ECOFRIENDLY UTILISATION OF DISTILLERY WASTE WATER IN AGRICULTURE




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2013

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On

MANAGEMENT OF SALT AFFECTED SOILS AND USE OF SALINE WATER IN AGRICULTURE

Bulletin on

Ecofriendly Utilisation of Distillery Waste Water in Agriculture

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PREFACE

India is a major producer and consumer of sugar in the world. The 579 sugar industries in the country produce 19.0 million tonnes of white sugar, about 7.5 million tonnes of molasses and 45 million tonnes of bagasse as valuable by-products.

Molasses is used as a raw material in the distillery industries where alcohol is produced. Distilleries are one of the 17 most polluting industries listed by the Central Pollution Control Board. At present, there are 319 distilleries in India with an installed capacity of 3.25 billion litres of alcohol, which are generating 48 billion litres of distillery spentwash annually. In Tamil Nadu there are 16 distilleries with a total installed capacity of 2.4 lakhs kilolitres of alcohol generating 36 lakhs kilolitres of distillery spentwash.

The distillery industrial waste water is non toxic, biodegradable, purely of plant origin and contains large quantities of soluble organic matter and plant nutrients, which may be utilized by the plants for their growth and yield. However, the only problem with distillery effluent is its high BOD, COD and salt content being observed as non eco-friendly.

The effluent contains high potassium (1.3 per cent) and sulphur (0.4 per cent) and appreciable amounts of nitrogen (0.2 per cent) and acts as a slow release fertilizer being mostly in the colloidal form. It also contains large amount of calcium, copper, manganese, zinc and a substantial quantity of organic matter essential for soil health. So, it can be applied directly to the land as nutrient as it helps in restoring and maintaining soil fertility, increasing soil micro flora, improving physical and chemical properties of the soil leading to better productivity of the soil.

Although the distillery effluent utilization in agriculture has augmented the crop yields, its unscientific and unsystematic use causes degradation of land and the environment. Thus, wherever there is uncontrolled discharge of distillery effluent, the environment is aesthetically unpleasant. Scientific utilization of distillery effluent in agriculture would save costs on fertilizers and facilitate reduction in pollution load on the environment and also improve the overall soil health. Keeping all this in view, this bulletin is prepared by compiling considerable information regarding the scientific rationale and utilization of distillery industrial wastewater in a ecofriendly way by the farmers for increasing the crop productivity.

We express our deep sense of gratitude to Dr.S.K. Ambast, Project Coordinator AICRP on Management of salt affected soils and use of saline water in Agriculture for his valuable guidance. M/S EID Parry (India) Ltd., M/S Chemplast sanmar Pvt. Ltd., M/S Kothari Sugars and M/S Trichy Distilleries are gratefully acknowledged for their financial assistance.

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	FOREWORD	**Date:27-05-2013**

India has emerged during recent years as the largest sugarcane producer in the world. To keep pace with the industrialization and development, a large number of sugar factories are being established all over the country and quite a substantial amount of molasses has been produced from these factories. In the present scenario as well as for future, demand for alcohol will increase in the country and so also the number of distilleries producing alcohol. This is clearly evident from the two fold increase in number of alcohol industries in India during the last decade. The proportion of wastewater, generally known as spent wash, is nearly 12 times the total alcohol production. This massive quantity, approximately 48 billion litres of effluent, if disposed untreated can cause considerable stress on the water courses leading to widespread damage to aquatic life. The enormous distillery wastewater has the potential to produce 1100 million cubic meters of biogas, considerable quantity of nitrogen and potassium, thus availability of nutrients in distillery effluents and possibility of substituting these for inorganic fertilizer in agriculture has a great promise. Hence, utilisation of distillery effluents in agriculture would save costs on fertilisers and facilitate reduction in pollution load on aquatic eco-system. The raw spent wash being acidic in nature and high in calcium content can be used as an amendment for sodic soil under controlled land application.

I complement the authors for bringing out this comprehensive information on ecofriendly utilization of distillery waste water in agriculture. I hope this publication will be useful to students, teachers, researchers and farmers for enhancing the crop production.

(K. RAMASAMY)

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1. INTRODUCTION

Distillleries are one of the most important agro based industries in India producing alcohol from molasses, a by-product from sugar factories. The sugar factories generate significant quantities of three valuable process residues *viz*., sugarcane bagasse, press mud and the molasses.

The demand for alcohol in India has grown up from 285 distilleries with a capacity of 1.5 billion litres of alcohol per year in 1998-99 to 319 distilleries with 3.3 billion litres of alcohol in 2006-2007. Continously increasing demand of alcohol for mixing five per cent ethanol with petrol as well as due to other usages such as industrial solvent and beverages has increased the number of molasses based industrial units. In the year 2006-07, the production of molasses amounted to 11.36 million litres and molasses based alcohol production was two billion litres. (Fig.1)

Approximately, 10-15 litres of spentwash is generated for the production of one litre of alcohol. Consequently, there has been a significant increase in the waste water generation from this sector.This massive quantity, approximately 48 billion litres of effluent, if disposed untreated can cause considerable stress on the water courses. The enormous distillery wastewater has potential to produce 1100 million cubic meters of biogas. The post methanation wastewater if used carefully for irrigation of agricultural crops can produce more than 80,000 tonnes of biomass annually (Table 1).

Spentwash is non-toxic, biodegradable, purely of plant origin and contains large quantities of soluble organic matter and plant nutrients, which the sugarcane plant has absorbed from the soil. The salts commonly present in this effluent are of K and SO_4 apart from N, P and micronutrients and all these elements are essential nutrients of plants. Therefore, its fertiliser potential can suitably be harnessed in agriculture by controlled land application following proper methods (pre-plant application or with proper dilution). Hence, utilisation of distillery effluents in agriculture would save costs on fertilisers and facilitate reduction in pollution load (Baskar *et al.,* 2003).

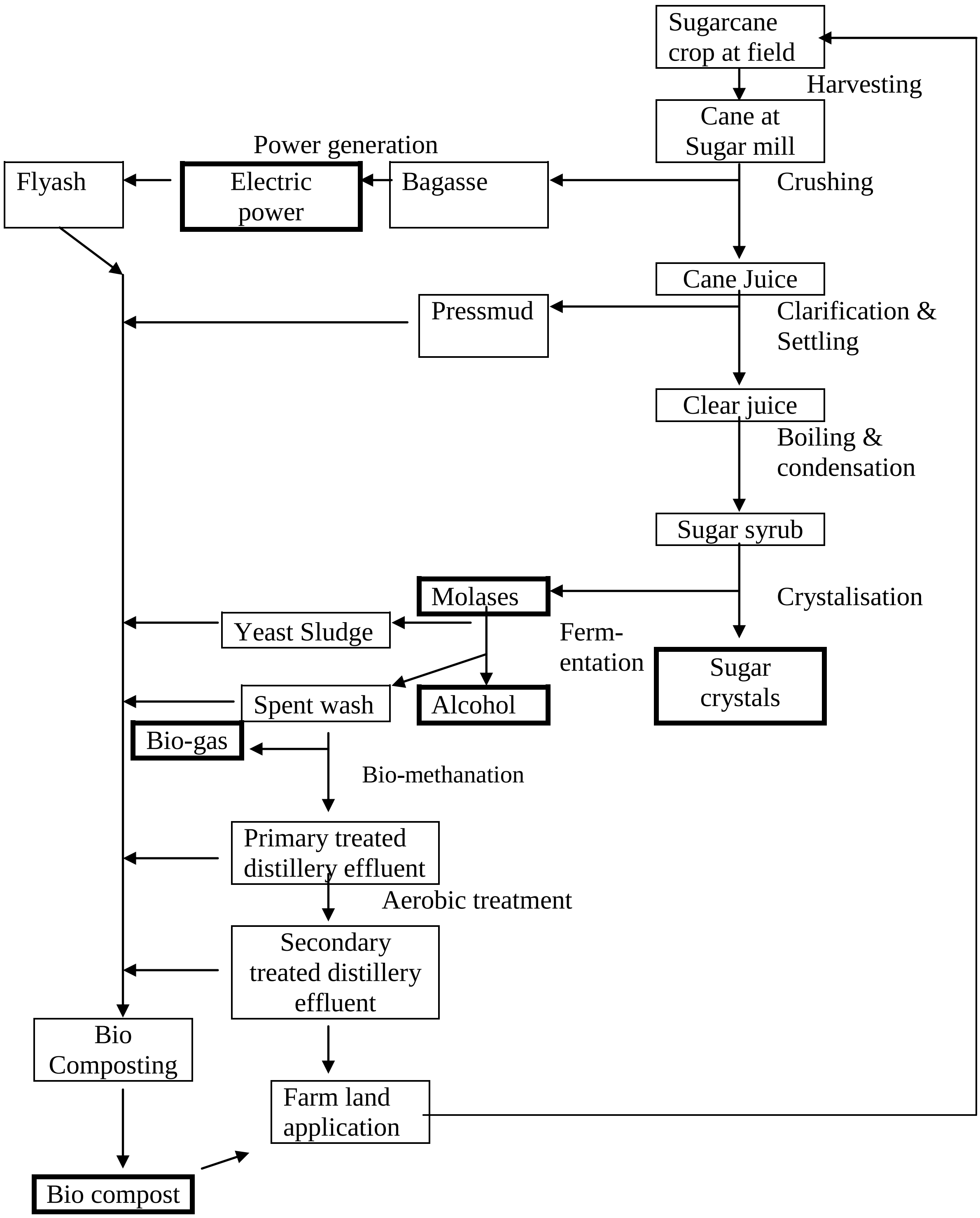

Fig.1 Sugar production and nutrient recycling by sugar and distillery industries

Table 1 : Annual bioenergy and plant nutrient potential of distillery effluent in various states of India

State	No. of* Distilleries	Total installed Capacity (MLtr/Yr.)	Total effluent generated (MLtr/Yr.)	Biogas (Million m^3)	Total Nitrogen (tonnes)	Total Potassium (tonnes)	Biomass Potential (tdm in ** tonnes)
Andhra-Pradesh	24	123	1852	50	556	11115	3704
Assam	1	2	24	0.7	7	144	48
Bihar	13	88	1323	35.7	397	7940	2646
Goa, Daman & Diu	6	15	218	6	65	1304	436
Gujarat	10	128	1919	51.8	576	11511	3838
Haryana	5	41	615	16.6	185	3690	1230
Himachal-Pradesh	2	3	39	1	12	234	78
J & K	7	24	366	11	110	2196	732
Karnataka	28	187	2799	75.6	840	16794	5598
Kerala	8	23	343	9.3	103	2064	686
Madhya-Pradesh	21	469	7036	190	2111	42219	14072
Maharashra	65	625	9367	253	2810	56217	18734
Nagaland	1	2	24	0.7	7	144	48
Orissa	7	13	189	4.6	58	1134	378
Pondicherry	3	11	165	4.5	50	990	330
Punjab	8	88	1317	35.6	395	7902	2634
Rajasthan	7	14	202	3	61	1215	404
Sikkim	1	7	98	5.5	29	585	196
Tamil Nadu	19	212	3178	86	953	19071	6356
Uttar Pradesh	43	617	9252	250	2776	55512	18504
West Bengal	6	24	371	10.1	111	2223	742
Total	285	2716	40697	1100	12212	244204	81394

- Source – All India Distillers Association, New Delhi. ** total dry mass

1.1 Fermentation Process for Alcohol production

The waste molasses from sugar industry which contains high concentration of sugar (sucrose) is used as the substrate for alcohol fermentation. Four to five kg molasses is required for producing one litre of alcohol. The molasses is diluted with enough water so that its sugar concentration remains at 10-15 percent. The pH of this dilute solution is adjusted to 4-5 with sulphuric acid and is also supplement with ammonium sulphate as a source of nitrogen. This diluted mixture called as 'mash' is fermented with yeast in steel or wooden tanks at 20-30^{o}C for 30-70 hours. Sucrose present in the molasses is converted to ethyl alcohol by the catalytic enzymes, invertase and zymase present in yeast. The liquor after fermentation called as Beer containing 8-10 per cent ethanol is concentrated and purified in series of distillation (analyser and rectifier) columns. The vapours from the top of the rectifier column are condensed and cooled as rectified spirit (Tapan Rouh and Dhanehwar, 1986).

a) $C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{Invertase}} 2\,C_6H_{12}O_6$

Sucrose glucose

b) $C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2\,C_2H_5OH + 2\,CO_2$

Ethyl alcohol

The dark brown opaque liquid of the analyser column remaining after removal of alcohol is disposable and called by various names such as spent wash, slops, stillage, still bottoms, mostovinasse and dunder.

The characteristic of the spent-wash varies and depends on the quality of the molasses being used. Generally molasses which is obtained from the sugar factory contains 46-50 % of total reducing sugars which includes 5 % of unfermentable sugars like pentoses and polysaccharides. Besides, it also contains other carbohydrates, ash, nitrogenous compounds, non nitrogenous acids, wax, sterols, pigments, vitamins etc. Fermentable sugars include glucose, fructose and sucrose which are converted into alcohol. The remaining constitutents are retained in the spent wash unless they are denatured.

Other by products produced during fermentation process are succinic acid (1-2 g/L of fermented wash), lactic acid (5-8 g/L of fermented wash), acetic acid (1-3 g/L of fermented wash), glycerol (5-10 g/L of fermented wash), acetoin (0.05-0.1 g/L of fermented wash), methanol (10- 40 ppm), acetaldehyde (500-1000 ppm), n-propanol (100-400 ppm), iso-amyl alcohol (10-50 ppm), n-butanol (10-50 ppm), ethylacetate (10-50 ppm) and diacetyl (10-50 ppm).

