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Review Article

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Distillery Spentwash Production, Treatment and Utilization in Agriculture – A Review

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ABSTRACT

Molasses (one of the important by-products of sugar industry) is the chief source for the production of alcohol in distilleries by fermentation method known as raw spent wash. It is one of the most complexes, troublesome and strongest organic industrial effluents, having extremely high COD and BOD values. Because of the high concentration of organic load, the distillery spent wash is the potential source of renewable energy. Industrial processes create a variety of wastewater pollutants; which are difficult and costly to treat. Wastewater characteristics and levels of pollutants vary significantly from industry to industry. Now-a-days emphasis is laid on waste minimization and revenue generation through by-product recovery. Pollution prevention focuses on preventing the generation of wastes, while waste minimization refers to reducing the volume or toxicity of hazardous wastes by water recycling and reuse. The land application of distillery spentwash often benefits for water pollution control and utilization for agricultural production. Hence, controlled application of spentwash to the land as irrigation water helps in restoring and maintaining soil fertility, increasing soil microflora, improving physical and chemical properties of soil leading to better water retaining capacity of the soil.

Key words: *Spentwash, Microflora, Pollution, Industrial processes, COD, BOD.*

INTRODUCTION

India is a major producer of sugar and its by-products. It is one of the significant exporters of sugar in the world and contributes substantially to economic development [11- 18]. Production of ethyl alcohol in distilleries based on cane sugar molasses constitutes a major industry in Asia and South America. The world's total production of alcohol from cane molasses is more than13 million m^3/annum. The aqueous distillery effluent stream known as spentwash is a dark brown highly organic effluent and is approximately 12-15 times by volume of the product alcohol[9-22]. It is one of the most complexes, troublesome and strongest organic industrial effluents, having extremely high COD (76,000- 1,08,000 mg L^{-1}) and BOD (32,800- 43,200 mg L^{-1}) [10].

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Because of the high concentration of organic load, distillery spentwash is a potential source of renewable energy. The 295 distilleries in India produce 2.7 billion litres of alcohol and generating 40 billion litres of wastewater annually[9]. The enormous distillery wastewater has potential to produce 1100 million cubic meters of biogas. 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 seven times more than the entire Indian population. This massive quantity, approximately 40 billion liters of effluent, if disposed untreated can cause considerable stress on the water courses leading to widespread damage to aquatic life. Irrigation water continues to be the single most important factors dictating the success of crop productivity in arid and semi arid agro-climatic zones. In the past five decades, the water availability has reduced to half and further reduction is fast approaching. This necessitates using every drop of water that can be recycled back to the crop production[19].

ALCOHOL PROCESS DESCRIPTION

BRIEF NOTE ON ALCOHOL MANUFACTURE IN DISTILLERY

Molasses is the mother liquor left out from sugar factory after sugar crystallization, which is the raw material for distillery and it contains about 45 – 50 per cent sugar comprising of disaccharide (Sucrose) and monosaccharide (Glucose and Fructose). The disaccharide present in molasses is first converted into monosaccharides and then converted into Alcohol.

FERMENTATION

Molasses is pumped to fermenters, diluted with water, inoculated with yeast culture and necessary nutrients are added. The fermentation period is about 24 to 30 hours and about 7.5 – 9.5 % alcohol is formed in the fermented wash.

DISTILLATION

After completion of fermentation, distillation of fermented wash is done to recover aqueous alcohol as distillate. Rectification of aqueous alcohol is done to separate concentrated alcohol. The distillery is adopting Multi Pressure Distillation (pressure and vacuum) technique to distill out the **Rectified Spirit (RS) / Extra Neutral Alcohol (ENA)** from the fermented wash.

ETHANOL

Fuel Ethanol is produced from Rectified Spirit by subjecting it in molecular sieve columns to remove the moisture content in it to achieve 99.8% v/v alcohol.

