A REPORT

ON

OPPORTUNITIES FOR GREEN CHEMISTRY INITIATIVES: MOLASSES BASED DISTILLERIES

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Vigyan Bhawan Annexe, New Delhi - 110 011
2014

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PREFACE

The human kind, in the developed and the developing countries alike - is facing environmental challenges. The mitigation of these challenges is being addressed through research and technology development all over the world. India cannot be an exception to this. Therefore, several attempts are being made at public and private institutions for tackling the issues emanating from excessive use of natural resources to meet the ever demanding needs of an increasing population. Therefore, the Government of India and rightly so, has been actively pursuing developments, following recommendations of committees comprising distinguished experts.

One of the imminent solutions that were recognised in the recent past has been in the form of introducing “Green Chemistry Approach” to pave the way for modifying existing processes and technologies and replace them with environmental-friendly ones. A predominant objective is to encourage processes and technologies that minimize the generation of hazardous wastes and of large volumes of effluents in order to enable the industry to approach, the “zero discharge” paradigm for such pollutants to the environment.

One such source of environmental pollution recognised over the years has been the waste from sugar and distillery industry in the country. This section of the industry is vital for the commercial health of the country as a large population segment throughout the country is dependent on the agricultural produce which goes into this sector as raw material. Since the industry in this sector depends predominantly on sugarcane as a source of feed stock, it is but natural that the ultimate by-product of this industry is cane molasses, which is generated after the sugar is extracted out of the concentrated cane juice as a result of several physicochemical processes. However commercial importance of this industry, though paramount, does not overemphasize a known fact that distilleries are among the most polluting industries identified and categorized by the Central Pollution Control Board (CPC). In addition to that, consumption of a large quantity of processed water and disposal of enormous volumes of effluent is a major challenge for this sector. The office of the Principal Scientific Adviser (PSA) to the Government of India has rightly identified this sector as one that could be studied more closely and to find ways and means of using “Green Chemistry” approach for this burning issue. Therefore, the office of the PSA constituted an Expert Committee to look into the Green Chemistry sector and, within that committee, an Expert Sub-Committee was constituted to study and assess the unit operations, including up- and down- stream processes of the Indian distilleries and suggest innovative and commercially viable ideas to find tangible solutions to the identified problems.

The Sub-Group visited six representative distilleries (including one distillery having grain-based plant along with molasses), spread across the country, in Uttar Pradesh, Tamil Nadu and Maharashtra covering one of the oldest distilleries, corporative distilleries attached with sugar mills, stand-alone distilleries as well as a well-equipped distillery having implemented several schemes of process integration and energy economy. The visits were extremely useful in understanding the problems and finding some of the solutions to address the problems.

Based on the data collected, the Sub-Group was able to put together the current status of Indian molasses-based distilleries, current technologies being used by the plants for disposal of waste and the major issues to be addressed. The Sub-Group has come out with a set of recommendations and potential R&D interventions as well as partners for the industry to collaborate.

As Chairman of the Sub-Group, I very much hope that this report will pave the way for collaborations between industry and R&D institutions, IITs and Universities to take up joint R&D programmes for technological interventions to the identified problems of this sector.

I would like to thank the Office of PSA for entrusting this responsibility on me and the members of Green Chemistry Core Group for their valuable input. I would like thank all the members of the Sub-Group for distillery sector, who had put in considerable efforts for industrial visits and drafting the report. Special thanks are due to Office of PSA and Vasantdada Sugar Institute, Pune for their contributions.

Dr. G.N. Qazi

LIST OF ABBREVIATIONS

AA : Anhydrous Alcohol

AnMBR : Anaerobic Membrane reactor

AOP's : Advanced oxidation processes

ATFE : Agitated Thin Film Evaporator

BMSW : Biomethanated Spentwash

BOD : Biological oxygen demand

CETP : Common Effluent Treatment Plant

CNG : Compressed Natural Gas

CO_2 : Carbon Dioxide

COD : Chemical oxygen demand

CLA : Controlled Land Application

CMS : Condensed Molasses Soluble

CREP : Corporate responsibility for environment protection

CSTR : Continuous Stirred Tank Reactor

CPCB : Central Pollution Control Board

EBP : Ethanol Blending Programme

ED : Extractive Distillation

EDTA : Ethylene Diamine Tetra-acetic Acid

ENA : Extra Neutral Alcohol

FC : Forced Circulation

FF : Falling Film

F/N : Fermentable to Non-fermentable

FFR : Fixed Film Reactor

FOC : Fusel Oil Concentration

FS : Fermentable Sugars

GoI : Government of India

HDPE : High-Density Polyethylene

IICT : Indian Institute of Chemical Technology

IIT : Indian Institute of Technology

KLPD : Kilo Liter per Day

KL	: Kilo Liter
MEE	: Multiple Effect Evaporation
MFC	: Microbial Fuel Cell
MoEF	: Ministry of Environment & Forests
MSW	: Municipal Solid Waste
MWCO	: Molecular Weight Cut Off
NBP	: National Biofuel Policy
NIO	: National Institute of Oceanography
ODS	: Ordinary Denatured Spirit
PAHs	: Polycyclic Aromatic Hydrocarbons
PCTP	: Process Condensate Treatment Plant
PMC	: Press Mud Cake
PSA	: Principal Scientific Adviser
R & D	: Research & Development
RO	: Reverse Osmosis
RS	: Rectified Spirit
SDS	: Special Denatured Spirit
SPCB	: State Pollution Control Board
SW	: Spent Wash
TDS	: Total Dissolved Solids
TMC	: Total Microbial Count
TOVA	: Total Organic Volatile Acidity
TRS	: Total Reducing Sugars
TSS	: Total Suspended Solids
TVR	: Thermo-Vapour Recompressors
UASB	: Upflow Anaerobic Sludge Blanket
UFS	: Unfermentable Sugars
UV	: Ultra Violet
v/v	: Volume by Volume
ZLD	: Zero Liquid Discharge

1.0 INTRODUCTION

India is the second largest producer of sugar and fourth largest producer of alcohol in the world. It is also the leading producer of alcohol in the South-East Asian region with about 65% of the share. The major raw material for Distilleries is the Molasses, a waste byproduct of sugar mills, and grains. Sugarcane, the raw material for sugar mills, is one of the leading crops of the country. Consequently, agricultural and rural economy is significantly dependent on the sugarcane farming and associated industries. Besides, sugar mills, distilleries and associated industries provide large employment potential and contribute substantially to economic development. It is estimated that the revenue contribution to government (both state and central) by sugar industry is about Rs.6000-6500 Crores per annum, while the figure for distillery (including bottling activities) is about Rs. 2.5-3.0 lakh Crores/annum. It is apparently the 2^{nd} largest revenue contributor per annum for the government.

Molasses, a byproduct of sugar industries is the major raw material for distilleries in India. A Few distilleries use grains such as sorghum, corn, rice, wheat, millet etc., as raw materials. There are about 356 molasses based distilleries and about 110 grain based distilleries in the country. Press mud and Spent Wash are the main waste materials resulting from sugar and distillery industries, respectively. Although the value of press mud as organic manure has been well recognized, disposal of Spent Wash having high COD & BOD and salt load is still a challenge. In the recent past there have been significant developments in treatment of Spent Wash, including adoption of anaerobic digestion where the Spent Wash is subjected to bio-digestion to produce methane that supplements the energy needs of the distillery as boiler fuel. Still, disposal of the large volume of bio-methanated Spent Wash and / or raw Spent Wash (about 10 – 12 KL/KL of Alcohol) is a serious concern of the distilleries. Central Pollution Control Board (CPCB) has also stipulated very stringent norms for its proper disposal as the spent wash may affect the land surface, particularly the physical, chemical and biological properties of soils.