This raw effluent which is dark in colour is essentially a plant extract from that of sugarcane and microbial residues and is called as spent wash. Though it does not contain toxic heavy metals or other toxic constituents, this spent wash is characterized by high BOD (40000, 45000 and 80000 ppm) and COD (90000, 100000 and 120000 ppm) for Batch / praj continuous and biostil processes respectively.

1.2 Solid wastes / sludge generated in the distillery

The following are the sources of solid wastes / sludge generated from a distillery unit.

1. Yeast sludge from the fermentation process
2. Hydrolysed yeast sludge from raw spent wash storage lagoons, tanks or cooling ponds.

3. Sludge from ETP viz., from anaerobic digester, aeration tanks and clarifer and treated effluent storage lagoon

Yeast is added to the fermenter for the production of alcohol. After the completion of fermentation, the yeast sludge is separated as a waste material. Some quantity of live yeast cells escape in the fermented wash and get hydrolysed in the analayser column. The dead hydrolysed yeast cells present in the raw spent wash settle in the storage lagoons / tanks. The settled yeast sludge and the fermenter yeast sludge are periodically removed and solar dried on open land. After drying it is either lifted by the farmers for land application as manure or taken to the compost yard for composting along with pressmud. This dried sludge is also being used as an animal feeds supplement by many industries.

1.3 Distillery waste water Treatment

The distillery spent wash is rich in organic and inorganic substances. Although the pollutants present in the waste water are not toxic but because of their highly putriscible nature cause immediate oxygen depletion in the receiving water, thereby creating imbalance in the biotic life of that water. The production of one cubic meter of alcohol from sugarcane generates 12-15 cubic metres of waste water which is equivalent to pollution in terms of BOD of the sewage produced by 6000-6500 people per day. The treatment of waste water of such high oxygen demand is essential before disposal.

According to Pollution Control Act distilleries are under legal obligation to treat spent wash so as satisfy the tolerance limits prescribed by ISI. This act has compelled the distilleries to adopt various methods for treatment and disposal of spent wash described and recommended by different investigators in India and abroad (Fig.2). The pollution control board standards require the reduction of BOD to very low level before it is discharged either on land for irrigation purposes or into streams or other water bodies. These processes include primary, secondary and tertiary treatments. During 1992, a committee constituted by the Central Pollution Control Board has evaluated various treatment technologies that are presently adopted in India and concluded that the following techologies could be viable alternatives.

(i) Composting (Alfa-Laval & EPRF)

(ii) Incineration (Sprannihilator)

(iii) Anaerobic digestion with biogas recovery followed by secondary biological treatments

(iv) Anaerobic digestion with biogas recovery followed by composting / vermicomposting.

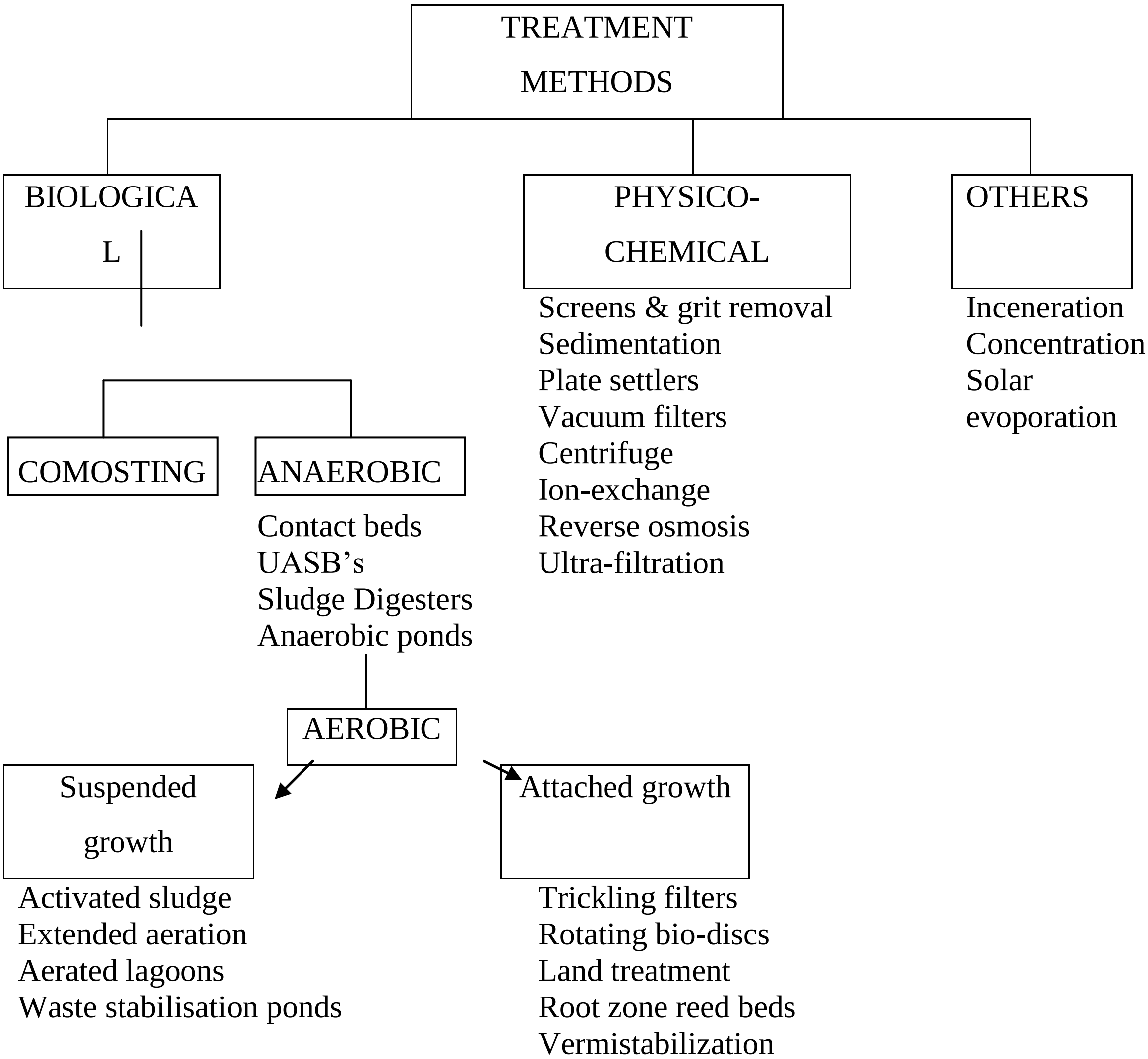

Fig.2 Distillery waste water treatment systems

1.3.1 Anaerobic Treatment System

The COD to BOD ratio of the spent –wash ranged from 1.8 to 2.4 which indicate that it is amenable to biological treatment. The wastewater containing high BOD, above 10,000 mg l^{-1} is generally considered suitable for anaerobic treatment. The chemical composition of the spent wash mainly contains carbohydrates and some protein and therefore it is suitable for anaerobic decomposition. The spent wash also contains high concentration of sulphates and on anaerobic decompostion hydrogen sulphide is formed in the concentration up to five per cent.

Anaeriobic decomposition is a biological phenomenon associated in the breakdown of complex organic matters to methane, carbon dioxide and water in absence of oxygen. It is currently recognised as three stage breakdown process (McCarty, 1981; Gujer and Zehnder, 1983) as shown in fig.3. The formation of methane has key importance in anaerobic decomposition because it is related directly to the COD reduction of the waste . Theoretically 350 ml of methane gas is generated for every gram of COD removal. The methane gas has high calorific value and is utilised as an alternative source of energy. The methane gas obtained could be used either as a fuel gas or as a raw material for the petrochemical industry.

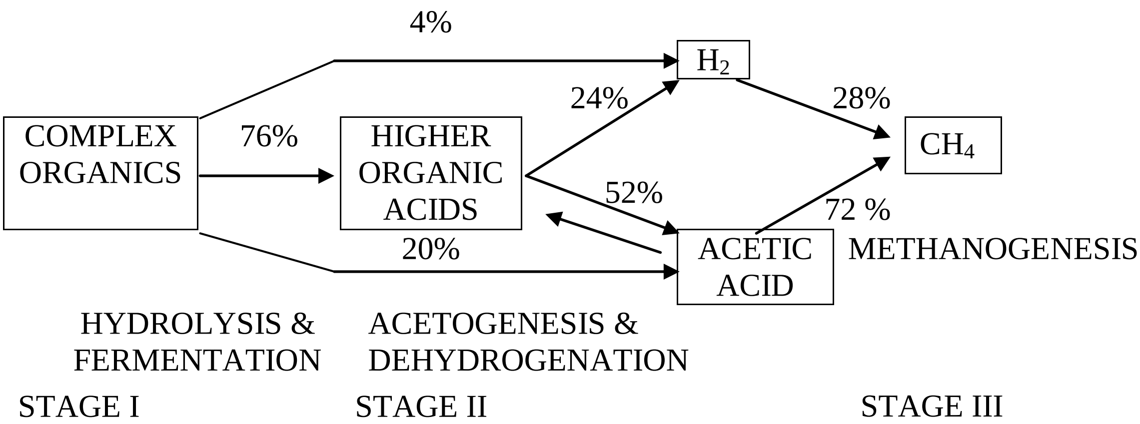

Fig.3 Anaerobic decomposition of complex organics to methane generation and flow of energy contents through three stages (McCarty, 1981)

1.3.2. Secondary / aerobic treatment

In order to reduce the requirement of dilution water to meet the prescribed standards, a secondary biological treatment process is used. The activated sludge process, which is an aerobic biological process, is the most commonly used secondary treatment system adopted. Designs employing two stage aeration, with intermediate and final sedimentation tanks having arrangements for sludge re-circulation give satisfactory operation. Studies conducted at the CPCB laboratory and field observations suggest that such a system is capable of reducing the BOD level to about 300 to 500 mg/l (Sengupta, 2001).

Table 2. Effect of aerobic treatment of anaerobically digested distillery waste on COD and BOD reductions of the effluent

Days	Influent (mg l^{-1})		Effluent (mg l^{-1})		Removal efficiency (%)	
	COD	BOD	COD	BOD	COD	BOD
1	29500	6400	1327	1665	55	74
4	2920	6300	6425	755	78	88
8	29500	6400	3895	270	86.8	95.3
12	29000	670	3655	216	87.4	97.8
16	29500	6500	3360	117	88.6	98.2
20	29800	6900	3190	110	89.9	98.4
24	29300	6480	3020	130	89.7	98.0
Average 1 to 7 days	28500 to 30000	6350 to 7200	2870 to 4025	84 to 325	86.5 to 90.1	95.3 to 98.7
7 to 24 days	29333	6662	3400	160	88.05	97.68

(6.9 L level studies ; HRT – 6 days; Inoculam density- 5 g /l)

(Panthade and Kale, 1999)

Assuming the BOD of the final effluent from the aerobic treatment as 500 mg/L, it will have to be diluted in the ratio of 1 to 5 to meet the effluent standard for BOD for application on land for irrigation. If it is assumed that the treated effluent, in the case of the batch process, has a dissolved inorganic solids concentration of 10,000 mg/L, a dilution ratio of 1 to 5 will also meet the standard for the dissolved inorganic solids. In case the dissolved inorganic solids concentration is higher, the dilution will be governed by the limit prescribed for irrigation water, i.e. 2100 mg/l (Table 2).

1.4. Composting

Composting is a biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temepratures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds and can be beneficially applied to the land. The process are characterised by a period of rapid decompostion and self–heating followed by a cooler, slower decay of remaining organic substrates. Regulating the kinds of organic substrates and controlling the physical and chemical attributes of the decomposition environment in the compost pile facilitate the process. Manipulating moisture content, pH, nutrient concentrations and oxygen can bring increased decomposition rates and change the characteristics of the compost.

Since the effluent contains organic materials and many plant nutrient elements, there is scope for using it advantageously in composting of other sugar industrial by-products namely pressmud, bagasse etc.,. The composting enables the degradation of coloured organics in the distillery effluent and evaporation of water rapidly and also reduction in BOD. Distillery effluent will also enrich the compost with plant nutrients especially potassium. Suitable compost can be made in three months from vinasse in different combinations e.g. vinasse + press mud cake or from vinasse + sugarcane bagasse + rice straw (Pandey *et al.*,1994). Devarajan *et al.*(1996c) stated that the distillery effluent based compost can be prepared by using pressmud and the compost could be enriched with the use of rock phosphate, gypsum, yeast sludge, bagasse, sugarcane trash, boiler ash, coir pith and water hyacinth. First, the pressmud is spread in the compost yard to form a heap of 1.5 m height, 3.5 m width and 300 m length. Ten litres of bacterial culture, diluted with water , in the ratio of 1: 10 is sufficient for a tonne of pressmud. After 3 days, distillery effluent is sprayed on the heaps to a moisture level of 60 per cent and the pressmud heaps are allowed for 4-5 hours to absorb the effluent. The heaps are then thoroughly mixed by aerotiller. When the moisture level drops below 30-40 per cent, again the effluent is sprayed, mixed with pressmud and heaps are again formed. Effluent can be sprayed once or twice in a week depending on the moisture content of pressmud heaps. Mixing of effluent and heap formation will be repeated for 8 weeks so that the pressmud and effluent proportion reaches an optimum ratio of 1: 3 . Then the heaps are allowed for curing for a month. The compost obtained from this process is neutral in pH with an EC of 3.12 to 6.40 dSm^{-1}. It contains 1.53 % N, 1.50 % P, 3.10 % K, 300 ppm Fe, 130 ppm Cu, 180 ppm Mn and 220 ppm Zn. The organic carbon and C:N ratio reduced from 36 to 18 % and from 28.12 to 16.3 respectively. The technology of using distillery effluent for composting of pressmud (Manavalan and Srinivasan, 1996; Ramalingam *et al.*,1996 ;Ramadurai *et al* .,1996 ; Nagappan *et al.*,1996c) , pressmud along with sugarcane trash and coir waste (Rajannan *et al*.,1996), pressmud plus bagasse ash (Devarajan *et al*., 1996c) and city garbage (Mohan Rao, 1996) have been successfully tested in so many places.