PRODUCTION AND TREATMENT OF DISTILLERY SPENTWASH

For every litre of alcohol, maximum 8 to 12 liters of spentwash is generated. The spentwash contains organic matters and nutrient minerals derived from the sugarcane. The spentwash is **Anaerobically treated in the Digester**. During this anaerobic degradation, the organic matters are converted into Biogas (55% methane) which brings down the BOD value to 6,000 – 7,000 ppm from the original level of about 45,000 ppm. The evolved bio-gas to be used as fuel in the boiler. The treated bio-methanated spentwash is subjected to **Reverse Osmosis (R.O)** membrane filtration to concentrate the spentwash and separate the usable permeate water. Further, the concentrated spentwash is utilized in **Biocomposting** using sugar factory pressmud to produce useful farmland manure, the biocompost.

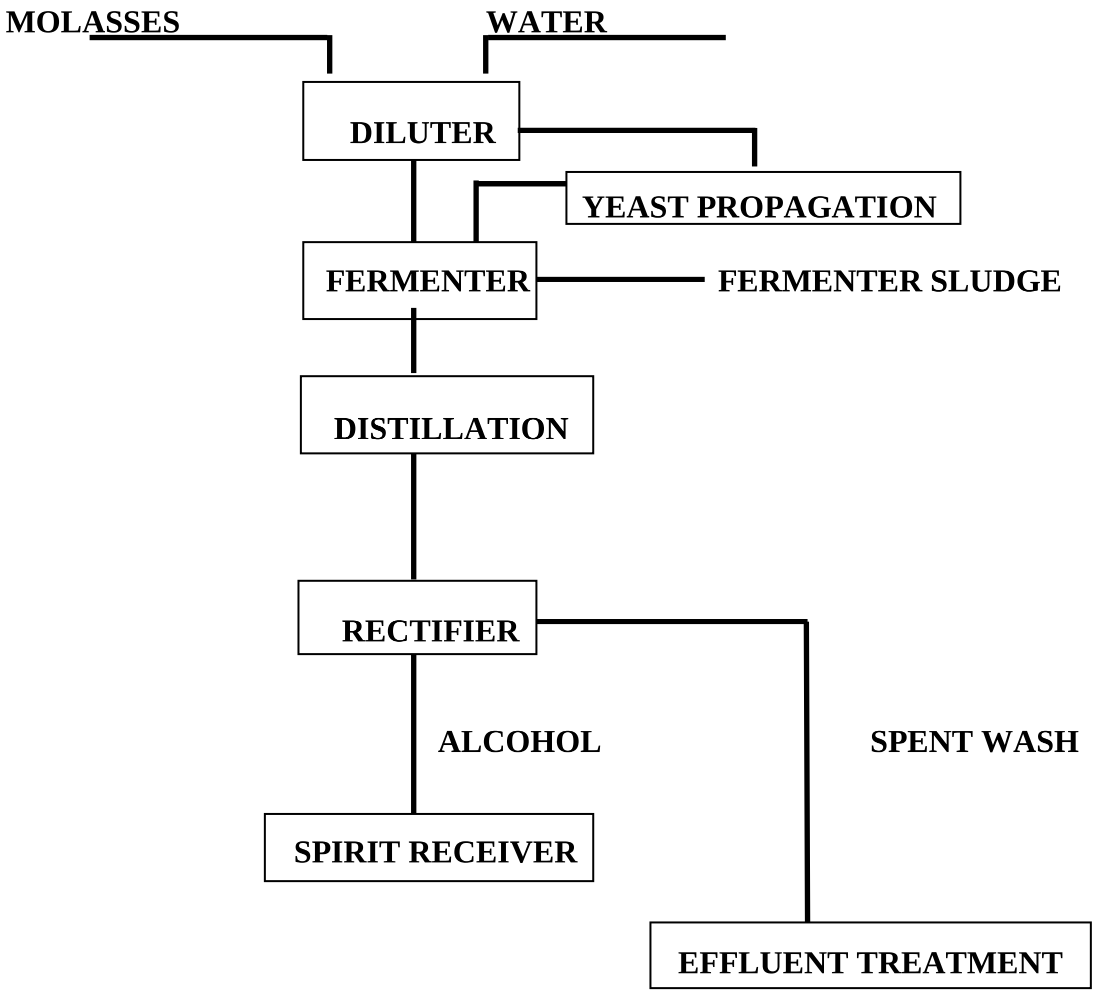

Fig. 1: Flow chart of alcohol production and spentwash treatment

Table 1: Characteristics of distillery bio-methanated spentwash (Ugar Sugar Factory)