Sugar industry and distilleries are mutually dependent and in a way are inseparable. Thus, an integrated approach, including Green Chemistry Principles, is the need of the hour to address the environmental issues of these industries. Such an approach will help in meeting the stringent norms of effluent disposal, besides achieving higher energy and product efficiencies.

1.1 Green Chemistry Approaches and Initiatives of Office of PSA to GoI

Recognizing the importance of the Green Chemistry approaches in Chemical processes and its likely impact on the environmental issues, the Office of PSA to the GoI has chosen Green Chemistry as one of the areas of focus for sustained R & D interventions in the chemical industry. Green chemistry approach is a philosophy of chemical research and engineering that encourages the design of products and processes which minimize the use and generation of hazardous pollutants. It combines critical elements of environmental improvement, economic performance, and social responsibility in addressing environmental problems as well as industry competitiveness. Accordingly, the Office of PSA to GoI constituted a Core Group to address specific issues of Chemical Industry. The composition of the committee is as follows:

- Dr. G.D. Yadav, Vice Chancellor, ICT, Mumbai — Co-Chairman
- Dr. J.S. Yadav, Former Director , IICT , Hyderabad — Co-Chairman
- Prof. Devang Khakhar, Director, IIT-Bombay, Mumbai — Member
- Dr. P.K. Ghosh, Director, CSMCRI, Bhavnagar — Member
- Chairman, CPCB, Delhi — Member
- Sh. Samir S. Somaiya, CMD, Godavari Bio-Refineries Ltd., Mumbai — Member
- Dr. D. Yogeswara Rao, Adviser, O/o PSA to GoI, New Delhi — Member-Secretary

In evolving the programme, the committee decided to follow a four pronged approach viz (i) sectorial project~~s~~ approach (ii) industry specific projects (iii) generic knowledge projects and (iv) new knowledge generation suited for these sectors. After a detailed discussion, the committee, as a first measure identified five sectors of Indian Chemical

Industry for developing a strategy and roadmap for R & D interventions. These are (i) Paper & Pulp (ii) Distillery (iii) Dyes and Dye intermediates (iv) Drugs and Pharmaceuticals, and (v) Bulk inorganic chemicals.

Detailed discussions were held with specific industrial sectors to arrive at a common and collective strategy. The major issues emerged during the discussions with leaders in the distillery sector are: (i) technological inputs leading to reduction in water consumption, (ii) in process energy management, (iii) multidimensional technical inputs to the technology of bio-composting of Spent Wash and value addition for soil health improvement (iv) R&D efforts leading to agricultural application of Spent Wash or bio-methanated Spent Wash. With a view to understanding the issues in detail and to identify the opportunities for R&D intervention, it was decided to undertake a scoping study of the sector.

1.2 Constitution of the sub-group of experts

In line with the decision, a small sub-group of experts was constituted to carry out a scoping study with the following composition:

i.	Dr. G. N. Qazi, Vice-Chancellor, Jamia Hamdard, New Delhi	Chairman
ii.	Prof. Subhas Chand, Emeritus Professor, Dept. of Biochemical Engg, IIT-Delhi, New Delhi	Member
iii.	Mr. Shivajirao Deshmukh, Director General, VSI, Pune	Member
iv.	Mr. V. N. Raina, Director General, AIDA, New Delhi	Member
v.	Dr. A. G. Rao, Scientist, BEEC Division, IICT, Hyderabad	Member
vi.	Dr. B. Subba Rao, President-EPRF, Sangli, Maharashtra	Member
vii.	Representative, CPCB	Member
viii.	Dr. S. V. Patil, Head and Technical Adviser, Department of Alcohol Technology, VSI, Pune	Special Invitee
ix.	Dr.D. Yogeswara Rao, Adviser, O/o of PSA to GoI	Special Invitee
x.	Dr. Manju Gerard, Scientist E, O/o of PSA to GoI, N Delhi	Member Secretary

Terms of Reference for the expert sub-group were as follows:

i. To undertake a scoping study of Distillery Industry covering all the existing problems regarding environment concerns;

ii. To prioritize the concerns in order of preference;
iii. To suggest possible R & D interventions to integrate concerns;
iv. To identify the researchers from various institutes and industry who can take up the R & D activity; and
v. Any other activity as assigned by the core group.

1.3 Visit of the expert sub-group to distilleries

The expert sub-group visited six representative distilleries (including one distillery having grain based plant along with molasses) across the country to understand the existing problems related to environmental concerns in consonance with the identified major issues during the interaction with the stakeholders. These visits were carried out during the period May 2013 to March 2014, in the various states i.e Uttar Pradesh, Tamil Nadu and Maharashtra. The committee visited the distilleries having production capacity ranging from 60 to 120 KLPD and using mostly molasses as raw material. During the visits the committee covered one of the oldest distilleries, distilleries attached with sugar mill, stand-alone distilleries as well as a well-equipped distillery having implemented several schemes of process integration and energy economy. These distilleries produce alcohol for beverages, extra neutral alcohol as well as fuel ethanol.

The report on molasses based distilleries by the expert sub-group is presented in the following sections.

2.0 STATUS OF DISTILLERIES IN INDIA

2.1 State-wise distribution of Molasses based distilleries & installed capacities

As indicated earlier, there are about 356 molasses based distilleries in the country. Among these, 141 distilleries are attached to Sugar Industry. The state wise numbers of Molasses distilleries in India is given in Table 1.

Table 1: State wise numbers of Molasses Distilleries in India (2012-13)

S.N.	State	No. of Distilleries		Annual Licensed Capacity (Million Liters)		Annual Installed Capacity (Million Liters)	
		Total	Affiliated to sugar factories	Total	Affiliated to sugar factories	Total	Affiliated to sugar factories
1	Andhra Pradesh	29	12	203.364	109.750	193.559	105.345
2	Aasam	0	0	0	0	0	0
3	Bihar	9	4	79.950	28.950	79.950	28.950
4	Chattisgarh	2	0	36.000	0	1.800	0
5	Daman	4	0	17.160	0	17.160	0
6	Goa	5	0	4.044	0	5.306	0
7	Gujrat	15	9	168.710	81.260	171.050	83.600
8	Haryana	9	1	85.950	4.550	85.950	4.550
9	Himachal Pradesh	3	0	12.486	0	13.600	0
10	Jammu & Kashmir	5	0	31.949	0	31.749	0
11	Karnataka	40	10	387.089	122.169	374.514	110.369
12	Kerala	10	2	28.328	4.418	23.730	5.520
13	Madhya Pradesh	18	0	298.576	0	308.051	0
14	Maharashtra	81	59	899.272	720.945	849.222	685.545
15	Nagaland	1	0	1.350	0	1.350	0
16	Odhisha	10	3	18.992	3.720	19.005	3.720
17	Puducherry	4	0	22.900	0	11.700	0
18	Punjab	13	4	287.479	36.120	256.847	36.060
19	Rajasthan	9	2	101.700	11.400	93.250	11.400
20	Sikkim	2	0	1.971	0	3.504	0
21	Tamilnadu	26	11	410.150	222.350	416.425	204.350
22	Uttar Pradesh	53	23	1227.374	618.000	1137.482	618.000
23	Uttarakhand	3	1	99.190	15.000	99.190	15.000
24	West Bengal	5	0	35.300	0	35.300	0
All India		356	141	4459.284	1978.632	4229.694	1912.409

(Source – August 2014; Vo.45, No.12 Cooperative Sugar)

The total installed capacity of molasses based distilleries in the country is about 4230 million liters per annum. The average capacities of Indian molasses based distilleries ranges between 30 to 60 KLPD. There are very few distilleries above 100 KLPD capacities and the largest distillery capacity in the country is 420 KLPD.