1.5. Concentration and Incineration

In this process, the spent wash from the distillation column after neutralisation with lime is subjected to concentration to about 65% solids. The concentrate is then incinerated. The incineration system consists of specially designed burners which incinerate the concentrated solution. The system yields steam and ash which is rich in potash. The steam can be utilised advantageously in the distillery unit and the ash can be sold as fertiliser. These in fact, provide the payback. The condensate is cooled and treated aerobically. This technology which makes a dubious claim of providing zero pollution, suffers from some serious drawbacks as it is highly capital intensive, energy intensive and the last but not the least it creates serious air pollution. Water pollution is abated, but air pollution is created by fine ash and the fine gases. Besides, for the maintenance of the consistency of the flame in the incinerator, furnace oil is required to the extent of 4 % to 5% of the total weight of the concentrated spent wash.

1.6. Solar Drying

After anaerobic and aerobic treatments, spentwash is dried in open shallow LDPE lined impervious ponds surrounded with green cover. Solar drying generally needs larger surface area and the rate of evaporation is between 18-24 m^3 per day per acre depending upon the climatic conditions.

1.7. Spent wash Treatment with Municipal Waste

The treatment of combined stillage and municipal wastewaters has received scant attention due to the fact that such treatment requires a large sewage to stillage flow ratio to give the required dilution for ensured success. This excludes the use of this disposal procedure in low population density regions.

2. ENVIRONMENTAL IMPACT OF DISTILLERY EFFLUENT

In recent years, industrial effluents have been regarded as common sources of pollution, because of lack of efficient treatment and improper mode for disposal of effluents generated by industries. Under these conditions aquatic life suffers resulting in a loss of productivity of natural waters and deterioration of water quality to such an extent that the water becomes unusable. Distillery wastewater poses a serious threat to water quality in several regions of the country. Lowering of pH value of the stream, increase in organic load, depletion of oxygen content, destruction of aquatic life and bad smell (obnoxious odour of H_2S from sulfates, indole and skatole from the yeast cells) are some of the major pollution problems due to distillery wastewater. The high BOD causes depletion of dissolved oxygen and proves very harmful to aquatic life. In some cases, particularly in Maharashtra, the colour problem in groundwater is so acute that distilleries have to provide separately potable water to surrounding villages. The population equivalent of distillery wastewater based on BOD has been reported to be as high as 6.2 billion which means that contribution of distillery waste in India to organic pollution is approximately 7 times more than the entire Indian population. Therefore, despite stringent standards imposed on effluent quality, the untreated or partially treated effluents very often find access to water courses. The spreading of the effluents along the marginal lands surrounding distilleries is a common sight. The retention of effluents in open anaerobic lagoons and solar drying ditches is responsible for the odour one encounters while passing through a distillery. Thus the distilleries in India have also been responsible for the pollution of the air, water and land. If the distillery effluent is not utilized in agriculture (land application / composting) and it finds access into the open drains , it will pose a serious threat to water quality and fragile ecosystem. The distillery spent wash is a major pollutant because of its high organic contents. The colour of the effluent persists even after anaerobic treatment due to the high sulphate content and poses a serious threat to the environment, as the water bodies receiving coloured waste might got coloured affecting the penetration of light which damages the ecosystem. Instances of large scale mortality of fish in river Gomtri due to distillery effluent had been reported by Joshi (1990). Joshi *et al.*(1994) noticed ground water contamination by effluent with high BOD and salt content near the lagoon sites in most of the distilleries. This problem have been overcome at some of the sites by lining the lagoons and ensuring effluent to be regularly used for composting / irrigation on a larger area under well devised agronomic plan resulting in minimum retention time in the lagoons.

2.1. Efforts of CPCB in Evolving Standards for Distillery

Recognising the problem of treating distillery effluent to a level suitable for disposal into the river/land, the Central Board constituted an expert group way back in 1980 to evolve Standards (MINAS) developed by the CPCB. The MINAS are:

BOD,(20^0C, 5 days) : 30 mg l^{-1} for disposal into inland surface water
:100 mg l^{-1} for disposal on land for irrigation

Based on the MINAS developed by CPCB, Ministry of Environment & Forests, through the EPA Notification, dated January 8, 1990, specified effluent standards according to the disposal conditions, i,e, the recipient environment.

The BOD (20^0C, 5 days) standards so specified are as follows

Disposal on stream/river	:	30 mg l^{-1}
Disposal on land	:	100 mg l^{-1}
Disposal on land when land is considred as a treatment medium (land treatment)	:	500 mg l^{-1}
Land treatment with effective monitoring systems for ground water quality	:	700 mg l^{-1}

The standards also include stipulations regarding net additional contribution to ground water quality in terms of BOD not to exceed 3 mg l^{-1} and nitrate not to exceed 10 mg l^{-1}.

The Government of India, Ministry of Environment & Forests, in his letter (No. Z-16011/18/99-OPA) dated 24.10.2000 to the All India Distilleries Association quoted to adopt any or combination of the following measures.

- Composting of spentwash with pressmud/baggasse/agro-residues proceeded by primary treatment (anaerobic digestion with methane recovery) and necessary measures to prevent contamination of groundwater due to leachages.
- Concentration and Incineration of spentwash.
- Primary and secondary treatment and utilization of treated effluent for irrigation to meet the norms of 500 mg l^{-1} of BOD and 2100 mg l^{-1} of TDS

for use of treated effluents in irrigation as per protocol developed by IARI .Since inorganic constituents are of primary concern for land application, TDS limit of 2000 mg l^{-1} may be applicable for inorganics. The treated effluent is to be stored in lined storage tanks, during the period when it is not used for irrigation.

- Primary and secondary treatment followed by either dilution with process water and tertiary treatment or mixing the treated effluent with the sewage for terminal treatment in the Municipal Sewage treatment plants.
- Any other method to ensure compliance of prescribed norms.

2.2. Operation and maintenance of ETPs

Performance assessment studies are to be carried out in each distillery to evaluate the energy requirement and efficiency of individual units of the ETPs vis-à-vis design parameters, performance of the ETPs, is to be periodically checked on the basis of records of energy consumption through the dedicated energy meters provided for ETPs and operating parameters including MLSS&Do in aeraton tanks.

2.3. Discharge of effluent

Discharge of effluent directly or indirectly through the drains into the drinking/bathing water courses should be avoided because of the colour, even when the treated effluent meets the BOD norms of 30 mg l^{-1}. Where it is unavoidable, distilleries must ensure colour removal besides conforming to the BOD limits to be prescribed depending upon the conditions of the receipient water bodies.

3. UTILISATION OF DISTILLERY EFFLUENT IN AGRICULTURE

3.1. Properties and nutrient potential of distillery effluent

The distillery spent wash is an acidic liquid (pH 3.8 to 4.0) and contains large quantities of organic carbon and plant nutrients like K, Ca, Mg, S etc. Its BOD (45,000 - 55,000 mg l^{-1}) and COD (90,000 - 1, 10,000 mg l^{-1}) are high. Since the distillery spent wash is highly acidic and contains fairly good amount of Ca and Mg, this could be utilised as an organic amendment for the reclamation of sodic soils. The distillery spentwash after the primary treatment is called distillery effluent. The distillery effluent (primary treated) is dark brown in colour and has an unpleasant smell of burnt or caramelised sugar. The composition of this effluent is found very similar to farmyard manure (Table 3)

Table 3. Comparision of distillery spentwash and farm yard manure

	FYM	DSW
pH	7.5	3.8
Moisture (%)	22.65	91.1
Organic matter (%)	21.75	31.50 (on solid basis)
Total N (%)	1.44	2.0
Total P (%)	0.83	0.28
Total K (%)	0.79	9.96
Mineral matter (%)	52.5	26.49
C : N ratio	15.10	15.75

(Rajukannu and Manikam, 1996)

The pre-treated distillery effluent is near neutral (7.8) in reaction and having high EC (24.3 dSm^{-1}). Sharma *et al.*,(2001) stated that potassium salts were mainly responsible for increasing the EC. It carries a huge organic load ie., BOD 5600 and COD 45,000 and total solids 81,000 ppm. The high COD of the raw effluent might be due to the presence of large quantity of chemicals in the raw effluent. The distillery effluent was concentrated with soluble forms of organic matter. It contains appreciable amount of K (10,000 - 13,000 mg K_2O l^{-1}), Ca (2100 - 3000 mg l^{-1}), Mg (2000 - 3300 mg l^{-1}), S (4000 - 5000 mg l^{-1}) and moderate amount of N (1200 - 1500 mg l^{-1}), P (400 - 600 mg P_2O_5 l^{-1}) and micro nutrients *viz.*, Fe (65 mg l^{-1}), Zn (10.5 mg l^{-1}) Mn (5.5 mg l^{-1}) and Cu (15.5 mg l^{-1}) (Table 4).

Table 4. Physico-chemical properties of Spentwash/distillery effluent

Parameters	Singh et al. (1980)	Patil et al. (1984)	Juwarkar et al. (1992)	Pathak et al. (1998)	Rajukkanu (1996)	Devarajan et al.(1993)		
	Spent Wash						Primary treated	Secondary treated
Colour	-	-	-	-	Reddish brown	Dark brown	Brownish	-
Odour	-	-	-	-	Unpleasent smell of burnt sugar	Unpleasant	Disagreeable	-
PH	5.0	3.8	4.0-5.0	-	3.8-4.0	3.9	8.0	8.0
EC(dsm^{-1})	7.5	28.0	-	-	28.0-30.5	27.7	32.5	27.0
BOD(5 d at 20^0 C)(mg/l)	-	-	-	40000-50000	45000-55000	4000	5625	1100
COD (mg/l)	-	-	-	90000-100000	90000-110000	102000	45000	2500
Moisture %	-	91.2						
Mineral matter % on O.D basis	-	26.5	-	-				
Total solids(mg/l)					80000-90000	92505	81000	31000
Total dissolved solids(mg/l)						86530	76500	28000
Total suspended solids(mg/l)					300-500	5975	4500	3000
Total volatile solids(mg/l)					55000-67000	68900	-	-
Organic carbon(%)						25.5	-	-
Total N(mg/l)			1200-2500	300	1200-1500	1661	1740	1200
C:N ratio		15.8			15.5	15.3	-	-
Total P as P_2O_5 (mg/l)		640	120-250	45	400-600	428	428	400
Total K as K_2O (mg/l)	10000	12000	9000-12000	7200	10000-13000	10000	11500	10000
Total Ca(mg/l)					2100-3000	2714	1050	-
Total Mg(mg/l)					2000-3300	2062	2208	-
Total Na(mg/l)	250.7					640	510	-
Total S(mg/l)					4000-5000	2980	2440	-
Total Zn(mg/l)					10.5	7.5	8.0	-
Total Cu(mg/l)					4.2	3.8	5.5	-
Total Fe(mg/l)					65	52.0	85.0	-
Total Mn(mg/l)					5.5	4.4	4.8	-
Chloride(mg/l)					5000-6000	10400	11200	-

3.2.Distillery spent wash - as soil amendment

Soil sodicity is characterised by high pH, water soluble and exchangeable sodium. The basic principle in the reclamation of sodic soils is to replace the Na^+ ion from soil exchange sites by cations like H^+, Ca^{++} and Mg^{++} ions. Since the distillery spentwash is highly acidic and contains fairly good amount of Ca and Mg and other essential plant nutrients, this could be used as an organic amendment to improve the soil properties particularly in reclamation of non-saline sodic soils (Table 5).