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

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

BIOCOMPOSTING PROCESS

In the bio-composting system, the process is carried out on a concrete floor yard by aerobic windrow technology using special aerobic microbial culture. The sugar industry pressmud and Yeast sludge / ETP sludge from distillery are mixed suitably and bio-activated on the concrete floor. The reaction is an exothermic one which helps to evaporate the water content. The necessary windrow moisture for the process is maintained by spraying of RO concentrated spentwash on the composting windrows. Aerotiller machine is used on the windrows to turn the material and uniformly spray the concentrated spentwash on the windrows to keep the process in aerobic condition. The bio-composting process would take about 60 days for completion and the ready bio-compost manure is utilized as farmland manure. Thus, the entire spentwash generated during the alcohol production will be converted into bio-compost manure.

BIO-ENERGY POTENTIAL FROM DISTILLERY EFFLUENTS

In India there are 295 distilleries producing 3.20 billion litres of alcohol generating 45 billion litres of wastewater annually. The enormous distillery wastewater has potential to produce 1200 million cubic meters of biogas. The post methanation wastewater if used carefully for irrigation of agricultural crops can produce more than 85000 tonne of biomass annually. This biogas normally contains 60% methane gas, which is a well-recognized fuel gas with minimum air pollution potential. If this source of energy is tapped, it will fetch additional energy units worth 5 trillion-kilo calories annually. Besides, the Post Methanation Effluent (PME) can provide 2,45,000 tones of potassium, 12500 tones of nitrogen and 2100 tones of phosphorus annually. Thus the manorial potential of effluent can be measured by the fact that one year's effluent can meet the potassium requirement of 1.55 million hectare land, nitrogen requirement of 0.13 million hectare land and phosphorus requirement of 0.025 million hectare land if two crops are taken in a year[2].

Table 2: Annual Bio energy Potential of Distillery Effluent in Various States of India

State	Units	Capacity (M Ltr/Yr)	Effluent (M Ltr/Yr)	Biogas (M m^3)	Total N (tones)	Total Ka (tones)	Biomass (tones)
A P	24	123	1852	50	566	11115	3704
Assam	1	2	24	0.7	7	144	48
Bihar	13	88	1323	35.7	397	7940	2646
Goa	6	15	218	6	65	1304	436
Gujarat	10	128	1919	51.8	576	11511	3838
Karnataka	28	187	2799	75.6	840	16794	5598
M P	21	469	7036	190	2111	42219	14072
Maharashtra	65	625	9367	253	2810	56217	18734
Punjab	8	88	1317	35.6	395	7902	2634
Tamil Nadu	19	212	3178	86	953	1971	6356
U P	43	617	9252	250	2776	55512	18504
W B	6	24	371	10.1	111	22223	742
Rajasthan	7	14	202	3	61	1215	404
Kerala	8	23	343	9.3	103	2064	686
Pondicherry	3	11	165	4.5	50	990	330
Sikkim	1	7	98	5.5	29	585	196
Nagaland	1	2	24	0.7	7	144	48
J & K	7	24	366	11	110	2196	732
H P	2	3	39	1	12	234	78
Haryana	5	41	615	16.6	185	3690	1230
Total	285	2703	40,508	1096.1	12,154	263,070	81016

Source: (BASL, 2012).