2.2 Alcohol production and Demand

India is the fourth largest producer of alcohol in the world and there has been a steady increase in its production over the last 15 years. The production doubled from

887.2 million liters in 1992-93 to 1,654 million liters in 1999-2000 and almost trebled to 2300 million liters by 2007-08. The present average alcohol production from molasses in the country is around 2500 million liters per annum. However, wide variation in ethanol production is observed over the last few years, due to the fluctuation in sugarcane production.

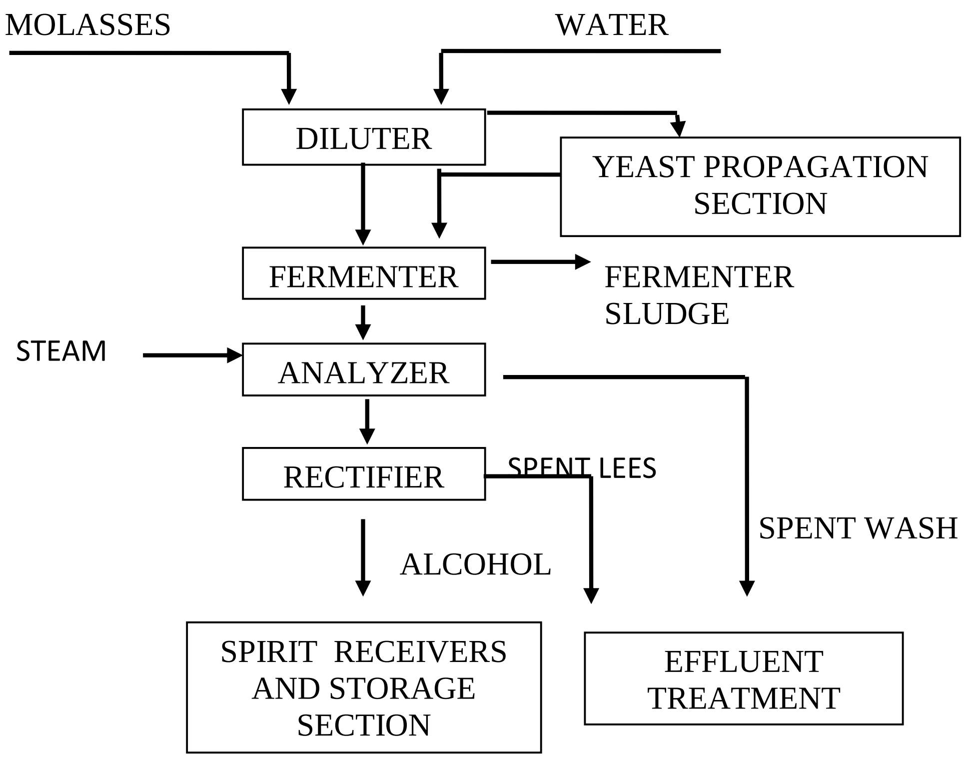
In India alcohol is largely produced in the form of either i) Rectified Spirit (RS) (95 to 96 % v/v ethanol) which is mainly used for industrial applications in the form of Ordinary Denatured Spirit (ODS) or Special Denatured Spirit (SDS), ii) Extra Neutral Alcohol (ENA) (96 % v/v ethanol) mainly used for manufacture of potable liquors and iii) Fuel Ethanol or Absolute Alcohol (AA) (99.8 % v/v) mainly used for blending with petrol.

Present consumption of ethanol in the potable, Chemical and other sectors (excluding for petrol blending) is about 1800 million liters per annum. Therefore, the net availability of ethanol for Fuel blending is about 700 million liters per annum. However, at the current levels of petroleum consumption, Ethanol requirement for 5% blending is about 1100 million liters per annum and for 10% blending it is 2200 million liters per annum. It is learnt that Oil companies are able to provide about 440 million liters of ethanol as against the 1100 million liters target for the five per cent mix. The National Biofuels Policy envisages the blending of alcohol to be enhanced to 20% by 2017. If this policy is to be implemented in letter and spirit, the demand for alcohol is likely to be increased significantly in the country. It may be noted that the alcohol production from grain based distilleries is largely used for potable purposes.

Before the introduction of Ethanol Blended Petrol (EBP) by the Government, ethanol had two major consumers – the liquor industry (country liquor & IMFL), which consumed 55-60 per cent of the production, and the chemical industry that consumed 40-45 per cent. These sectors have also been stating that ethanol availability is not sufficient to meet their current needs. The blending programme might therefore force the country to import ethanol, which may be uncompetitive. Some state governments have also stepped in to support these industries by restricting movement of molasses or ethanol.

3.0 THE MANUFACTURING PROCESS

Manufacture of alcohol comprises broadly 3 sections, viz. (i) Fermentation (ii) Distillation and (iii) Effluent treatment and disposal. Typical alcohol manufacturing process from molasses is illustrated in following process flow diagram.



3.1 Indian molasses

The main raw material, Molasses, is one of the byproduct of sugar manufacture. Molasses production is approximately 3.5 to 4.5 % of sugar cane crushed. The typical characteristics of Indian cane molasses is given in table 2. The quality of Indian molasses is inferior as compared to the molasses available in countries such as Brazil and Australia and also varies widely within the country. For example the Total Reducing Sugars (TRS) content of the molasses, that determines the quantity of product alcohol per ton of molasses, varies between 42 to 52%. This is because of the fact that Indian Sugar Mills typically produce plantation/ white sugar (as against raw sugar produced in other countries) that involves double sulphitation route and three boiling system to exhaust the molasses.

Table 2: Typical characteristics of Indian cane molasses

Sr. No.	Particulars	Test values
1	^{o}Brix	86.00-90.00
2	Moisture content (%)	15.00-21.50
3	Total suspended solids (%)	3.50-7.00
4	Total dissolved solids (%)	72.00-82.00
5	pH of molasses	4.20-4.50
6	Total reducing sugars (%) by mass	42.00-52.00
7	Total fermentable sugars (%) by mass	40.00-48.00
8	Calcium content (gms/100^{0} brix)	1.80-2.75
9	Fermentable/Non fermentable ratio (F/N)	1.50-2.00
10	Carbonated ash (%)	8.00-12.00
11	Sulphated ash (%)	11.00-15.00
12	Nitrogen (% of molasses)	0.700-1.200
13	Potassium (% of ash)	15.00-16.50
14	Sodium (% of ash)	0.90-0.95
15	Chlorides (% of ash)	13.00-14.00
16	Phosphates (% of ash)	0.25-0.35
17	Total organic volatile acids (mg/lit.)	2500-7000

3.2 Fermentation processes

Alcoholic fermentation is the process in which sucrose and reducing sugars (i.e. glucose and fructose) present in molasses are converted into ethyl alcohol and carbon dioxide by the action of several enzymes present in the "Yeast". However, all the sugars cannot be converted into alcohol. Some sugars get converted to products other than ethyl alcohol such as yeast cell biomass, glycerol, succinic acid and other minor by-products leading to decrease in ethanol yield. Typically, 1 MT of molasses containing 47 % Fermentable Sugars (FS) (sucrose + glucose + fructose) yields 265 to 270 liters of RS. As mentioned earlier, the fermentable sugar content of the molasses plays an important role in alcohol yield.