Table 5. Effect of Spentwash and gypsum on the physico-chemical properties and the nutrient availability of non-saline sodic soils

S. No	Parameters	Control	Gypsum@50%_GR		Spentwash@ 150 ml kg^{-1} soil	
			Before leaching	After two leaching	Before leaching	After two leaching
1.	pH	9.37	9.02	8.94	7.50	7.67
2.	EC(dsm^{-1})	0.55	0.84	0.10	2.56	0.744
3.	SAR(1:2.5)	11.14	6.88	5.98	6.54	2.30
4.	ESP	36.94	29.65	23.85	15.94	9.65
5.	Free $CaCo_3$(%)	1.89	1.92	1.91	1.60	1.52
6.	Organic carbon(%)	0.29	0.29	0.25	0.65	0.49
7.	Bulk density (mg m^{-3})	1.62	1.51	1.57	1.24	1.36
8.	Hydraulic conductivity(x 10 6 ms^{-1})	0.44	2.42	1.25	6.16	2.57
9.	Water dispersible clay (%)	7.29	2.64	3.92	0.00	2.26
10.	Pore space(%)	44.67	45.73	45.13	50.40	47.67
11.	Available N(Kg ha^{-1})	116	132.0	147.0	222.0	244.0
12.	Available P(Kg ha^{-1})	6.13	8.03	8.33	20.33	25.13
13.	Available K(Kg ha^{-1})	193.0	261.0	246.0	2647.0	1654
14.	0.15% $CaCl_2^-$ S (mg kg^{-1})	16.0	255.0	50.0	410.0	106.0
15.	DTPA –Zn (mg kg^{-1})	0.48	0.67	0.82	2.70	3.03
16.	DTPA –Cu (mg kg^{-1})	1.12	1.21	1.26	1.73	1.82
17.	DTPA –Fe (mg kg^{-1})	11.85	18.37	23.72	32.80	51.20
18	DTPA –Mn (mg kg^{-1})	10.70	13.63	13.66	18.30	17.97

Valliappan (1998)

The potential of distillery spent wash to supply H^+ (since DSW is highly acidic), Ca^{++} and Mg^{++} has been used as a basic principle to reclaim the sodic soil (ie, to replace Na^+ ions in the soil exchange complex) (Valliappan,1999). Valliappan *et al.*(2001) reported that one time application of spentwash at 150 ml kg^{-1} soil followed by two leaching and transplanting rice on 40th day of its application had proved to be more effective than lower dose of spentwash and gypsum @ 50% GR in reducing the soil pH, ESP and SAR of sodic soil to the level of < 8, < 10.9 and < 3.0 respectively (Table). The EC of the spentwash treated soils was brought down to < 1.0 dSm^{-1} after two leaching. Rajukkannu *et al.* (1996) and Sharmila et al. (2001) have given stepwise sodic soil reclamation procedure using distillery spent wash which includes,

i. dividing the lands into compartments of convenient size,

ii. ploughing the land

iii. applying distillery spentwash evenly @ 5 lakh l ha^{-1}

iv. mpound water to a depth of 10-15 cm after 7 days

v. draining after 24 hours

vi. repeating of impounding water and drainage two to three times

vii. ploughing at optimal moisture level

viii. application of well decomposed FYM or composted press mud @ 5 t ha^{-1}

ix.sowing / transplanting after 60 days of spentwash application.

They also suggested that reclamation should be carried out preferably during summer months. The studies conducted by Rajukkannu *et al.*(1996) revealed that application of distillery spent wash @ 5 lakh litres ha^{-1} to the air dried non-saline sodic soil, followed by two or three leachings with water could effectively reclaim sodic soil and suggested a fair period of 60 days from the days of its application and transplanting of rice seedlings for the establishment of rice crop. The study revealed that the saturated hydraulic conductivity and pore space of the spent wash treated leached soils had been considerably increased from 0.44 to 2.57 x 10^{-6} m s^{-1} and 44.67% to 47.67% respectively with simultaneous reduction in the bulk density and water dispersible clay from 1.62 to 1.36 Mg m^{-3} and 7.29 to 2.26% indicating the unique feature of distillery spentwash on the reclamation of sodic soils . The availability of N, P, K, S, Zn, Cu, Fe and Mn in the spentwash ammended sodic soils was found tremendously increased to the level of 244 kg ha^{-1}, 25.13 kg ha^{-1}, 1654 kg ha^{-1}, 106 mg kg^{-1}, 3.03 mg kg^{-1}, 1.82 mg kg^{-1}, 51.2 mg kg^{-1}, 17.97 mg kg^{-1}, as against 116 kg ha^{-1}, 6.13 kg ha^{-1}, 193 kg ha^{-1}, 16 mg kg^{-1}, 0.48 mg kg^{-1}, 1.12 mg kg^{-1}, 11.85 mg kg^{-1} and 10.7 mg kg^{-1} in the control respectively. The reasons for such remarkable effect of spentwash application on greater nutrient availability of sodic soils are such as i, contribution of huge amounts of K and organic matter, considerable quantities of N, P and S and traces of micronutrients through added spentwash ii, by serving as a source of food for soil fungi, bacteria and actinomycets, it helps in rapid multiplication and build up and consequently increases the activity of many enzymes iii, conversion of the unavailable native soil nutrients into available nutrients particularly P and micronutrients due to the action of acidic spent wash iv, formation of relatively stable chelates with organic legends.

The experiment conducted by Lenin (2012) revealed that the application of RSW @7.0 lakh litres ha^{-1} (L6) significantly reduced the soil pH (Fig.4), exchangeable Na and ESP under high pH soils (pH 9.5). The percentage of yield increase due to application of RSW @7.0 lakh litres ha^{-1} (L6) was much higher in alkaline soils than in neutral soil.

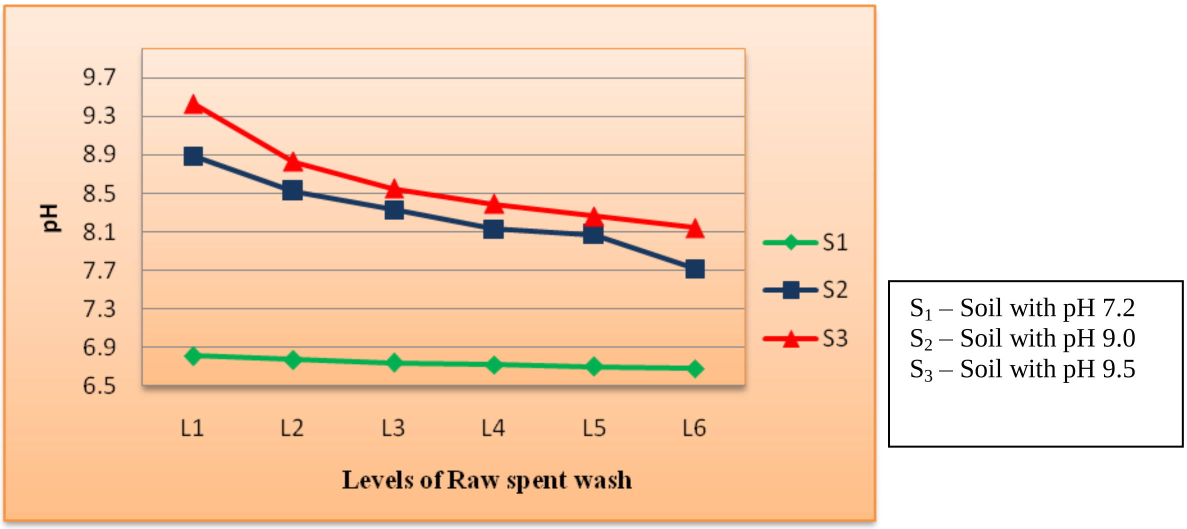

Fig. 4. Soil pH as influenced by different levels of raw spent wash

3.3 Distillery effluent - as composting agent

Since the effluent contains organic materials and many plant nutrient elements, there is scope for using it advantageously in composting of other sugar industrial by-products namely pressmud, bagasse etc. The composting enables the degradation of coloured organics in the distillery effluent and evaporation of water rapidly and also reduction in BOD. Devarajan *et al.*(1996) stated that the distillery effluent based compost can be prepared by using pressmud and the compost could be enriched with the use of rock phosphate, gypsum, yeast sludge, bagasse, sugarcane trash, boiler ash, coir pith and water hyacinth.

- First, the pressmud is spread in the compost yard to form a heap of 1.5 m height, 3.5 m width and 300 m length.
- Ten litres of bacterial culture, diluted with water in the ratio of 1: 10 is sufficient for a tonne of pressmud.
- After 3 days, distillery effluent is sprayed on the heaps to a moisture level of 60 per cent and the pressmud heaps are allowed for 4-5 hours to absorb the effluent.
- The heaps are then thoroughly mixed by aerotiller. When the moisture level drops below 30-40 per cent, again the effluent is sprayed, mixed with pressmud and heaps are again formed.
- Effluent can be sprayed once or twice in a week depending on the moisture content of pressmud heaps.
- Mixing of effluent and heap formation will be repeated for 8 weeks so that the pressmud and effluent proportion reaches an optimum ratio of 1: 3.
- Then the heaps are allowed for curing for a month.

The compost obtained from this process is neutral in pH with an EC of 3.12 to 6.40 dSm^{-1}. It contains 1.53 % N, 1.50 % P, 3.10 % K, 300 ppm Fe, 130 ppm Cu, 180 ppm Mn and 220 ppm Zn. The organic carbon and C:N ratio reduced from 36 to 18 % and from 28.12 to 16.3 respectively. The technology of using distillery effluent for composting of pressmud (Manavalan and Srinivasan, 1996; Ramalingam *et al.,*1996 ;Ramadurai *et al* .,1996 ; Nagappan *et al.,*1996c) , pressmud along with sugarcane trash and coir waste (Rajannan *et al*.,1996), pressmud plus bagasse ash (Devarajan *et al*., 1996c) and city garbage (Mohan Rao, 1996) have been successfully tested in many places.

3.4 Distillery effluent as fertiliser substitute

The distillery effluent contains fairly high amounts of N, P, K, Ca, Mg and S besides appreciable amounts of micronutrients which the sugarcane crop has absorbed from the soil (Manickam,1996). Application of distillery effluent @ 50 m^3 ha^{-1} will supply 75 kg N, 40 kg P_2O_5, 500 kg K which represent almost half the N and P and 100 % of the K requirement (Rajukkannu and Manickam, 1996). It will also supply 105 kg Ca, 100 kg Mg, 200 kg S, 0.5 kg Zn, 3.25 kg Fe, 0.2 kg Cu and 0.25 kg Mn. The sorghum crop grown on a *Typic chromustert* irrigated with 25 times diluted spentwash and supplied with 75% recommended dose fertiliser were equal to that obtained through FYM + 100% recommended dose of fertiliser (Zalawadia and Raman ,1994). Joshi *et al*.(1996) reported that effluent treattment at 20% dilution with 50 % NP application had shown the best yield (5.3 t ha^{-1}) in case of maize, saving 50% N and P and 100% K. Baskar *et al*.(2001) stated that in distillery effluent applied plots, N&P and NPK gave comparable yields which indicated that K fertilizer could be skipped in the distillery effluent applied fields.

Maheshwari (2011) reported that TDE has potential enough to supply N up to PI stage of rice crop. As the organic sources released N in a phased manner, it might have matched the N demand of the rice crop. TDE application @ 1.0 lakh litres ha^{-1} with LCC based N application was found better in improving the growth and yield attributes and nutrient uptake, which was reflected on rice yield (Table). She also suggested that LCC based N application is absolutely necessary for TDE applied field to save cost on N fertilizer and to avoid yield loss due to excessive N. In the LCC based N treatments, the N application has been considerably reduced to the tune of 60, 90 and 90 kg ha^{-1} in 0.5, 1.0 and 1.5 lakh litres per ha of TDE applied fields when compared to 100 per cent RDN. K fertilization could be skipped from the fertilizer schedule in TDE applied fields (Table 6).

Table 6. Effect of different levels of TDE and N fertilizer on grain yield (kg ha^{-1}) of rice

Treatments	No N	100% N	75% N	50% N	25% N	LCC based N	Mean
M_1	2782	4261	3971	3682	3374	4246	3719
M_2	3454	4740	4510	4298	3782	4810	4266
M_3	3851	5183	5190	4760	4307	5392	4781
M_4	4085	5127	5210	4896	4380	5380	4846
Mean	3543	4828	4720	4409	3961	4957	4403

	M	S	M x S	S x M
SE d	65	64	132	129
CD (0.05)	159	130	282	260

Lenin (2012) studied the nutrient supplying capacity of TDE and compared with biocompost using paddy (ADT 43) as a test crop in sandy clay soil *(Typic haplustert)*. The experiment was conducted in a split plot design with four main plots *viz*., control(M1); TDE @ 0.5 lakh litres ha^{-1} (M2); TDE @ 1.0 lakh litres ha^{-1}(M3); TDE @ 1.5 lakh litres ha^{-1}(M4). Different levels of N fertilizers *viz.,* 100 per cent N as urea(S2), 75 per cent N as urea(S3), 100 per cent N as biocompost(S4), 75 per cent N as biocompost(S5), 75 per cent N as urea and 25 per cent N as biocompost(S6), 37.5 per cent N as urea and 37.5 per cent N as biocompost(S7) and control(S1) were imposed as seven subplot treatments. TDE was uniformly applied to each plot as per the treatment schedule at 45 days before planting. The experimental soil was non calcareous soil with sandy clay texture. The soil reaction was neutral, normal in electrical conductivity, low in organic carbon and available N, medium in available P and K status and all other micronutrients above the critical limits except Zn which was found to be deficient (Table 7).

Table 7. Grain yield of paddy as influenced by levels of TDE and biocompost

Treatments	Grain yield (kg/ha)							
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**Mean**
M1	2400	3935	3735	3210	2800	4760	3345	**3464**
M2	3420	4630	4420	4100	3650	4820	4210	**4170**
M3	3900	5160	4980	4300	3954	5175	5480	**4707**
M4	4012	5120	5138	4450	4160	5350	5400	**4804**
Mean	**3433**	**4711**	**4568**	**4015**	**3641**	**5026**	**4609**	

	M	**S**	**M at S**	**S at M**
SEd	54	9	57	18
CD(5%)	172	19	174	37

The application of TDE @ 1.0 lakh litres ha^{-1}(M3) or TDE @ 1.5 lakh litres ha^{-1} (M4) along with 37.5% N as urea + 37.5 % N as biocompost (S7) recorded the highest yield and uptake of nutrients by paddy. Further, the combination increased the soil available nutrients, microbial population and enzyme activities in the soil.

