biological methods employing different fungi, bacteria and algae, and (ii) physico-chemical methods such as adsorption, coagulation/precipitation and oxidation and membrane filtration.343

This study is primarily concerned with the strategies adopted by large and medium scale sugar mills to control environmental pollution. Since sugar mills are pollution prone industry, they must be careful and honest to comply fully with pollution control measures. Source reduction, reus, and recycling treatment and disposal strategies are followed by the sugar industries of developed countries very effectively. In Nepalese context, however, most of the sugar mills have adopted only one or two strategies which can not be considered sufficient to control environmental pollution. Only Sri Ram Sugar Mill Ltd., Rautahat has established Anaerobic Digestion Process (ADP) for the treatment of effluents of sugar and distillery plants which is an advance step for controlling environmental pollution.344

Rampant use of chemical fertilizers contributes largely to soil degradation and adversely impacted agricultural productivity deteriorating the environment. The lack of sustainability in production in recent years is becoming a major concern. Proper management of waste can produce good quality organic manure which can act as soil conditioners. The organic wastes generated due to domestic activities contain decomposable substances that can form substrates to produce organic manure by composting and Vermicomposting. Spentwash produced from distillery industries is rich in organic material and characteristically less toxic and easily amenable for microorganisms. An attempt is made to use the spentwash as an ameliorant to enhance the organic manure form kitchen wastes using composting and Vermicomposting. A bioassay study result of cowpea plant (Vigna unguiculata) has proved the productive character of distillery spentwash as an ameliorant for composting and Vermicomposting. The present result also advocates a new eco-friendly, economical and environmentally safe strategy to utilize the distillery effluent for producing valuable organic fertilizer that reduces environmental hazards to meet the needs of the agriculturalists and the industrialists.345
2.9 STUDIES ON THE IMPACT OF DISTILLERY SPENTWASH ON IRRIGATION