The industry employs different types of fermentation processes and these are briefly described below:

Batch fermentation process is characterized by higher residence time for reaction to reach completion and more by-product formation. Fresh yeast is required for each batch resulting in low fermentation efficiency. During the process of batch fermentation, parameters such as sugar concentration, alcohol concentration, cell count etc. vary with respect to time. Therefore, batch fermentation process is characterized by "Unsteady State Conditions". This was the traditional method used by Indian distilleries during 1960 to 1980s.

In **Continuous fermentation**, process substrate flows in to fermenter and fermented wash flows out of the fermenter continuously. As opposed to batch fermentation, parameters such as alcohol concentration, sugar concentration, pH and cell count etc. remain constant with respect to time. Thus, continuous fermentation process is characterized by "Steady State Conditions". Because of its many advantages like continuity of operation, higher efficiency, consistent performance over a long period and ease of operation, many modern ethanol production plants have adopted this technology. However, continuous fermentation systems require good quality of molasses and are susceptible to contamination. **Cascade continuous** fermentation system with and without yeast recycle as well as **Biostill continuous** fermentation system employing osmophilic yeast, ***Schizosaccharomyces pombe,*** are in operation in Indian distilleries.

In **Fed-batch fermentation** process the substrate feeding rate is the only manipulated variable. The regulation of the substrate concentration in fermenter is most effective in overcoming effects such as substrate inhibition, product inhibition, initial load of contamination in molasses etc. During the process of fed-batch fermentation, parameters such as sugar concentration, alcohol concentration, cell count etcetera also vary with respect to time. The advantages of fed-batch fermentation include tolerance to inferior quality of molasses, higher alcohol concentration in fermentation broth and reduction in spent wash generation.

All the above mentioned fermentation technologies are used in different distilleries in the country.

Many distilleries in the country are now trying to use spent wash recycle system with a view to reducing the water requirement for molasses dilution and final effluent volume generation. However, it is learnt that spent wash recycle can inhibit/ retard fermentation process and affect the final product quality, particularly when alcohol is supposed to be used for potable purpose.

3.3 Distillation Processes

Two types of distillation systems are usually employed in distilleries. These are:

Atmospheric pressure distillation system: This process separates alcohol from fermented wash and concentrates it to 95-96 % (v/v), called as RS. It employs degasifying cum analyzer column and Rectification cum exhaust column. In this distillation, separation of components is carried out close to atmospheric pressure. The distillation columns consist of number of bubble cap plates where wash is boiled and alcoholic vapors are separated and concentrated on each plate stage by stage.

Multi-pressure distillation system (MPR): MPR distillation is based on the concept of heat integration in which vapors generated in one column are used to drive other column. MPR system for production of RS consists of distillation columns namely – Degasifying cum analyzer column, Pre-rectification column, Rectification cum exhaust column and Fusel Oil Concentration (FOC) column. On the other hand, MPR distillation system for production of ENA consists of distillation columns namely – Degasifying cum analyzer column, Pre-rectification cum Exhaust column, ED/Purifier Column, Rectifier cum Exhaust column, Recovery/FOC and Simmering Column. The major advantages of multi-pressure distillation system are i) Reduced steam consumption, ii) Reduced SW generation, iii) Improved alcohol quality and iv) reduced scaling problem in analyzer column.

3.4 Fresh water consumption in distilleries

Water is required for dilution of molasses during fermentation, dilution of spirit during distillation (extractive distillation), for generation of steam, as make-up water in cooling towers as well as for non-process application such as for pump gland cooling, vacuum pump, floor and fermenter washing etc. Due to variations in the process as well as quality of raw material (molasses), the total fresh water consumption range from 9.0 to 21.0 liters per liter of alcohol production. As per the CPCB norms, total fresh water consumption allowed in molasses based distilleries is 15.0 liters per liter of alcohol production.

With latest technologies of fermentation, distillation, reverse osmosis (RO), multiple effect evaporation (MEE) systems and condensate/low strength waste water treatment technologies, the fresh water consumption in molasses based distilleries was brought down considerably. Typical fresh water consumption in a conventional and a modern distillery plants is given in the tables 3 and 4, respectively.

Table 3: Water Balance for 60 KLPD Distillery

(Cascade fermentation & Atmospheric distillation)

Sr No.	Section	Water Requirement (M^3/day)	Recycle Quantity (M^3/day)	Actual fresh water consumption (M^3/day)
i	Water consumption, KL/KL of alcohol production	**17.12**	**3.46**	**13.66**

(Source: Vasantdada Sugar Institute, Pune)

Table 4: Water Balance for 120 KLPD Distillery

(Biostil fermentation & MPR distillation with integrated evaporation)

Sr No.	Section	Water Requirement (M^3/day)	Recycle Quantity (M^3/day)	Actual fresh water consumption (M^3/day)
i	Water consumption, KL/KL of alcohol production	**22.96**	**14.61**	**8.35**

(Source: Vasantdada Sugar Institute, Pune)

3.5 Effluent generation

Molasses based distilleries consume significant quantities of fresh water and generate large volumes of Spent Wash (vinasse) having very high pollution load. Depending upon the technology and quality of molasses, the spent wash generation can vary from 7.0 to 15.0 liters per liter of alcohol produced. The general characteristics of spent wash generated by batch, cascade continuous and biostil continuous fermentation based distilleries are given in the table 5.

Table 5: General raw spent wash characteristics

Sr. No.	Parameter	Batch process	Cascade continuous process	Biostil continuous process
1	Volume of SW generated in L/L Alcohol	13-15	10-12	7-8
2	Colour	Dark brown	Dark brown	Dark brown
3	pH	3.7-4.5	4.0-4.3	4.0-4.2
4	COD	80,000-1,10,000	1,10,000-1,30,000	1,40,000-1,60,000
5	BOD	45,000-50,000	55,000-65,000	60,000-70,000
6	Total Solids Total Volatile Dissolved Inorganics	90,000-1,20,000 60,000-70,000 30,000-40,000	1,30,000-1,60,000 60,000-75,000 35,000-45,000	1,60,000-2,10,000 80,000-90,000 60,000-90,000
7	Chlorides	5,000-6,000	6,000-7,500	10,000-12,000
8	Sulphates	4,000-8,000	4,500-8,500	8,000-10,000
9	Total nitrogen	1,000-1,200	1,000-1,400	2,000-2,500
10	Potassium	8,000-12,000	10,000-14,000	20,000-22,000
11	Phosphorus	200-300	300-500	1,600-2,000
12	Sodium	400-600	1,400-1,500	1,200-1,500
13	Calcium	2,000-3,500	4,500-6,000	5,000-6,500

Note: All values from S. No. 4 -13 are in mg/L. The SW characteristics mentioned above are general in nature and vary from region to region depending on molasses quality.

SW has very high BOD, COD and inorganic substances such as chlorides, sulphates, phosphates, sodium, potassium and calcium. Although minor in quantities, the compounds like melanoidines, caramel, polyphenols and variety of sugar decomposition products such as anthocyanins, tannins and different xenobiotic compounds in effluents are recalcitrant in nature. The unpleasant odour of the effluent is due to the presence of skatole, indole and other sulphur compounds, which are not effectively decomposed during fermentation and distillation. High COD, total nitrogen and phosphate content of spent wash can result in eutrophication of natural water bodies. Further, the highly coloured compounds of the spent wash reduce sunlight penetration in water bodies, which in turn decrease both photosynthetic activity and dissolved oxygen concentration affecting aquatic life.