4. METHOD OF APPLICATION

The undiluted spent wash / effluent (treated spent wash) could not be directly applied to the growing crops because of their excessive BOD ,COD and EC. Therefore it should be applied to the field well before the planting of crop to give sufficient time for the natural oxidation of organic materials or diluted with normal water to bring down the excessive BOD ,COD and EC and then applied to the growing crops. Application of undiluted spentwash followed by irrigation rather than the dilution of spent wash at the time of its application was very effective in the reclamation of sodic soils (Singh *et al* ., 1980). The distillery effluent could be transported from distillery factory to the agricultural field through pipelines or tanker lorries. The distillery factories are giving full / half of the transport cost to the farmers.

4.1 Diluted effluent application to growing crops as fertigation

The primary treated distillery effluent is found to contain all major and micronutrients in considerable amount to sustain growth and yield of crops. Technology has been developed to use this effluent as fertigation source to crops like sugarcane, sunflower, soybean etc., after diluting it with irrigation water.

Kayalvizhi (2000) found that the cane yield was higher at 1:10 dilution of distillery effluent in suagrcane. Devarajan *et al.*(1993) and Rajannan *et al.* (1996) have concluded that distillery spent wash at 40 to 50 times dilutions increased the yield of sugarcane, banana , gingelly and rice. The results of the field experiments (Table 8) conducted in different soil types of EID Parry (I) Ltd., command area at Cuddalore district of Tamil Nadu by TNAU revealed that application of distillery effluent along with irrigation water (4 time per year starting from 45^{th} days at 45 days interval) at 1:10 NS 1: 20 dilutions were optimum for light and heavy textured soils respectively for getting significantly higher cane yield of sugarcane.

Table 8. Influence of distillery effluent at different dilutions on cane yield (t ha^{-1}) in different soil types

Treatments	Light textured soil		Heavy textured soil	
	Sandy loam	Sandy clay loam	Clay loam	Clay
1:10	115	112	140	159
1:20	110	110	147	163
1:30	106	107	143	158
1:40	102	105	139	152
1:50	96	103	131	143
C	87	96	119	133
CD (0.05)	3.3	3.8	3.4	4.0

(Anon 2002)

Kayalvizhi (2000) found that the cane yield was higher at 1:10 dilution of distillery effluent in medium textured soils. Paddy recorded lower grain yield even in 50 times diluted effluent irrigation than water control. In gingelly crop, higher seed and oil yield were recorded with 40 and 50 times diluted irrigations. Groundnut, Soybean, sunflower and forage crops recorded higher yield at 30 to 50 times dilutions.

A reduction in rhizome yield of turmeric was noticed with effluent irrigations even at higher diliutions (Devarajan *et al.*, 1993). The experiment conducted by Kathiresan *et al.*(2001) revealed that diluted (3:1- water + effluent) effluent application after tillering phase (from 110 DAP to harvest) registered significantly more number of millable cane (98.6 t ha^{-1}), lengthier cane (135.9 cm), higher cane (105.6 t ha^{-1}) and sugar yield (12.6 t ha^{-1}).

4.2 Pre-plant application of undiluted distillery effluent

Although the fertigation of distillery effluent to crops after diluting the effluent with irrigation water has given good results, farmers are finding this technology cumbersome as there are no proper contrivances to adjust the effluent water ratios in the field. Further the effluent or effluent mixture could not be transported to field situated interior during cropping season. Therefore, it was thought that the undiluted effluent if applied in fallow lands during summer, facilitating oxidation of organic matter and reduction of BOD levels could take care of the soil fertility problems and increase the crop yields.

Devarajan and Oblisamy (1995) reported that pre-plant application of distillery effluent @ 125 t ha^{-1} registered the highest cane yield. Pre-plant application of distillery effluent at 150 and 300 t/ha increased the sugarcane yield by 53.8 and 44.0 % respectively when compared with untreated control. Baskar *et al.*(2001) reported that application of pre-treated distillery effluent at graded doses (0, 1.25, 2.5, 3.75, 5.0 and 6.25 lakh litres per acre) progressively increased the cane yield of sugarcane when it was applied well before (40 days) planting in sandy soil (Table 9).

Table 9.Influence of pre-plant application of distillery effluent and fertilisers on cane yield in sandy clay loam soil

Treatments	C	N	NP	NK	PK	NPK	Mean
C	65	92	108	105	93	119	97
1.25 lakh lit / ha	81	115	128	112	98	130	111
2.50 lakh lit / ha	92	121	133	119	108	134	118
3.75 lakh lit / ha	98	125	136	125	112	136	122
5.00 lakh lit / ha	103	128	137	129	115	138	125
Mean	88	116	128	118	105	131	

CD (0.05)	M	S	S x M	M x S	
	5	7	14	15	

(Anon, 2002)

The results of the experiments (Table 10) conducted by TNAU in different soil types of EID Parry (I) Ltd., Command area, Cuddalore district, Tamil Nadu revealed that application of distillery effluent significantly increased the yield of sugarcane even at higher doses (6.25 lakh litre ha^{-1} in sandy soil and 5 lakh litres ha^{-1} in sandy loam soil).

The result also showed that application of TDE @3.75 lakh litres ha^{-1} and NP fertilizer in sandy, 1.25 lakh litres ha^{-1} with NP fertilizer in loam and sandy clay loam soils were found to be best for getting higher yield of sugarcane (Anon,2002). Previna (2012) reported that preplant application of TDE @ 1.5 lakh liters per ha is comparable with pressmud @ 5 t per ha for increasing the cane yield of sugarcane.

Table 10. Influence of pre-plant application of distillery effluent and fertilisers on cane yield in sandy soil

Treatments	C	N	NP	NPK	Mean
C	29.1	48.8	60.2	69.8	52.0
1.25 lakh lit / ha	53.4	63.5	71.2	74.6	65.7
2.50 lakh lit / ha	61.8	71.8	80.2	81.0	73.7
3.75 lakh lit / ha	69.9	81.3	87.5	87.9	81.7
5.00 lakh lit / ha	76.1	84.2	88.5	89.3	84.5
6.25 lakh lit / ha	80.2	86.9	90.1	91.2	87.1
Mean	61.8	72.8	79.6	82.3	
CD (0.05)	M	S	S x M	M x S	
	2.5	1.9	4.5	4.9	

(Anon, 2002)

5. EFFECT OF DISTILLERY EFFLUENT ON SOIL

5.1 Effect on physical properties of soil

The distillery effluent contains appreciable amount of organic matter and hence, its application significantly alter the physical properties of soil. Soil permeability is an important parameter when planning for liquid waste disposal to agricultural land. The reduction in hydraulic conductivity by effluent irrigation was due to accumulation of solids at the soil surface. Devarajan *et al* .(1996) also reported that the infiltration rate of the soils was significantly reduced with effluent irrigations and the reduction was marginal at 50 times dilution (5.2 %) and appreciable at 10 times dilution (54.5 %). In soils, heavily overloaded with organic carbon compounds due to liquid wastes, there is build up in the waste water solids and the solids formed by bacterial activity under anaerobic conditions, caused by the high oxygen demand which will inturn cause a decrease in the infiltration rate. Jhosi *et al.* (1996) found that there was an improvement in saturated hydraulic conductivity and reduction in bulk density of the soils with effluent amendment over the control (Table 11).

Table 11. Influence of continuous application of distillery effluent for two seasons on physical properties of surface soil (0 – 15 cm)

Quantity of effluent ($m^3\ ha^{-1}$)	Saturated hydraulic conductivity ($cm\ hr^{-1}$)		Bulk density ($Mg\ m^3$)		Saturated water content (5 v/v)	
	After wheat	After Rice	After wheat	After rice	After wheat	After rice
Control	0.10		1.53		37.1	
60	0.11		1.41		38.8	
120	0.15		1.41		41.7	
180	0.19		1.35		40.1	
240	0.21		1.36		44.3	

(Joshi *et al.*,1996)

5.2. Effect on physico-chemical properties of soil

Since the distillery effluent contains appreciable amount of basic cations, organic matter and higher salt load, its application to soil may affect the physco-chemical properties of soil. Addition of distillery effluent regardless of rate, raised the soil pH, owing to increase in soil K, Ca, Mg and Na levels and also by the organic matter oxidation brought out by microbial activity was responsible for increased pH of the soil treated with distillery effluent. One time application of treated undiluted effluent before planting of the crop and ploughed into the soils raised the pH slightly to the alkaline (7.87) and soil EC was not raised beyond 0.25 dSm^{-1} even at 500 t/ha of treated effluent application. The results of the field experiment s conducted by TNAU in collaboration with EID Parry (I) Ltd., Nellikuppam were given in Table 12. Irrespective of the soil type and initial soil pH, application of TDE brought the soil pH to near neutral. Though application of distillery effluent slightly changed the exchangeable Na content of the soil, it did not increase the ESP of the soil due to increase of other beneficial cations viz., Ca and Mg.

Table 12. Effect of treated distillery effluent (TDE) on physico-chemical properties of different soil types

TDE	PH	EC	Ex.Na	Ex.Ca	Ex.Mg	ESP
(lakh lit ha^{-1})		dSm^{-1}	cmol(p+)kg^{-1}			(%)
Sandy clay loam soil						
Control	8.24	0.214	2.13	13.82	8.27	8.70
1.25	8.20	0.220	2.10	14.38	8.52	8.29
2.50	8.13	0.224	2.11	15.22	8.83	7.98
3.75	8.09	0.241	2.12	15.85	9.37	7.65
5.00	8.02	0.247	2.13	16.32	9.73	7.46
CD (0.05)	0.09	0.015	NS	0.45	0.24	NS
Sandy loam soil						
Control	8.45	0.093	1.45	7.40	3.70	11.3
1.25	8.41	0.096	1.46	7.65	3.84	11.0
2.50	8.35	0.098	1.47	7.80	3.97	10.8
3.75	8.27	0.107	1.47	7.97	4.13	10.6
5.00	8.22	0.111	1.48	8.10	4.24	10.4
CD (0.05)	0.11	0.01	NS	0.23	0.21	NS
Sandy soil						
Control	7.11	0.065	0.35	6.24	2.14	3.95
1.25	7.11	0.067	0.38	6.56	2.48	3.98
2.50	7.14	0.068	0.40	6.74	2.90	3.93
3.75	7.19	0.078	0.43	7.07	3.24	3.88
5.00	7.22	0.082	0.44	7.21	3.40	3.85
CD (0.05)	0.08	0.005	0.09	0.35	0.15	NS

(Anon, 2002)

Table 13.Changes in soil EC (dsm^{-1}) due to distillery effluent application and crop rotation in sandy clay loam soil

	Initial	1st crop	2nd crop	3rd crop	4th crop	5th crop	6th crop
C	0.18	0.18	0.18	0.2	0.21	0.21	0.19
1:50	0.18	0.21	0.21	0.21	0.23	0.22	0.2
1:40	0.18	0.22	0.22	0.24	0.25	0.23	0.21
1:30	0.18	0.24	0.23	0.25	0.27	0.23	0.21
1:20	0.18	0.26	0.28	0.31	0.33	0.29	0.23
1:10	0.18	0.27	0.29	0.33	0.36	0.32	0.24
CD		0.05	0.06	0.03	0.05	0.04	0.04

(Anon, 2002)

(*Distillery effluent was applied upto 4th crop; 1 to 5th crop – sugarcane; 6th crop - sun flower)

Baskar *et al*. (2001) reported that pre-plant application of graded doses of distillery effluent correspondingly increased the pH (Table 14) and EC of the soil (Table 13) from the initial level and they stated that the high salt load of effluent might have increased the soluble salt content of the post harvest soil.

Table 14 Influence of continuous application of distillery effluent for two seasons on pH of soil at different depths.

Depth (cm)	**Wheat**					**Rice**				
	Quantity of distillery effluent applied (m^3 ha^{-1})									
	C	60	120	180	240	C	60	120	180	240
0-15	7.51	7.99	7.94	7.40	7.66	8.43	8.24	8.27	8.25	8.30
15-30	7.37	8.13	8.12	7.65	8.12	8.43	8.31	8.21	8.23	8.20
30-45	7.63	7.99	8.12	7.66	8.08	8.17	8.21	8.19	8.20	8.27
45-60	7.59	8.07	8.07	7.26	8.00	8.19	7.87	7.99	8.24	8.16
60-75	7.61	8.06	8.00	7.60	8.10	8.24	7.90	7.94	8.12	8.05
75-90	7.49	8.15	8.09	7.47	8.38	8.19	7.85	8.04	8.40	8.04

(Joshi *et al.*,1996)

However the increase in the EC of the soil was well within the safe limit of 1.0 $dSm^{-1.}$ Jhosi et al (1996) reported that application of distillery effluent increased the EC after wheat harvest in surface layer (0-15 cm) and the increase was very marginal at lower depth (Table 15). He also observed that EC of the effluent treated soil was significantly reduced after rice crop. This could be due to leaching of the salts during rice crop as standing water of 5 cm was maintained which helped in removing the excess salts from soil profile.

Table 15: Influence of continuous application of distillery effluent for two seasons on EC (dSm^{-1}) of soil at different depths.