PRESENT STATUS OF TREATMENT AND DISPOSAL

Spentwash treatment is proposed by three different routes currently *viz;* (a) Concentration followed by incineration, (b) Anaerobic digestion with biogas recovery followed by aerobic polishing and (c) Direct wet oxidation of stillage by air at high temperature with generation of steam followed by aerobic polishing. All of these processes are capital intensive. The incineration process involves an investment of the order of 400% of the distillery cost, whereas the other two processes along with the secondary treatment require an investment of 200-300% of the distillery cost. The unfavorable economics make it difficult to implement these treatment processes on the plant scale. Because anaerobic digestion and wet oxidation are less expensive, these alternatives are more attractive. However, there is a need for development of a suitable process with lower investments and higher energy recovery. Many distilleries in India are allowing their effluent for application on land as direct irrigation water, spent wash cake and spent wash-press mud compost. The advances manifesting the possibilities of energy conservation are also discernible in the case of distilleries. The methane gas generated in the digesters is used as a fuel to compensate the energy needs of the industry. A general estimate suggests that the cost of an anaerobic biological digester is recovered within 2-3 years of installation because of substantial saving of coal and other fuels.

DISTILLERY WASTE WATER UTILISATION IN AGRICULTURE

Application of industrial wastes as fertilizer and soil amendment has become popular in agriculture. Irrigation water quality is believed to have effects on the soil and agricultural crops. Being very rich in organic matters, the utilization of distillery effluents in agricultural fields creates organic fertilization in the soil which raises the pH of the soil, increases availability of certain nutrients and capability to retain water and also improves the physical structure of soil. Mostly the distillery wastewaters are used for pre-sowing irrigation. The post-harvest fields are filled with distillery effluents. After 15-20 days, when the surface is almost dried, the fields are tilled and the crops are sown and subsequent irrigation is given with fresh water. However, the effluent is diluted 2-3 times before application on crops[19]. Apparently, the irrigation with distillery wastewater seems to be an attractive agricultural practice which not only augments crop yield but also provides a plausible solution for the land disposal of the effluents. One cubic meter of methanated effluent contains nearly 5 kg of potassium, 300 grams of nitrogen and 20 grams of phosphorus. If one centimeter of post methanation effluent is applied on one hectare of agricultural land annually, it will yield nearly 600 kg of potassium, 360 kg of calcium, 100 kg of sulphates, 28 kg of nitrogen and 2 kg of phosphates. The distillery effluent contains 0.6 to 21.5 per cent potash as K_2O, 0.1 to 1.0 per cent phosphorus as P_2O and 0.01 to 1.5 per cent Nitrogen [22]. [8]conducted an experiment on chemical composition of untreated distillery spentwash and primary treated distillery effluent. There was a considerable change in pH of untreated and primary treated spentwash with acidic (3.8) and alkaline (8.0) reaction, respectively. Electrical conductivity of untreated and primary treated spentwash was 30.0 and 32.5 dS m^{-1}, respectively. Total solids content in untreated and primary spentwash was 90,000 and 81,000 mg L^{-1}, respectively.

It contains high amount of nutrients such as nitrogen, phosphorous, potassium, sulphur and a large amount of micronutrients. The land application of distillery spent wash often benefits water pollution control and utilization for agricultural production[9]. So it can be applied directly to the land as irrigation water as it helps in restoring and maintaining soil fertility, increasing soil microflora, improving physical and chemical properties of soil leading to better water retaining capacity of the soil. The effluent is ideal for sugarcane, maize, wheat and rape seed production [6]. It has been reported that waste water from different industries produced continuously could cater the needs of irrigated crops [10]. Thus the distillery spent wash will not only prevent waste from being an environmental hazard but also served as an additional potential source of fertilizer for agricultural use. Diluted spent wash increased the growth of shoot length, leaf number per plant, leaf area and chlorophyll content of peas. It was also reported that the water holding capacity, cation exchange capacity, increases the availability of nitrogen, phosphorus, potassium, copper, zinc, iron, manganese; but with reduced biochemical oxygen demand (BOD) with addition of sewage sludge to a course textured sandy and calcareous soil. An increase in the soil organic matter by 1% with sugar factory effluent applied to soils was observed in Cuba (Valdes *et al.*, 1996). Many workers reported an adverse effect of higher concentration of different types of industrial effluents in the growth rate of different crops[7-13-17].