3.6 Biomethanted Spent wash

As the Spent wash generated in the distilleries have high potential to produce methane, it is subjected to anaerobic digestion for methane recovery. The process of biomethanation is now well-engrained in distilleries. Commonly used reactor systems are anaerobic fixed film reactor (AFFR), up-flow anaerobic sludge blanket reactor(UASB), continuous stirred tank reactor(CSTR) and mesophillic & thermophillic reactor. The post methanation effluent i.e. biomethanated spent wash is also characterized by high BOD and COD, intense brown colour and high salt levels apart from being rich in plant nutrients. Though the biomethanation process brings down the BOD load from 50,000mg/l (in raw spent wash) to 5000-8000 mg/l, due to their high organic load and salts further treatment is still required for safe disposal. The characteristics of bio-methanated spent wash is given in table 6.

Table 6: Typical Characteristics of Bio-methanated spent wash Discharged from Indian Distillery

Sr. No.	Parameters	Bio-methanated spent wash
1	pH	7.0-7.5
2	COD	25000-35000
3	BOD	5000-8000
4	Total solids	35000-40000
5	Total volatile solids	6000-7500
6	Inorganic dissolved	25000-35000
7	Chlorides	5000-6000
8	Sulfates	2000-5000
9	Total nitrogen	1000-1200(1.0 kg/m^3)
10	Potassium	8000-10000 (9 kg/m^3)
11	Phosphorus	800-1200 (0.8 kg/m^3)
12	Sodium	600-1200(1.0 kg/m^3)
13	Calcium	4000-5000(4.5 kg/m^3)

Note: All the values in, mg/lit except for volume and pH.

4.0 CPCB GUIDELINES FOR THE TREATMENT AND DISPOSAL OF SPENT WASH FROM MOLASSES BASED DISTILLERIES

4.1 As per the Environment (Protection) Rules, 1986, the Indian Standards for the Distillery Industry are

Table 7: Indian Standards for Distilleries, Environment (Protection) Rules, 1986

S.No	Parameter	Standards
1.	pH	5.5-9.0
2.	Colour & Odour	All efforts should be made to remove colour & unpleasant odour as far as practicable
3.	Suspended Solids [BOD (3 days at 27^{o}C)] [-disposal into inland surface waters or river/streams] [-disposal on land or for irrigation]	100 30 100

Concentration in the effluents not to exceed milligramme per litre (except for pH and colour & odour)

(Source: CPCB)

Distilleries are now classified as "Red Category" among the 17 categories of highly polluting industries by CPCB, it has become necessary to reduce fresh water consumption in distilleries, which in turn may reduce the generation of Spent Wash. For every distillery in the country it is now mandatory to achieve 'zero Spent Wash discharge' as per CPCB. Since the standards prescribed are very stringent and difficult to practically achieve, a Charter on Corporate Responsibility for Environmental Protection (CREP), CPCB 2003 was proposed for distilleries. Following are the guidelines given by CPCB to achieve zero spent wash discharge.

4.2 CREP conditions for existing molasses based distilleries

Existing molasses based distilleries to Zero Effluent Discharge by Dec. 2005, through any or combination of the following measures:

I) Compost making with pressmud/agricultural residue/municipal waste.

II) Concentration and drying/incineration.

III) Treatment of spent wash through biomethanation followed by two stage secondary treatment and dilution of the treated effluent with process water for irrigation as per norms prescribed by CPCB/MoEF.

IV) Treatment of spent wash through bio-methanation followed by secondary treatment (BOD < 2500 mg/l) for controlled discharge into sea through a proper submerged marine outfall at a point permitted by SPCB/CPCB in consultation with National Institute of Oceanography (NIO), so that dissolved oxygen in the mixing zone does not deplete less than 4.0 mg/l.

V) For taking decision on feasibility of one time controlled land application of treated effluent, a study will be under taken within three months.

Till 100% utilization of spentwash is achieved, controlled and restricted discharge of treated effluent form lined lagoons during rainy season will be allowed by SPCB/CPCB in such a way that the perceptible colouring of river water bodies does not occur.

4.2.1 Consent conditions according to CREP norms for distilleries

1) Storage capacity of raw spent wash, treated effluent shall not exceed 30 days. The lagoons should be lined with HDPE sheets and protected with stone/concrete/brick lining.
2) The compost yard shall be lined with HDPE sheets and protected with brick/concrete/stone lining. Provisions should be made for leachate collection gutter and sump well.

Detailed protocols proposed by CPCB, New Delhi, for utilization of distillery effluent for making compost with pressmud, irrigation etc. is presented in Annexure -I

4.3 Modifications in the recommendations of CPCB for Distilleries (2008)

Subsequent to the problems associated with distilleries due to the treatment methods used, CPCB modified the recommendations for composting, ferti-irrigation and one time land application of spent wash. The modified recommendations are as follows:

I) Ferti-irrigation and one time land application of spent wash by new stand - alone distilleries may not be considered by SPCB/MoEF/PCC.

II) Establishment of new distilleries attached with sugar units may be considered if one of the following options is followed

- Bio-methanation followed by bio-composting; or
- Reboiler/Evaporation/Concentration followed by incineration of concentrated spent wash in boiler(for power generation)

III) Existing stand-alone distilleries may not consider increase of production/expansion based on composting, ferti-irrigation and one time application of spent wash.

IV) Existing distilleries (both stand alone and those attached with sugar units) that not complying with the required environmental standards may be asked to switch over to emerging technologies from existing technologies of composting, ferti-irrigation and one time land application of spent wash in a time bound manner.

5.0 OBSERVATIONS OF THE EXPERT SUB-GROUP

The Expert group visited distilleries representing viz. standalone distilleries, distilleries attached with sugar factories, Co-operative sugar mill and most modern distillery producing RS, ENA, and fuel ethanol. The observations of the Sub-group are briefly presented below:

i. In sugar mills during the production process the sugar is extracted from clarified juice and the rest of the components are passed onto the molasses which is the raw material for the distilleries. It was observed by the committee that popularly in the industry circle the distilleries are viewed as the effluent treatment plants of sugar industry. If there were no molasses based distilleries, the disposal of the entire molasses as effluent would be the responsibility of sugar industry. Thus, both these industries are mutually dependent and it is very important that they work in tandem.

ii. Indian sugar mills produce mainly plantation white sugar by double suphitation method and employ three boiling systems. Molasses is exhausted to the maximum possible limit to extract sucrose as much as possible. This results in generation of inferior quality molasses as compared to the B Heavy molasses typically generated in Brazilian sugar mills producing raw sugar. There is also significant variation in the quality of molasses produced in different parts of the country. For example, molasses produced in North Indian sugar mills has TRS in the range of 38 to 43 % as compared to 48 to 50% TRS content of molasses produced in sugar mills in Western India. Apart from the Total Reducing Sugars(TRS) content of molasses, the Fermentable Sugar(FS), Unfermentable sugars(UFS), Total Organic Volatile Acidity (TOVA), Dissolved Sulphur di-oxide(SO_2) content, Total Microbial Count (TMC), fermentable to Non-fermentable (F/N), Ca and Sludge content of molasses plays very important role in fermentability of molasses. Ensuring good quality of molasses is one of the important issues.

iii. In molasses the presence of Potassium, Sodium etc. is carried from the cane itself but the increased levels of Calcium, phosphorus and sulphur is due to the use of "milk of lime" during the clarification process and sulphitation process. Alternate methods of clarification in place of "milk of lime" may improve the quality of molasses by reducing these elements, rendering the usability of biomethanated spent wash (after further treatment) for agriculture applications.

iv. Because of the seasonal nature of the operation and availability of raw material, the average capacity utilization of Indian distilleries is rather low. Besides, the distilleries attached to sugar mills operate only during sugarcane crushing season due to following reasons:

    a. Non availability of utilities i.e. steam & power during off-season.
    b. Non availability of molasses, the main raw material.

c. Insufficient PMC availability for bio-composting.