Depth (cm)	Wheat					Rice				
	Quantity of distillery effluent applied (m^3 ha^{-1})									
	C	60	120	180	240	C	60	120	180	240
0-15	0.20	0.20	0.44	0.64	0.79	0.10	0.16	0.15	0.35	0.55
15-30	0.18	0.13	0.19	0.25	0.24	0.05	0.06	0.10	0.16	0.18
30-45	0.10	0.14	0.10	0.14	0.16	0.10	0.09	0.08	0.11	0.13
45-60	0.08	0.20	0.12	0.11	0.17	0.13	0.08	0.20	0.12	0.14
60-75	0.17	0.19	0.12	0.09	0.15	0.06	0.10	0.10	0.16	0.13
75-90	0.09	0.18	0.16	0.10	0.19	0.10	0.12	0.13	0.15	0.14

5.3. Effect on available nutrients of soil

Since the distillery effluent is a plant extract, it contains high organic load. So the application of this distillery effluent significantly increased organic carbon content of the post harvest soil (Devarajan *et al*. (1996), Rajukkannu *et al*.,1996, Kayalvizhi *et al*.,2001). Baskar *et al*., (2001) stated that though the distillery effluent contains only small quantity of nitrogen, its application significantly increased the available N status of post harvest soil. This might be due to its direct contribution as well as through increased microbial activity by the supply of other essential nutrients and organic matter which inturn might have increased microbial decomposition and released the native N source . Mena *et al*. (1986) also reported that the vinasse to soil increased the total N,C and organic matter contents and modified the C: N ratio. Devarajan *et al* .(1996) reported that the available N increased from 276 to 412 kg $ha^{-1}$with 10 times diluted distillery effluent irrigation .

Application of effluent increased the available P and K status of the soil to the tune of two to three times from the initial soil test value inspite of the crop removal which might be due to the higher P and K contents of the effluent (Devarajan *et al*., 1996a; Baskar *et al* 2001; Kayalvizhi *et al*.,2001). Application of distillery spent wash to alkali soil significantly increased the available P content of the soil. The acidity and HCO_3 of distillery spent wash had solubilised the native insoluble soil P and thus helped to increase the available P (Rajukkannu *et al*., 1996).

Table 16: Effect of treated distillery effluent (TDE) on fertilty status of different soil types

TDE (lakh lit ha^{-1})	OC	Av.N	Av.P	Av.K	Av.Zn	Av.Fe	Av.Cu	Av.Mn
	%	kg ha^{-1}			mg kg^{-1}			
Sandy clay loam soil								
Control	0.46	163	11.6	192	2.58	26.8	2.08	14.4
1.25	0.49	174	12.3	238	2.71	28.0	2.19	14.9
2.50	0.51	180	13.1	275	2.85	29.4	2.30	15.3
3.75	0.53	188	14.0	301	2.97	30.5	2.43	15.8
5.00	0.57	195	14.5	325	3.09	31.3	2.58	16.4
CD	0.03	8.0	0.50	14	0.12	0.9	0.12	0.45
Sandy loam								
Control	0.49	134	17.4	231	2.16	9.50	2.07	9.76
1.25	0.50	144	18.1	266	2.28	10.20	2.18	9.82
2.50	0.52	150	18.9	292	2.34	10.80	2.34	9.96
3.75	0.55	157	19.6	311	2.39	11.80	2.45	10.17
5.00	0.58	162	21.2	337	2.58	12.80	2.62	10.54
CD	0.02	5.0	0.60	11	0.09	0.53	0.08	0.38
Sandy soil								
Control	0.36	167	9.1	138	0.60	4.99	1.08	6.07
1.25	0.40	173	10.7	153	0.66	5.51	1.22	6.66
2.50	0.42	175	11.6	180	0.74	5.97	1.28	7.07
3.75	0.45	185	12.3	199	0.79	6.23	1.44	7.39
5.00	0.47	189	13.2	214	0.88	6.86	1.55	8.20
CD	0.03	7	0.40	7	0.04	0.42	0.05	0.21

(Anon, 2002)

Application of vinasse to the main crop of sugarcane increased the available K content of the surface soil and remained high even after the harvest of the first ratoon. Thus the effluent had not only supplied the nutrients to the existing crop but also maintained and improved the soil fertility (for the next crop). The experiment conducted by Joshi *et al.*(1996) revealed that at surface layer the available K content of the post harvest soil (after wheat crop) was substantially increased from 87 ppm (control) to 1075 ppm due to one time application of distillery effluent @ 240 m^3 ha^{-1}. They observed a buildup in K content in the lower depths also (313 ppm in distillery effluent @ 240 m^3 ha^{-1} applied plot as compared to control (88ppm) at 75 - 90 cm depth) but the magnitude was less than that of the surface layer. Somashekar *et al* (1984) opined that the mineralization of organic material as well as the nutrients present in the effluents is responsible for the increase in the availability of plant nutrients. Field experiments conducted by TNAU in different soil types of EID Parry (I) Ltd, Command area, Cuddalore dstrict, Tamil Nadu revealed (Table 16) that application of graded doses of distillery effluent significantly increased the fertility status of the soils in terms of organic carbon and available nutrients.

The exchangeable Ca, Mg and Na contents of the post harvest soil were significantly increased due to the application graded doses of distillery effluent. This might be due to Ca, Mg and Na contents of the effluent. Cepro and Machado (1987) stated that the cane field irrigation with sugar factory waste water effected a tendency for the exchangeable Ca to increase. Sweeney and Graetz (1991) reported that the digested distillery effluent application increased soil concentrations of most elements particularly K and Na. They also stated that the increase in the contents of these elements might be the reason for the little increase in the pH of post harvest soil due to effluent application. Devarajan *et al*.,(1996) observed an increase of available Ca and Mg from 1400 ppm to 2200 ppm and 126 ppm to 470 ppm respectively due to the application of 10 times diluted distillery effluent.

Devarajan *et al*.(1996) reported that the available micronutrients *viz.,* Zn, Fe, Cu and Mn of the post harvest soil were increased from 2.2 to 3.9 ppm, 22.9 to 31.6 ppm, 4.1 to 7.3 ppm and 15.5 to 25.8 ppm respectively due fertigation with 10 times diluted distillery effluent. Similar increase in the availability of micronutrients were also observed by Kayalvizhi *et al*.(2001). Baskar *et al*.,(2001) reported that the available micronutrients v*iz.,* Fe, Mn, Zn and Cu were progressively increased by the graded levels of distillery effluent and the availability being maximum with the application of distillery effluent @ 2.5 lakh litres per acre. They also stated that increased availability might be due to direct contribution from the effluent as well as solubilisation and chelation effect of organic matter supplied by the effluent.

5.4 Effect on biological properties of soil

As this distillery effluent contains highly bio-degradable organic matter with high content of dissolved salts of essential plant nutrients, it is expected to alter soil biological health as well as enzyme process. The chemical analysis revealed that some of the characteristics (neutral pH, OC, N, P, K and other nutrients) are likely to influence the microbial growth in soil favorably, while others (high EC,BOD, COD and Cl) may affect the microbial growth as well as enzyme activities adversely. The rhizosphere region could be influenced by various environmental factors and physiological conditions of the plant, which might have been responsible for variations in the population dynamics of different groups of microflora in the rhizosphere of crops as influenced by effluent irrigation. The experiment conducted by Rajukkannu *et al*.(1996) revealed that application of distillery spent wash drastically reduced the number of bacteria, fungi and actinomycets during the initial periods (Table 17).

Table 17. Effect of application of spent wash as sodic soil amendment on pH and microbial population

	Spent wash applied (lakh litres / ha)			
	0	5	7.5	10
PH				
Initial	9.4	9.4	9.4	9.4
After reclamation	-	8.2	8.3	8.2
Post – harvest	9.2	8.6	8.6	8.6
Bacteria (x 10^6)				
Initial	21.4	21.2	21.4	20.2
After 7 days	-	11.2	6.4	2.8
After reclamation	-	18.6	15.6	12.8
Post – harvest	23.0	30.4	27.2	25.4
Fungi (x10^3)				
Initial	7.8	7.8	7.8	7.8
After 7 days	-	0.8	Nil	Nil
After reclamation	-	3.2	1.8	1.4
Post – harvest	7.0	10.4	8.4	5.4
Actinomycets (x 10^4)				
Initial	9.6	9.6	9.6	9.6
After 7 days	-	Nil	Nil	Nil
After reclamation	-	2.0	2.0	Nil
Post – harvest	10.6	18.2	16.4	15.4

(Rajukannu *et al.*,1996)

The higher BOD of the DSW and the resultant depletion of oxygen in the soil would have drastically reduced the microbial population. However, the post harvest soil samples had showed the built up of microbial population greater than the original level in the treated soil samples. Therefore a minimum period of 45 - 60 days should be given between the undiluted spent wash application and planting. The experiments conducted by TNAU in different soil types of EID parry (I) Ltd., command area, Cuddalore district, Tamil Nadu revealed that application of graded doses of distillery effluent to sugarcane crop significantly increased the microbial population (Table 18) of the post harvest soil (Anon, 2002).

Table 18. Influence of treated distillery effluent on microbial population dynamics in different soil types

Qnty. of TDE (lakh lit.ha^{-1})	Bacteria (x10^5)			Fungi (x 10^3)			Actinomycets (x10^3)		
	SCL	SL	S	SCL	SL	S	SCL	SL	**S**
Control	32.2	50.2	22.5	5.0	5.33	5.7	2.23	3.88	2.45
1.25	49.3	52.5	23.9	8.5	6.98	5.9	3.46	5.02	3.34
2.50	50.2	53.5	26.7	9.7	7.30	7.0	3.80	5.08	4.18
3.75	52.6	54.3	27.0	11.3	7.60	7.6	4.56	5.14	4.62
5.00	54.0	55.1	29.6	13.9	8.07	8.2	5.17	5.25	4.72
CD (p=0.05)	2.0	1.8	0.541	0.27	0.22	0.50	0.08	0.16	0.47

(SCL – Sandy clay loam soil; SL – Sandy loam soil; S- Sandy soil)

(Anon, 2002)

The population dynamics of bacteria, actinomycets, fungi, Azospirillum and Azotobacter in the field soils grown with turmeric, paddy, gingelly, cotton, banana and groundnut showed that the 50 time and 40 time diluted effluent irrigations enhanced or maintained the microbial populations in the soils (Devarajan *et al.*,1993). The soil enzyme activities were also maintained with 50 times diluted effluent irrigation. The results of the experiments (Table 19) conducted by Kundu *et al.*(2001) revealed that there was no adverse effect of soil application of post methanated distillery effluent on microbial population *vis-à-vis* urease activity in the soil. Rather, there was an enhanced microbial growth as evidenced by marked reduction of time taken for the hydrolysis of 90 per cent of the applied urea.

At each level of distillery effluent application, shorter the period of soil sampling the smaller was the magnitude of increase in urease activity. The easily oxidisable C added to the soil through distillery effluent might have resulted in the increased microbial activity in soil and therefore, the soil samples collected after 37 days after application of distillery effluent showed higher urease activity.

Table 19. Influence of distillery effluent application on urease activity, rate of urea hydrolysis

Qty. of distillery effluent (ha-cm)	Sampling time (days) after application	Urease activity (mg urea kg^{-1} h^{-1})	% increase in urease activity	First order rate constant 'k'(h^{-1})	Time taken(h) for hydrolysis of	
					50% of applied urea*	90 % of applied urea*
Control		77.0	-	0.0431	16.1	53.4
2.5	37	115.4	46.1	0.0682	10.2	33.8
2.5	22	106.6	34.9	-	-	-
2.5	7	88.0	11.4	-	-	-
5.0	37	129.0	63.3	0.0791	8.8	29.1
5.0	22	126.5	60.2	-	-	-
5.0	7	95.9	21.4	-	-	-
10.0	37	156.5	98.0	0.0985	7.0	23.4
10.0	22	137.0	73.5	-		
CD ($p=0.05$)		9.5	-			

* 5 g soil mixed with 5 ml urea solution (containing 2 g urea) (Kundu,2001)

6. EFFECT OF DISTILLERY EFFLUENT ON CROPS

Since the distillery effluent is essentially a plant extract and contains high level of organic carbon, K, Ca, Mg, S and appreciable quantities of micronutrients and does not contain any toxic constituents, it has been advantageously used as source of nutrients and water for crops.

Application of spent wash increased the cane yield of sugarcane in Philippines (Gonzales and Tianco, 1982), Australia (Usher and Wellington, 1979), Cuba (Vieira, 1982) and South America (Scandaliaris *et al*., 1987). Ghugare and Magar (1995) reported that application of 50 fold diluted 16 Mg ha^{-1} lagoon stored vinasse (BOD 4350 mg L^{-1}) to medium black soil gave 20% higher cane yield. Devarajan and Oblisami (1995) recorded similar observation. An increase of 5.5, 8.4, 11.4, 12.7, 13.7 t ac^{-1} of cane yield were recorded due to the pre-plant (40 days before planting) application of 0.5, 1.0, 1.5, 2.0 and 2.5 lakh litres ac^{-1} of distillery effluent over control (Baskar *et al*.,2001). Anon (1986) reported that the application of distillery effluent at 150 and 300 t/ha increased the sugarcane yield by 53.8 and 44.0 % respectively when compared with untreated control. The brix percentage in cane juice was found significantly increased in plots irrigated with 10 times diluted effluent (23.0%) over river water irrigation (22.34%). The results of the studies conducted by Zalawadia *et al.*(1997) revealed that application of distillery effluent diluted at any level increased sugarcane yield and nutrient uptake significantly over well water irrigation (Table 20). Less diluted distillery effluent gave higher yield of biomass than higher dilutions.