On seed germination and growth of leaves Vegetables, the nutrients of Cabbage and Mint Leaf, the nutrients of some top vegetables, the nutrients of top vegetables on the soil characteristics, the yields of some fruits, nutrients of pulses in untreated and Treated soil, nutrients of Leaves vegetables, the nutrients of Pulses, the growth, yield and nutrients of leafy vegetables in untreated and treated soil, the nutrients of some condiments and root vegetables, the nutrients of some fruits. An effective eco-friendly irrigation medium, yields of some root vegetables, yields of some top vegetables (Creepers), the yields of some condiments, the growth of Leafy Vegetables in Untreated and Treated Soil, yields of some Root vegetables in Untreated and spentwash treated soil, nutrients of condiments irrigated by distillery spentwash in untreated and spentwash treated soil, nutrients of fruits in untreated and spentwash treated soil, nutrients of top vegetables (Creepers) in normal and spentwash treated soil, Nutritional additives of spentwash on pulses production, Creeper Medicinal plants in Normal and Spentwash Treated Soil, yields of creeper medicinal plants, yield of leafy vegetables irrigated by distillery spentwash in normal and spentwash treated soil, nutrients of creeper medicinal plants, Nutrients of Leafy Medicinal Plants, Nutrients of Root Vegetables in Untreated and Spentwash Treated Soil, nutrients uptake of herbal medicinal plants in normal and spentwash treated soil, yields of tuber/root medicinal plants, on the production of Radish, Onion (Allium cepa) and Garlic (Allium cepa) Medicinal Plants in Normal and Spentwash Treated Soil, Growth, Yield and Nutrients of Leafy Vegetables, the nutrients of tuber/root medicinal plants, the nutrients of Banana, (MUSA PARAISSICA) and Papaya (CARCIA PAPAYA) fruits, yields of herbal medicinal Plants, Sustainability of Common Carp (cyprinus carpio) Fishes, production of leafy medicinal plants in normal and spentwash treated soil, Yield of Leafy Medicinal Plants, Nutrients of Ginger (Zingiber officinale) and Turmeric (Curcuma longa) Medicinal Plants in Normal and Spentwash Treated Soil, yields of creeper medicinal plants in normal and spentwash treated soil, Nutrients Uptake of Top Vegetables Irrigated By Distillery Spentwash in Normal and Spentwash Treated Soil, Nutrients of Herbal Medicinal Plants, Yields of Radish (Raphanus sativus), Onions (Allium cepa) and Garlic (Allium cepa).
Onion (Allium cepa) and Garlic (Allium sativum) Yields of Tuber/Root Medicinal Plants in Normal And Spentwash Treated Soil, Germination and Growth of Cotton and Groundnut Seeds yields of leafy medicinal plants in normal and spentwash treated soil Life Sustainability of Grass Carp (Ctenopharyngodon idella) Fishes on Implication of Distillery Spentwash Sprouting and Growth studies of Rose (Rosa) and Hibiscus (Hibiscus rosasinensis) lowering plants irrigated by distillery spentwash Nutritional Additives of Distillery Spentwash on the Production of Creeper Medicinal plants in Normal and Spentwash Treated Soil Implication of Distillery Spentwash on the Sustainability of Catla (catla catla) Fishes Yields of Herbal Medicinal Plants Irrigated by Distillery Spentwash in Normal and Spentwash Treated Soil Studies on the germination and growth of Zinnia (Asteraceae) and Vinca (Apocynaceae) seeds irrigated by distillery spentwash Studies on the Germination and Growth of Mustard (Brasica nigra) and Castor (Ricinus communis) seeds irrigated by Distillery Spentwash, Bioresearch Bulletin Sprouting and Growth of Gardenia (Rubiaceae) Flowering plant Sprouting and Growth of Tagetes (Asteraceae) Flowering plant Sprouting and Growth of Himalayan Balsam (Balsaminaceae) and Crossandra (Acanthaceae) Flowering plants Spentwash as an Effective Liquid Fertilizer and Alternative Irrigation Medium in Floriculture Germination and Growth of Chrysanthemum indicum and Polianthes tuberosa Flowering Plants Yields of Mustard (Brassica nigra) and Castor (Ricinus communis) Oil Seed Plants sprouting, growth and yield of Nerium Oleander (Apocynaceae) flowering plant yields of Himalayan Balsam (Balsaminaceae) and Crossandra (Acanthaceae) Flowering Plants.

2.10 OBJECTIVES AND SCOPE OF THE PRESENT WORK

In recent past days ethanol is being used as ecofriendly fuel by blended with petrol/diesel in automobiles. The production of ethanol is renewable, agrobased and is more oxygenated gives high fuel efficiency. As a result the production of ethanol is considerably increased and hence the amount of spentwash generated from the distilleries drastically increased. Spentwash characteristics are not tolerable and cause environmental pollution (soil, air and water). The disposal of the spentwash is great problem but fortunately the spentwash is enriched with macro and micro plant nutrients. Therefore the spentwash can be used for irrigation in agriculture. But the
spentwash is highly acidic with high values of COD and BOD and hence it spoils the soil characteristics and makes unfit for agriculture. It was found that diluted spentwash could be conveniently used for irrigation purpose. Therefore, at present, we intend to study the nature of growth, yield and nutrients of different varieties of mulberry plants by irrigation with different proportion of spentwash and to find a solution for effective utilization of distillery spentwash in agriculture, a field experiment on “The impact of distillery spentwash irrigation on mulberry plants and growth of silkworms” was conducted with the following objectives.

1. To characterize the distillery spentwash for physical and chemical properties.

2. To study the irrigational impact of distillery spentwash on the yields and nutrients of mulberry plant leaves.

3. To study the yields and influence on the overall performance of the different silkworm cocoons reared with varieties of mulberry plant leaves irrigated by different proportions of spentwash.

4. To study the mineralization of major nutrients in spentwash treated soil.