This in turn results in insufficient availability of SW for feeding to bio-methanation plant, resulting in non-operation of the digester and underutilization of distillery capacity.

v. Further, the effluent discharge guidelines for distilleries having bio-composting system are not allowed to work during rainy season from 10^{th} June to 10^{th} September. Therefore, distilleries can operate only for a maximum of 270 days in a year.

vi. Most of the Indian distilleries have adopted cascade continuous/fed-batch fermentation and MPR distillation systems. Few units are based on Biostil fermentation process. Most of the distilleries have biomethanation plant and bio-composting systems and few distilleries have installed reverse osmosis plant, MEE plant to reduce the effluent quantity and very few have biogas power plants. The sub-group was informed about the operational difficulties of RO system. It frequently gets clogged necessitating frequent maintenance and quick change of membranes. This is resulting in high operational cost of RO system.

vii. The modern distillery, that was visited, has adopted various available technologies and achieved improvements with respect to productivity, quality, proper management of effluent treatment, waste water recycle for process and non-process applications, minimum fresh water consumption etc. This distillery had also installed a new Multiple Effect Evaporation (MEE) plant for concentration of BMSW and Process Condensate Treatment Plant (PCTP) for stripping of NH_3 and further treatment of process condensate. These technologies have helped the unit to recycle and reduce its fresh water consumption. The fresh water consumption for this unit, as stated, is 6.40 KL/KL of alcohol production after considering recycle streams. The unit has achieved minimum fresh water consumption, minimum concentrated Spent Wash generation, and maximum ratio of Spent Wash to press mud cake in bio-composting process that has resulted in near zero discharge of Spent Wash.

viii. The distilleries have adopted selectively some of the improved technologies as appropriate. These are: reboilers along with distillation column, Integrated evaporation system to concentrate the spent wash, Aerobic Bio-composting, Membrane filtration /Reverse osmosis with different degree of success, Multiple effect evaporation, Aerobic treatment (Secondary or tertiary treatment), Ferti-irrigation, Controlled land application, Turbo-Mist evaporation, Incineration of concentrated spent wash, Gasification of distillery Spent Wash, Co-processing in Cement, steel and power plants. Details of these technologies are presented in annexure – 2.

ix. The spent wash is generated on an average 10-12 liters per liter of alcohol produced and is treated first in the bio-methanation plant to reduce the BOD by 85 – 90 % and COD by 60 – 65 %. The bio-methanated Spent Wash is then passed through RO and /or MEE reducing the quantum of waste by 45-50% and the permeate/process condensate is recycled. The rejects/concentrates are used in bio composting. The bio-composting plant have modern facilities for windrow preparation, windrow dressing, spent wash application, aeration & turning etc. The bio-compost prepared is further enriched with bio-fertilizers and micronutrients.

x. During the visit to one of the mills in the southern region, it was learnt that out of the 1000 M^3 of bio-methanated Spent Wash generated every day by the distillery, 600 M^3 is consumed in the tertiary bio-composting system. The balance is used in controlled land application under the supervision of an Agricultural University as per the protocol of CPCB. The plant applies spent wash to about 10 acres of land every day. About 4000 acres of agricultural land is required every year for controlled land application (CLA). The management of the distillery informed that there is consistent demand for BMSW from nearby farmers because of the observed improvement in crop yield. It was also informed that there are no reports of ground water pollution and any harmful effect on soil fertility. During the visit the committee also interacted with the farmers and visited the agricultural field where this spent wash is being applied.

xi. During the visit to Maharashtra region the committee was informed that the plants practiced CLA as per the CPCB protocol under the supervision of Agricultural University for several years. However, CLA of spent wash has since been suspended as per the state pollution control board instructions. Availability of press mud for mixing with spent wash for bio-composting is a major problem for standalone distilleries.

xii. As per CREP norms only 30 days Spent Wash storage is allowed. The storage tank is also required to be made impervious as per CREP norms by putting 250 micron HDPE sheet. The industry felt that it is too short a period and requested for storage of 90 days should be allowed so that distilleries can operate throughout the year to minimize the production losses.

xiii. As per CREP norms it is mandatory for all distilleries in the country to achieve Zero Spent Wash discharge. In practice, it is very difficult to achieve zero Spent Wash discharge.

6.0 RECOMMENDATIONS OF THE EXPERT SUB-GROUP & IDENTIFICATION OF AREAS FOR R&D INTERVENTIONS

The sub-group reviewed the various processes adopted by the select distilleries. It also reviewed the results of the field trials provided by the industry which was carried out by various agricultural universities/ colleges in using raw spent wash or bio-methanated wash as well as value added bio-composed materials produced by the industry and used by farmers for various agricultural crops. The sub group had detailed discussions among the members in arriving at the recommendations. It was felt that the large distilleries are able to spend adequate resources to modernize the processes and adopted / adopting a multi-pronged approach for achieving near zero discharge conditions. Appropriate technologies have been acquired from far and wide to meet the environment regulations. However, the industry still faces many challenges. The sub-group makes the following recommendations for betterment of the industry:

6.1 Water consumption in distilleries (In plant control-reduce/recycle)

Fresh water requirement for process and non-process applications in distilleries need to be reduced by recycling Spent Wash and low strength waste water after proper treatment. The low strength waste water includes spent lees, air blower water, vacuum pump water, pump gland cooling water, evaporation process condensate, cooling tower /boiler blow down, etc. It is therefore suggested that non-process water and process water streams may be segregated and treated separately. Technologies that are available may be deployed for treatment/polishing of low strength waste water generated in distilleries. The treated low strength waste water may be recycled in process and non-process applications helping to reduce fresh water requirement in distilleries.

6.2 Raw material quality

i. Fermentation is the most crucial step of distillery plant operation and is dependent on quality of raw material, appropriate strain of yeast being used and process control facilities. Availability of good quality of molasses is beneficial to the sector. Distilleries may not be treated as effluent treatment plants of sugar mills and there is a need for both these industries to work in close cooperation for mutual benefit. It is recommended that molasses with High Brix, better TRS & less volatile acids be made available to distilleries.

ii. Further, the sub-group discussed at length and prepared comparative table of sugar production & ethanol production with a sugarcane crushing rate of 9000 TCD using various grades of B-heavy molasses and secondary juice. These are presented in Table 8. Comparative revenue generation is shown in Table 9. The variation in bagasse revenue under different conditions is due to the bagasse saved on requirement of steam in individual routes.