Table 3: Effect of spentwash on agricultural crops

Response of crop	Reference
The application 5 lakh liters ha^{-1} of spentwash to sodic soil improved grain yield 50 times dilution increased yield of rice crop	Rajukkannu and Manickam (1996)
Application of spentwash Improved cane yield upto 250 m^3 ha^{-1} per acre and significantly cane yield increased @ 375 m^3 ha^{-1}	Baskar *et al.* (2001)
150 m^3 ha^{-1} improved cob length and grain yield	Mallika (2001)
Groundnut 40-50 times dilution increased shelling per cent, oil and crude protein content.	Devarajan *et al.* (1998)
Fodder grass 37.5 m3 ha-1 improved the biomass of Cumbu Napier Hybrid	Banulekha (2007)

The land application of distillery spentwash often benefits water pollution control and utilization for agricultural production [11]. So it can be applied directly to the land as irrigation water as it helps in restoring and maintaining soil fertility, increasing soil microflora, improving physical and chemical properties of soil leading to better water retaining capacity of the soil. The effluent is ideal for sugarcane, maize, wheat and rape seed production 6. It has been reported that waste water from different industries produced continuously could cater the needs of irrigated crops [15]. Thus the distillery spent wash will not only prevent waste from being an environmental hazard but also served as an additional potential source of fertilizer for agricultural use. Diluted spent wash increased the growth of shoot length, leaf number per plant, leaf area and chlorophyll content of peas [21]. It was also reported that the water holding capacity, cation exchange capacity, increases the availability of nitrogen, phosphorus, potassium, copper, zinc, iron, manganese; but with reduced biochemical oxygen demand (BOD) with addition of sewage sludge to a course textured sandy and calcareous soil [1]. An increase in the soil organic matter by 1 per cent with sugar factory effluent applied to soils was observed in Cuba. Many workers reported an adverse effect of higher concentration of different types of industrial effluents in the growth rate of different crops. There have been studies related to the application of distillery spent wash to agriculture in India as well as other parts of the world. Spentwash at the rate of 35-50 m^3 ha^{-1} was recommended as optimum dose for higher sugarcane yield in Brazil and in Australia.

The distillery effluent can be conveniently used as source of irrigation in crop production. But, it has to be used judiciously because of high organic and chemical load [3]. He cautioned that continuous usage of the effluent on the same land might result in development of sodicity, if the soils are ill drained. [14-9-10] concluded that non-judicious use of spentwash adversely affected crop growth and soil properties by increasing soil salinity. Salinity causes reduction in leaf area as well as the rate of photosynthesis, which together result in reduced crop growth parameters. Also, high concentration of salt was reported to slow down or stop root elongation and reduction in root production. In the initial years, the beneficial use of spentwash to the sugarcane was due to its nutritive and growth promoting effect. However, long-term use of spentwash not only polluted the environment but also resulted in the accumulation of salts in the root zone. Soil salinity has been considered a limiting factor on sugarcane productivity in arid and semi-arid regions. Soil saturated extract (ECe) conductivities greater than 1.7 dS m^{-1} was reported to decrease yield[16].

In Sau Paulo, Brazil, the crop productivity was 2-10 times higher as compared to the untreated lands. Distillery spent wash was found to increase the cane yield in sugarcane and decrease the potassium fertilizer need in a study conducted by Caroni Research Station, Trinidad and Tobago. In Philippines, spent wash application at the rate of 80-240 m^3 ha^{-1} in addition to chemical fertilizers increased the cane yield by 10- 12 per cent and sugar yield by 13-16 percent compared to normal irrigation. In Cuba, spent wash application at the rate of 90-150 m^3 ha^{-1} increased the potassium content of the soil, with increased cane yield and sugar recovery [12]. In a study conducted in Kiev, Ukraine has shown increased yield of grasses, maize and fodder beet by 45-100 % using distillery effluent. In India, extensive studies on distillery spent wash have been carried out successfully with respect to various crops in different agro-climatic regions[12-15-5].

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