The results of the field studies conducted by Pujar and Manjunathaiah (1996) revealed that application of distillery effluent at 1:10 dilution recorded highest yield in sugarcane (Table 21) and maize (Table 22) where as the highest yield in wheat was favoured by 1:50 dilution. The quality parameters in sugarcane were not influenced due to diluted effluent irrigation. The protein per cent in wheat grains showed an increased trend at lower dilutions of effluent irrigation but the starch per cent in maize grains was vice versa (Table 22).

Table 20. Effect of irrigation with diluted treated distillery effluent on biomass yield and uptake of nutrients by sugar cane

Paramaters	Unit	Treatments				CD (p=0.05)
		Well water	25 times diution* (3.82 L pot^{-1})	50 times dilution* (1.91 L pot^{-1})	100 times dilution* (0.955 L pot^{-1})	
Total Biomass yield (fresh)	g pot^{-1}	579	850	718	635	31.7
Total Biomass yield (Dry)	g pot^{-1}	210	277	244	228	11.7
N –uptake	mg pot^{-1}	1436	3002	2261	1803	402
P –uptake	mg pot^{-1}	261	548	379	312	32
K –uptake	mg pot^{-1}	3218	7091	5631	4333	754
Ca –uptake	mg pot^{-1}	424	631	539	494	75
Mg –uptake	mg pot^{-1}	684	965	840	776	120
S –uptake	mg pot^{-1}	380	790	587	442	49
Fe –uptake	mg pot^{-1}	59.8	96.0	85.3	70.0	5.60
Zn –uptake	mg pot^{-1}	4.69	11.8	8.40	5.90	0.77
Cu –uptake	mg pot^{-1}	1.37	2.88	2.16	1.76	0.33
Mn –uptake	mg pot^{-1}	6.97	15.7	11.5	8.80	1.41

(Zalawadia *et al*, 1997)

(* Crop was initially irrigated with tube well water for establishment and subsequently irrigated as per treatments)

Table 21. Effect of distillery effluent at different dilutions on yield attributes and quality of sugarcane

Diltions of DE*	No. of cane tillers	Height of millable cane (m)	Cane yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Brix (%)	POL (%)	Purity (%)	CCS (%)
1:10	148	66.1	82.8	48.1	22.6	20.3	89.9	14.2
1: 25	141	65.7	74.3	45.2	21.9	19.3	88.2	13.3
1: 50	139	64.8	68.8	40.3	21.7	19.4	89.2	13.4
Control	137	66.0	63.9	38.4	22.4	20.2	90.3	14.2
CD (0.05)	2.2	2.0	4.1	1.58	22.2	NS	NS	NS

(* 12 irrigations) (Pujar and Manjunathaiah,1996)

Table 22. Effect of distillery effluent at different dilutions on yield attributes and quality of wheat and maize

Dilutions of DE*	Wheat				Maize			
	No.of Productive tillers	Seed yield (q / ha)	100 seed weight (g)	Protein content (%)	Seed yield (q /ha)	Stover yield (q /ha)	100 seed weight (g)	Starch content (%)
1:10	130	25.3	26.8	12.9	74.7	79.8	30.8	64.8
1: 25	144	26.0	29.2	12.8	67.8	76.6	26.8	65.1
1: 50	154	29.0	34.3	12.7	65.4	74.3	27.6	65.4
Control	152	28.2	34.3	12.5	64.4	72.1	27.2	65.4
CD (0.05)	11.0	1.60	2.9	0.22	1.61	1.42	0.84	65.3

(* wheat = 5 irigations; Maize = 6 irrigations) (Pujar and Manjunathaiah,1996)

Pathak *et al*.(1998) observed that the distillery effluent after methanation (BOD 5000 mg L^{-1} **;** COD 25,000 mg L^{-1}**)** can be used for irrigation to wheat and rice crop in an Inceptisol without significant effect on rice crop by diluting it suitably to a BOD level below 1000 mg L^{-1}.

They also stated that application of distillery effluent decreased the grain yield of wheat whereas the rice grain yield registered an increasing trend upto BOD 2000 mg L^{-1}. Madrod *et al.* (1986) reported that the protein per cent in wheat grains showed an increased trend at lower dilutions of effluent irrigation but the starch per cent in maize grains was vice versa.

Nagappan *et al*.(1996) reported that application of distillery effluent @ 0.30 lakh litres per acre per month along with irrigation water for wet land and garden land crops and 0.90 lakh litres per acre for rainfed crops (Table 23) increased the yield of crops *viz.*, wet land sugarcane, wet land paddy, garden land sugarcane, garden land paddy, garden land cotton, rainfed maize, rainfed sorghum, rainfed bajra and rainfed redgram to the tune of 39.01, 0.070, 28.85, 0.79, 0.50, 0.17, 0.23, 0.26, and 0.43 tonnes per ha respectively over control.

Table 23. Effect of secondary treated distillery effluent on yield (t ha^{-1}) of crops

Treatments	Wet land		Garden land			Rainfed			
	Sugar cane	Paddy	Sugarcane	Paddy	Cotton	Maize	Sorghum	Bajra	Red gram
Control	98.4	3.82	88.3	3.37	3.11	0.59	0.63	1.11	0.99
Effluent applied*	134.4	4.52	117	4.16	3.61	0.76	0.86	1.37	1.42
CD (p=0.05)	3.8	0.13	7.4	0.21	0.13	NS	0.15	0.13	0.33

(*Wet land & garden land crops- DE @ 30000 lit ac^{-1} per month along with irrigation water; rainfed crop- DE @ 90000 lit. ac^{-1} before sowing) (Nagappan *et al.*,1996a)

The results of the field studies conducted by Devarajan *et al.*(1998) revealed that application of distillery effluent at 50 times dilution along with irrigation water significantly increased the oil content, yield and yield attributes of oil seed crops *viz.*, gingelly, groundnut, soybean and sunflower (Table 24).

Table 24. Effect of treated distillery effluent on yield and quality of oil seed crops

Treatments	Gingelly		Groundnut				Soyabean			Sunflower	
	Seed yield	Oil content	Pod yield	Shelling %	Oil content	Crude protein	Seed yield	Oil content	Crude protein	Seed yield	Oil content
T_1	799	48.5	1734	75.4	48.4	46.1	1555	19.0	39.5	1386	38.1
T_2	897	49.0	2121	78.6	49.2	47.6	2175	19.3	40.1	1632	37.8
CD (p=0.05	46	1.0	84	3.2	0.5	0.7	180	0.9	0.7	56	0.4

(T_1- Control; T_2- Effluent applied 7 days after establishment of crops along with irrigation water at 50 times dilution) (Devarajan *et al.*,1998)

Sharma (2001) reported that vinasse (2.5 - 3.5 t ha^{-1}) increased the yield of sugarbeet, potatoes and other vegetables by 20 %, but had adverse effect on legumes.

Devarajan *et al.* (1993) reported that there was a reduction in rhizome yield of turmeric with effluent irrigations even at higher dilutions and the other crops viz., groundnut, soybean, sunflower and forage crops recorded higher yield at 30-50 times dilutions.

Devarajan and Oblisamy (1994) found that the highest annual yield of Banana cv. Poovan (48.4 t ha^{-1}) was obtained from the control treatment, although the yields with the 50 and 40 times dilutions gave comparable results (47.6 and 45.5 t ha^{-1} respectively) and the yield increased with increasing effluent concentration, falling to 16.9 t ha^{-1} with the 10 times dilution and they concluded that the higher dilutions could be used without adversely affecting soil fertility or crop yield.

To study the influence of TDE, biocompost and FYM on the yield of maize crop, field experiments were conducted by Dinesh (2010) with maize at farmers' fields in Vellore district. The soil type of the experimental field were deep red sandy loam soil (*Typic Rhodustalfs*) and black clay loam soil (*Typic Haplusterts*), having neutral and slightly alkaline reactions (pH 6.58 and 8.41); with low and medium soluble salts (EC 0.14 and 0.30 dSm^{-1}) and low and high organic carbon status (3.90 and 7.40 g kg^{-1}) respectively. Different doses of distillery effluent were compared with various levels of N, P and K fertilizers (Table 25).

The results indicates that, the application of TDE @1.0 lakh litres ha^{-1} along with either 100 % RD of NPK fertilizers (M_3S_5) or100 % RD of NP fertilizers (M_3S_4) or 75 % RD of NP fertilizers (M_3S_3) registered higher grain and stover yield with an increase to the tune of 12.5 - 43.2 and 12.5 - 44.4 per cent, respectively over the control in red loamy soil. In black clay loam soil, the same treatment combinations (M_3S_5, M_3S_4 and M_3S_3) being comparable with the application of FYM @ 12.5 t ha^{-1} along with either 100 % RD of NPK fertilizers (M_5S_5) or 100 % NP fertilizers (M_5S_4) registered higher grain and stover yield with an increase to the tune of 18.3 – 26.3 and 37.6 - 47.1 per cent respectively over the control.

From the results of the field experiments, it is concluded that the application of TDE could save 100% RD of K fertilization in both red sandy loam and black clay loam soils, while in the red sandy loam soil it could also save upto 25% of N and P fertilization. The application of FYM @ 12.5 t ha^{-1} along with 100% NP performed equally better as that of 100% NPK and it could be inferred that complete skipping of

K fertilization in the black clay loam soil is also possible if integrated nutrient management involving FYM and biofertilizers are practiced.

Table 25.Effect of TDE, Biocompost and FYM on grain and stover yield (t ha^{-1}) of maize crop

Trts.	Red sandy loam soil						Black clay loam soil					
	C	50 % NP	75 %NP	100 %NP	100 % NPK	**Mean**	C	50 %NP	75 %NP	100 % NP	100 % NPK	**Mean**
M1	1.8	2.8	3.3	3.8	4.2	**3.2**	2.6	3.7	4.2	4.6	4.9	**4.0**
M2	3.2	3.8	4.2	4.4	4.4	**4.0**	3.4	4.2	4.8	5.2	5.2	**4.6**
M3	3.6	4.2	4.7	4.8	4.8	**4.4**	3.6	4.7	5.4	5.8	5.8	**5.1**
M4	3.2	3.9	4.3	4.6	4.7	**4.1**	3.5	4.3	4.9	5.3	5.4	**4.7**
M5	3.1	3.9	4.5	4.7	4.9	**4.2**	3.5	4..5	5.1	5.8	5.9	**5.0**
Mean	**3.0**	**3.7**	**4.2**	**4.4**	**4.6**	**4.0**	3.3	4.3	4.9	5.3	5.5	**4.7**
	M	**S**	**M x S**	**S x M**			**M**	**S**	**M x S**	**S x M**		
CD (0.05)	0.21	0.13	0.33	0.29			0.32	0.15	0.44	0.33		

M1- No organics, M2- TDE@ 0.5 lakh lit. ha^{-1}, M3- TDE@ 1.0 lakh lit. ha^{-1},
M4- Bio compost @ 5 t ha^{-1},M5- FYM @ 12.5 t ha^{-1} + biofert.

7. IMPACT OF AGRICULTURAL USE OF DISTILLERY EFFLUENT ON ENVIRONMENT

The use of the distillery effluents is in practice for last 50 years. The users of the treated distillery effluent in the agricultural fields generally follow two kinds of practices, ie., pre-sown and post-sown applications. However, the use of liquid effluents in agriculture is confined only to very limited areas in the immediate vicinity of most of disitilleries. The actual area in which the distillery effluent use is in practice is very small with respect to enormous amount of effluent generated by the distillery industry. Any uncontrolled effluent irrigation may adversely affect both the plant, soil and water. The changes in soil properties caused by application of effluent and degradation of the effluent in the soil have implications for runoff chemistry. Run-off through, and erosion of, these soil surface layers may influence stream pH and stream quality, with consequent ecological effects.

The deleterious effect of salts in the irrigation water can result from (a) direct effect of salts in preventing water uptake by plants (osmatic effect); (b) direct chemical effects upon the metabolic reactions of the plant (toxic effects); and or (c) indirect effects through changes in the soil structure, permeability and aeration. Since the organic matter applied with effluent through controlled land application is completely decomposed in the top soil, there is little or no possibility of its reaching the ground water. Degradation of distillery waste in the soil is approximately four times faster than ordinary farm yard manure. Distillery effluent has been shown to degrade faster in dried soils, liberating high levels of CO_2 (Minhone and Cerri,1987). The survey conducted by Koteswaran *et al.*(1999) at EID Parry Command area, Nellikuppam, Tamil Nadu clearly indicated that the quality of bore well water was not affected by using distillery effluent as a source of organic manure and also the parameters of bore well water confirm the irrigation water standards even though effluent is being used continuously. The results of the survey conducted by Joshi *et al.*(1999) showed no organic contamination in the groundwater in samples drawn near the various distilleries in Uttar Pradesh. However, the electrical conductivity of treated soil has appreciably increased at a few places, indicating raise in salt concentration in soil profile. Hence if this effluent is used for irrigation, it is necessary to enforce some basic safety and monitoring measures, such as, rotation of crops, application of only fresh water during germination and seedling growth and regularly monitoring of soil and ground water characteristics for any adverse effect.