Table 8: Comparative sugar & ethanol production

Particulars	Sugar Production (Tonnes/day)	Sugar Production Reduction (%)	Ethanol Production (KLPD)	Ethanol Production Increase (Times)
Conventional	1033.65		92.28	
B-Heavy,Purity- 58	826.83	20	204.73	2.21
B-Heavy, Purity -55	862.74	16.5	185.57	2.00
B-Heavy,Purity-50	912.96	11.7	158.76	1.72
Total Secondary Juice	627.21	40.0	311.66	3.37
Partial Secondary Juice	937.17	09.3	146.38	1.59

(Source: Vasantdada Sugar Institute, Pune)

Table 9: Comparative revenue Generation (Rs.lac/day)

Particulars	Sugar Revenue	Bagasse Revenue	Ethanol Revenue	Bolder grain revenue	Total Revenue
Conventional	289.42	10.95	41.53	0.00	341.90
B-Heavy,Purity-58	231.51	17.08	92.13	3.15	343.87
B-Heavy,Purity-55	241.57	17.08	83.51	3.15	345.31
B-Heavy,Purity-50	255.63	16.47	71.44	2.70	345.24
Total Secondary juice	175.62	19.32	140.25	3.15	338.34
Partial Secondary Juice	262.41	14.62	65.87	2.70	345.60

(Source: Vasantdada Sugar Institute, Pune)

It can be seen from the tables above that with better quality of available raw material the production of ethanol will increase substantially and will reduce the requirement of process water, besides improving the quantity of spent wash/KL of alcohol. Further the additional alcohol thus produced can be diverted for doping petroleum fuel as per the policy of the Government. Based on the comparative assessment it is recommended:

a. Use of secondary juice of cane for ethanol production: Productivity of alcohol would substantially be improved by substituting molasses with secondary juice resulting also in generation of better quality of effluents with less COD/BOD. It would also reduce the requirement of water for dilution significantly. On the flip side, the distilleries would need additional infrastructure to store the juice, which is difficult as it is highly susceptible to contamination. It is recommended that the distilleries attached with sugar mills may use the secondary juice during the crushing season and supplement it with molasses as appropriately based on the demand of the sugar. The stand alone distilleries may use the molasses and acquire press mud for mixing with the spentwash for biocomposting.

b. Use of B heavy molasses: In this approach, the alcohol production shall be more than double (as compared to residual molasses). B heavy molasses can be stored in same molasses tanks that are used for C final molasses needing no additional capital investment. It will not only increase the availability of ethanol for blending with petrol, but also decrease the requirement of water for dilution of molasses thereby reducing the spent wash volume by about 2.0 lit/lit ethanol. Higher alcohol concentration in fermented wash can be achieved (10-12%v/v) which will result in better energy utilization by steam for distillation. Further this approach provides flexibility to the sugar units to alter production balance between sugar and ethanol based on market demand. However this approach may not significantly change the issues associated with effluent.

6.3 Fermentation process

Yeast based Fermentation process using *Saccharomyces cerevisiae,* for ease of handling and process economics still remains the first choice for industrial ethanol production, though many other classes of microorganisms have been studied over the years. Industrial yeast strains have been developed over the decades by public and private institutes in the country. A Yeast strain that can withstand osmotic stress conditions due to high viscosity and total sugar content in molasses feed stock and can adapt easily by modifying their metabolic activities to avoid substantial viability loss is preferred by the industry. However, the Indian distilleries generally prefer to use their own isolated strains rather than procuring the high efficiency strains at a cost, perhaps due to lack of authentic data and cost benefit ratio worked out at operational scales by the developing institutions. Therefore

i. collation of authentic and dependable data on available Yeast strains developed in various public and private laboratories for attributes indicated above may be considered. Authentication for industrial use of these strains need be established through a pilot study conducted in industrial setting.

ii. the conditioning of molasses by addition of different additives like EDTA, Potassium Ferrocyanide and Zeolites etc. capable of neutralizing the inhibitory effects of undesirable components in Indian molasses have been considered. Besides, the addition of a minimum inhibitory concentration of acids to molasses will stop bacterial growth and increase ethanol yields as well as avoid the need for antibiotics for infection control. Fermentable substrates (molasses) may be supplemented with nutritional elements/factors for promoting the yeast growth. Low cost commercial enzyme complex of amylases, cellulases and amylopectinases is recommended for use to allow the conversion of non-fermentable substances into fermentable compounds. Cost benefit for such additives need be established for various types of molasses used by distilleries.

iii. high sugar concentration in the fermentation feed stock leads to high alcohol accumulation which in turn retards the overall process and productivity.

Therefore, apart from using a high alcohol tolerant yeast strain, the entire process for up and down stream can be integrated in such a manner that ethanol is recovered from fermentation broth as it is produced. A fed batch or semi-continuous fermentation process with continuous alcohol distillation through a loop reactor can be a useful alternative process. However, it needs to be tried and tested in an industrial setting, even though a number of reports for its advantage are available in public domain.

6.4 Storage of Spent Wash

The present guidelines permit only 30 days storage of Spent Wash in the distilleries. The storage tank is also required to be made impervious as per CPCB norms by putting 250 micron HDPE sheet. The committee recommends that storage of 60 days should be allowed so that distilleries can operate for more no. of days and can minimize the production losses.

6.5 Treatment of Spent Wash

A closer examination of the constituents of the Molasses and Spent wash, reveals that most of the constituents are carried from the Molasses. The excess calcium, phosphorous and sulfates are the result of clarification and sulfitation processes used in the sugar production. The rest of the elements come from the sugar cane. The spent wash is rich in Potassium, Nitrogen, phosphorus and good for soil. Therefore efforts must be made to fruitfully utilize the spent wash for agricultural applications. The following measures could be considered:

i. The COD of the spent wash in some cases can increase to about 2,00,000 to 2,50,000 mg/L due to the installation of integrated evaporation. This concentrated Spent Wash can be anaerobically digested (Thermophilic and mesophilic digestion) to reduce the COD. Even if the anaerobic digestion system works for higher COD spent wash, COD of the digested effluent will be at the level of 70,000 to 1,00,000 mg/L as COD treatment efficiency is usually in the range of 60 to 65%. Therefore, research efforts must be made to substantially reduce the COD and BOD to meet the permissible norms. Sulfates in the spent wash will also increase in the same ratio as COD due to the installation of integrated evaporation system. Due to this, sulfide level in the digester will increase beyond the inhibition level and a study is required to understand the process stability of anaerobic digester under these conditions.

ii. Lately pulsed corona technology is being used to enhance the anaerobic biodegradability. This technology may be tried for biomethanated spent wash. A research project is necessary to understand the dynamics of pulsed corona technology for the enhancement of biodegradability of biomethanated-spent wash.

iii. The possibility of treating raw spent wash using anaerobic membrane bioreactor (AnMBR) needs to be studied so that in the single digester, biogas and pure water could be generated simultaneously. Reject from the membrane could be used directly with press mud for composting.

iv. Generation of electricity from wastewater employing MFC is emerging as one of the futuristic technology. Therefore, it is suggested that MFC technology may be tried for spent wash to understand whether distilleries would benefit from such technologies.

6.6 Controlled land application of Biomethanted spent wash(BMSW)

Controlled application of BMSW may be beneficial for reclamation of sodic soil as BMSW has large quantity of Ca & Mg compared to Na, and if the soil is well drained soluble salts of Na can easily leach out from surface soil. Pre sowing application of BMSW followed by two irrigations can leach out soluble salts from surface soil for better germination and growth of the crop.