7.1. Long term Studies conducted by TNAU at EID Parry(I) Ltd.,Nellikuppam, Tamil Nadu

Tamil Nadu Agricultural University in collaboration with EID Parry (I) Ltd., Nellikuppam conducting long term studies to study the effect of long term application of treated distillery effluent on soil, crop and water.

To study the downward movement of distillery effluent and posible ground water contamination, piezometers were installed at different depths viz., 0.5, 1.0, 1.5 and 2.0 m in the long term field experiments being conducted at EID Parry (I) Ltd., Nellikuppam cane farm since 2001. The piezometers were installed in pre-sown/plant undiluted treated distillery effluent (TDE) applied field, diluted treated distillery effluent applied field and in control plot (without distillery effluent application). Three replication were maintained for each treatment.

Details of TDE application

1. Pre-sown/plant application

For plant crop TDE was applied 40 days before planting @ 5 lakh litres ha^{-1} and for ratoon crop, TDE was applied 45 days after ratooning @ 80,000 litres ha^{-1}

2. Diluted TDE application (1:10 dilution)

TDE was applied @ 1 lakh litres ha^{-1} along with irrigation water(1:10 dilution) at 45 days after planting. The TDE was applied 4 times at 40 days interval (45, 85, 125 and 165 days after planting/ ratooning) every year.

3. Sampling and analysis

Piezometers were examined for the presence of water every month. However water collected in the piezometers only during the rainy months (only after heavy rains). The water samples were analysed for pH, EC, cations, anions, SAR, BOD and COD.

The results of the average values of the 12^{th} year were given in the Table 26. The results showed that there was considerable and significant increase in EC, cation and anion contents in the water samples collected at 0.5 m depths in the distillery effluent applied fields when compared to control plots and no change in colour. Slight increase in salt content at this depth was observed over years. However in the water samples collected below 1 m depths, there was no significant difference between control plots and effluent applied plots indicating that the salts applied through distillery effluent remains only in the surface layer and never reached the sub-surface layer/ underground layers. The presence of hard subsurface layer might have prevented the downward movement of the distillery effluent. Moreover the applied quantity is not sufficient to reach the sub-surface layer. Since most of the salts added through distillery effluents are plant nutrients, the salts buildup in the surface layer will be removed by the crop during continuous cultivation.

Table 26 Influence of distillery effluent on ground water quality

Parameters	0.5 m depth			1.0 m depth			1.5 m depth			2 m depth				CD
	C	1:10	5 lakh L/ha	C	1:10	5 lakh L/ha	C	1:10	5 lakh L/ha	C	1:10	5 lakh L/ha	Bore well water	(0.05)
Colour	No change in color													
pH	8.36	8.28	8.32	8.34	8.31	8.33	8.31	8.28	8.30	8.42	8.35	8.40	8.32	NS
EC(dSm^{-1})	0.88	0.95	1.03	0.85	0.94	0.89	0.85	0.88	0.83	0.82	0.84	0.83	0.84	0.07
Ca^{2+} ($me.l^{-1}$)	1.88	1.88	1.94	1.87	2.05	1.97	1.93	1.77	1.60	1.43	1.48	1.40	1.42	0.15
Mg^{2+}($me.l^{-1}$)	2.35	3.08	3.38	2.58	2.60	2.87	2.31	2.27	2.35	2.21	2.39	2.45	2.36	0.10
Na^{+} ($me.l^{-1}$)	4.40	4.27	4.34	4.26	4.21	4.56	4.37	4.12	4.14	4.45	4.43	4.38	4.41	NS
K^{+} ($me.l^{-1}$)	0.13	0.43	0.36	0.14	0.23	0.30	0.15	0.20	0.15	0.17	0.20	0.19	0.15	0.08
Cl^{-} ($me.l^{-1}$)	2.38	2.62	2.68	2.57	2.60	2.47	2.60	2.67	2.47	2.18	2.30	2.56	2.41	0.13
CO_3^{2-}($me.l^{-1}$)	0.45	0.37	0.47	0.39	0.46	0.76	0.56	0.42	0.43	0.41	0.51	0.37	0.42	0.06
HCO_3^{-}($me.l^{-1}$)	5.51	5.68	5.61	4.20	4.03	5.36	4.73	4.65	4.57	4.56	4.48	4.78	4.71	0.25
SO_4^{2-} ($me.l^{-1}$)	1.20	1.23	1.28	1.08	1.50	1.63	1.36	1.27	1.11	1.20	1.28	1.16	1.19	0.11
SAR	3.10	2.75	2.63	2.81	2.71	2.89	2.95	2.85	2.89	3.26	3.23	3.25	3.36	0.14
RSC	1.73	1.09	0.76	0.14	-0.16	1.28	1.05	1.03	1.05	1.33	1.12	1.30	1.35	0.40
BOD ($mg\ l^{-1}$)	14.5	12.2	13.1	12.3	13.4	13.9	11.9	10.6	11.7	13.2	13.5	14.2	12.5	0.38
COD ($mg\ l^{-1}$)	24.2	19.6	23.6	20.9	22.1	23.9	21.5	20.4	21.2	24.2	24.8	25.2	20.4	0.28

7.2. Long term Soil quality monitoring

The results of the long term experiment conducted by TNAU in collaboration with EID Parry (I) Ltd., Nellikuppam at Sugarcane Research Station, Cuddalore were given in Table 33. The experiment was started during 1997. For experiment purpose, high dose of distillery effluent (Table 27) was applied (Four times per year).

Table 27. Changes in soil EC (dsm^{-1}) due to distillery effluent application and crop rotation in sandy clay loam soil

Trt	DE applied per year (litres ha^{-1})	Total quantity of DE applied in 4 years (litres ha^{-1})	1st crop	2nd crop	3rd crop	4th crop	5th crop	6th crop	Increase in EC due to DE in 4 years	Reduction in EC in one and half year by growing crops without DE
C	-	-	0.18	0.18	0.2	0.21	0.21	0.19	0.03	0.02
1:50	80,000	3,20,000	0.21	0.21	0.21	0.23	0.22	0.20	0.05	0.03
1:40	1,00,000	4,00,000	0.22	0.22	0.24	0.25	0.23	0.21	0.07	0.04
1:30	1,33,000	5,32,000	0.24	0.23	0.25	0.27	0.23	0.21	0.09	0.06
1:20	2,00,000	8,00,000	0.26	0.28	0.31	0.33	0.29	0.23	0.15	0.10
1:10	4,00,000	16,00,000	0.27	0.29	0.33	0.36	0.32	0.24	0.18	0.12
CD			0.05	0.06	0.03	0.05	0.04	0.04		

(*Distillery effluent was applied upto 4th crop; 1 to 5th crop – sugarcane; 6th crop - sunflower) (Anon,2002)

The highest increase in EC was 0.15 dSm^{-1} due to application of highest dose (16 lakhs litres ha^{-1}) of distillery effluent over four years. In the same treatment, the decrease in EC over one and half years (including crop rotation with sunflower) is 0.12 dSm^{-1}. The EC of the DE applied soil was almost attained to the original level with in one and half years after distillery effluent application.

The long term experiment on pre-plant application of TDE initiated during 2002 at EID Parry (I) Ltd., cane farm, was continued by Previna (2012) in the same layout during July, 2010 on 10th crop (Sugarcane – CO 86032). The experimental soil was red sandy loam belonging to Vadapudupet series (*Typic Haplustalf*).The results revealed that application of graded doses of TDE continuously for 10 years slightly reduced the pH of soil and significantly increased the EC (Table 28). However, the EC of the soil was well within the safe limit for crop growth even at higher dose of TDE (5.0 lakh litres ha^{-1}).

The soluble salt content measured in the long term experiment showed that the salt accumulation over a period of 10 years was not alarming. The concentrations of Ca, Mg were significantly high due to application of TDE, whereas Na concentration in soil was decreased resulting a low ESP. TDE with its high organic load increased the organic carbon content of post harvest soils.

Table 28. Long term effect (10th crop) of treated distillery effluent on physico-chemical properties of soil

TDE (lakh lit ha^{-1})	pH	EC dSm^{-1}	OC (%)	Ex.Ca	Ex.Mg	Ex.Na	Ex.K	ESP
				cmol(p+)kg^{-1}				
Control	8.32	0.11	0.39	7.37	3.29	1.39	0.24	11.41
1.25	8.14	0.12	0.77	8.16	4.16	1.39	0.32	9.91
2.50	8.10	0.13	0.82	8.23	4.22	1.39	0.38	9.78
3.75	8.08	0.14	0.89	8.35	4.43	1.40	0.46	9.56
5.0	8.06	0.15	0.92	8.54	4.84	1.43	0.52	9.28
CD	0.13	0.005	0.04	0.52	0.20	NS	0.01	0.31

Previna (2012)

The organic carbon content and available nutrients got increased due to continuous addition of TDE for over 10 years. Application of TDE @ 5.0 lakh litres ha^{-1} resulted in highest value of available N (206 kg ha^{-1}), P and K (20.1 and 403 kg ha^{-1}) in soil (Table 29). The NPK fertilizers (S_6) recorded highest available NPK and organic carbon in the soil. The available micronutrients were significantly increased due to application of TDE. The highest DTPA –Zn, Cu, Fe and Mn were recorded in the higher dose of TDE @ 5.0 lakh litres ha^{-1}. The TDE application increased the microbial population and enzyme activities in soil. The highest microbial population and the highest enzyme activities were resulted due to the application of TDE at the rate of 5.0 lakh litres ha^{-1} (Table 30)..

Table 29. Long term effect (10^{th} crop) of treated distillery effluent on available nutrient status of soil

TDE (lakh lit ha^{-1})	**Av.N**	**Av. P**	**Av. K**	**Av Zn**	**Av Fe**	**Av Cu**	**Av Mn**
Control	134	16.9	216	2.01	9.06	1.73	13.2
1.25	179	17.7	322	2.32	11.4	2.23	16.0
2.50	191	18.5	364	2.43	12.9	2.38	16.8
3.75	200	19.3	390	2.63	13.2	2.69	17.8
5.0	206	20.1	403	2.80	14.4	2.89	17.9
CD	8.0	0.7	11.0	0.12	0.32	0.17	0.15

Previna (2012)

Table 30. Long term effect (10^{th} crop) of treated distillery effluent on biological properties of soil

TDE (lakh lit ha^{-1})	Bacteria	Fungi	Actinomycets	Dehydrogenase	Phosphatase	Urease
	(x10^6 CFU g^{-1})	(x10^3 CFU g^{-1})	(x10^5 CFU g^{-1})	(µg TPF g^{-1} soil h^{-1})	(µg nitrophenol g^{-1} soil h^{-1})	(µg NH_4-N g^{-1} soil h^{-1})
Control	55.74	6.56	3.99	2.67	10.10	3.50
1.25	60.49	8.19	5.34	4.09	17.74	8.64
2.50	63.63	8.57	5.51	4.76	22.71	10.45
3.75	67.40	9.07	5.62	5.62	27.40	11.48
5.0	71.14	10.32	5.94	6.59	31.47	12.62
CD	1.97	0.26	0.12	0.21	5.65	2.44

Previna (2012)

8. SUMMARY

The best strategy for utilisation of this effluent as nutrient and irrigation source for agriculture crops should emerge from the realisation by all the concerned agencies be it distilleries, pollution control agencies, farmers or research organisations that this effluent is a valuable resource which should not be wasted under any circumstances. Once the resource value of the effluent as a source of bioenergy and biomass is recognised, all agencies can work together to explore the possibilities for harnessing full potential of the effluent. The post methanation effluent has lower C:N ratio and so it would degrade more swiftly in the soil than untreated spent wash. Hence, there should not be any problem with its use in agriculture. The volume of the effluent is enormous. For a distillery with 30 kl of alcohol production, capacity not less than 270 ha of land is required. Such large area of land may be available with the distilleries or even with a single farm house. In such case more than one farm holding (sometimes number may even go over 50) have to be brought together to utilise the effluent. A cooperative system has to be evolved which is crucial for the success of such a programme. Distilleries have to provide lined irrigation channels to reach farmers' fields so as to make the package attractive for farmers. Land treatment or agro recycling of the distillery effluent is a convenient process but sometimes it is impracticable due to non availability of sufficient land area or dilution water. In such situations the effluent can be transformed into a biofertiliser for which costly but viable technologies are available. Composting with pressmud and vermiculture are a few alternatives which can be ventured to utilise the manurial potential of the distillery effluent.

The use of spent wash for presown treatment of agricultural land which has been in practice for last five decades and studies by various workers all over the world seems to be lucrative. Although various workers have suggested suitable application rates for this effluent under different conditions, the local studies are essential to determine optimum loading rates in order to avoid the possibility of reduction in crop yields because of inorganic toxicity. Effluent application will reduce the nutrient requirement through fertilisers. However, high salt load, mainly potassium and sulphur, into the soil system may hamper the sustained crop yields due to continued long term application of effluents. Therefore the effects on soil and crop productivity have to be visualised on long term and sustainable basis. The industries like EID Parry (I) Ltd., Nellikuppam has already started location specific long term studies in collaboration with research institutes viz., Tamil Nadu Agricultural University for continuous monitoring. Similarly other distilleries / distilleries association should also start location specific long term studies. All efforts should be made to reduce colour from the effluents. Identification of suitable cropping system, agronomic practices, irrigation scheduling and water management with distillery effluent has to be done for implementing such irrigation ensuring minimum damage caused to the soil, crop and ground water.

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