For preseason sugarcane crop the recommended dose of NPK by state university in Maharashtra is 340:170:170 based on the nutrient contents in BMSW. The calculations for BMSW quantity to be applied to fulfill the nutrient requirement are as below:-

A) BMSW application on the basis of N requirement (340 kg /ha) of sugarcane

N content in BMSW	Total BMSW to be added for 340 kg/ha N	Nutrients added through 170 m3 BMSW (kg/ha)			Other essential nutrients (Kg/ha)						Na added (kg/ha)
		N	P	K	Ca	Mg	SO_4	Mn	Zn	Cu	
1 kg /m^3	340 m^3	340	272	3060	1360	680	1088	1.7	1.7	0.34	340
Remarks		No additional use of N – fertilizers required	Excess by 102 kg. No need to add extra P	Excess by 2890kg. No need to add							

B) BMSW application on the basis of P requirement (170 kg /ha) of sugarcane

P content in BMSW	Total BMSW to be added for 170 kg/ha P	Nutrients added through 113 m3 BMSW (kg/ha)			Other essential nutrients (Kg/ha)						Na added (kg/ha)
		N	P	K	Ca	Mg	SO_4	Mn	Zn	Cu	
1.0 kg/m^3	170 m^3	170	170	1700	680	340	544	0.85	0.85	0.17	170
Remarks		Additional use of 170 kg N through Urea is required	No additional use of P – fertilizers required	Excess by 1530 kg							

C) BMSW application on the basis of K requirement (170 kg /ha) of sugarcane

N content in BMSW	Total BMSW to be added for 170 kg/ha K	Nutrients added through 68 m3 BMSW (kg/ha)			Other essential nutrients (Kg/ha)						Na added (kg/ha)
		N	P	K	Ca	Mg	SO_4	Mn	Zn	Cu	
9 kg/ m^3	19 m^3	19	19	171	76	38	60.8	0.095	0.095	0.019	19
Remarks		Additional use of 306 kg N through Urea is required.	Additional use of 151 kg P through SSP is required.	No additional use of K – fertilizers required							

Following are the some suggestions based on the contents of BMSW and the quantity of BMSW to be applied in sugarcane

- The present protocol of controlled land application of BMSW is based on N content in BMSW (@1.0 kg N/m^3) and RDN to be applied per ha. For application of 340 kg N /ha in Maharashtra 340 m^3 BMSW is required. The quantum of BMSW is very high and can create water permeability and salt accumulation in clay soils and also ground water pollution in coarse textured soils. In Maharashtra, if RDP of sugarcane and P content in BMSW (@1.0 kg P/m^3) is considered the BMSW requirement will be 170 m^3 and if RDK of sugarcane and K content in BMSW (@9.0 kg K/m^3) considered, quantum will be 19 m^3.
- It is recommended to consider BMSW application rate on the basis of K content in effluent and K requirement of crop and the soil type which will be less in quantum, easy to use and fewer problems in soil. However, continuous use of BMSW will create water permeability and lead to salt accumulation in soil. Therefore, limited use of BMSW with permissible BOD is desirable for controlled land application.
- A long term comprehensive research project on these aspects should be undertaken to verify the above hypothesis in various types of soils in different agro-climatic zones of India for different crops along with national agricultural institutes. To aid such effort, AIDA may collect the information regarding the use of BMSW for ferti-irrigation in countries like, Brazil and Australia and submit it to concerned authority.

6.7 Incineration of spent wash

BMSW is rich in potash and nutrients. And wasting the BMSW is not desirable since the country depends on import of potash. However, recovery of potash from spent wash by evaporation and incineration would not be an economically viable option. R&D on alternate technologies to recover the potash exclusively from the BMSW is recommended. There are now about 35 to 40 incineration boilers installed in molasses based distilleries and the industry is not satisfied with its performance. Distilleries are not positive about this technology due to the high capital cost coupled with high maintenance cost. Even after incineration of BMSW, the safe disposal of ash generated with high concentration of inorganic salts will still be a problem. Therefore, before insisting on implementing this technology in the industry, it would be necessary to undertake detailed evaluation studies.

7.0 A FEW OTHER IDENTIFIED RESEARCH PROJECTS

- Clarification and demineralization of sugarcane juice by alternate methods.
- Exclusive removal of Potassium, Sodium & Calcium in presence of others from sugar cane juice/molasses/Biomethanated Spent wash
- Development of potential yeast strains to tolerate higher concentrations of recycled spent wash.
- Development of high sugar, high temperature and high alcohol tolerant yeast strains for high gravity fermentation
- Pre-clarification of molasses to improve the performance of alcoholic fermentation
- Use of raw spent wash from integrated evaporation process for composting to establish press mud to spent wash ratio

8.0 CONCLUSIONS

The available quality of molasses as raw material, disposal of large amount of spent wash generated having high COD,BOD and salts are some of the major issues in Indian molasses based distilleries. Though most of distilleries have adopted the available technologies to reduce the spent wash but still the disposal of this enormous quantity of effluent is a challenge.

The major thrust areas requiring R&D interventions have been identified in this report. The use of better quality of molasses will have a significant impact on the ethanol production yield and existing problems regarding the environment concerns. Few developmental and pilot projects have been suggested in the report which may be taken up along with industry to improve the technologies. The industry may collaborate with the suggested R&D organizations to take up these R&D projects.

Annexure-I

PROTOCOL FOR UTILIZATION OF DISTILLERY EFFLUENTS FOR IRRIGATION OF AGRICULTURAL CROPS

Based on the field and experimental studies carried out by the Indian Agricultural Research Institute (IARI), Delhi and the experience of the Central Pollution Control Board for application of industrial effluents on land using it as a treatment medium, the following protocols are recommended for the utilization of treated distillery effluents (BOD 100 mg/1) for irrigation of agricultural crops.

1. BASIC REQUIREMENTS

i. Any distillery desirous of utilization the effluent for irrigation should have completed the construction and commissioning for bio-methanation plant for primary treatment of spent wash followed by secondary biological treatment (aerobic) with two stage aeration before utilization on land for irrigation.

The BOD value of the finally treated effluent before storage in the lined storage tank small not exceed 500 mg/1

The BOD value of the effluent in the storage lagoon shall not exceed 100 mg/1

It shall not be transported to the filed for irrigation through tanker.

ii. The distillery shall construct concrete and lined storage tank with a minimum retention time of 1 month for storing the final treated and diluted effluent during the monsoon and /or non-irrigation period.

iii. The command area requirement for irrigation shall be calculated at the rate of not less than 9 ha/kilolitre of daily alcohol production capacity. For 30 kld installed alcohol production capacity, the distillery will require minimum 270 ha of land for irrigation under the scheme.

iv. The distillery shall construct distillery channel network for transporting effluent, preferably of closed conduits or of pucca construction, to cover the area irrigated under the scheme.

v. The distillery after fulfilling the above basic requirements shall prepare a comprehensive ‘Irrigation Management Plan’ (IMP) for utilization of it’s effluent and got it approved by the State Pollution

Control Board at the time of grant of consent. The IMP include the details on:

a) Survey/plot (khasra) numbers of land for irrigation under the scheme along with their area.

b) Written agreement with the owners (farmers) of the land mentioned in (i) above, to bring their land for use under the scheme.

c) The treated spent wash from the storage lagoon with a BOD value of 100 mg/1 and TDS (inorganic) as 2100 mg/1, maximum shall be utilization for irrigation.

d) The depth of one irrigation shall not be more than 10 cm or as per the crop requirement, whichever is less. The total number of irrigation shall not exceed six for any crop.

e) Agronomic plan for effective utilization of land by crop rotation.

f) Effluent distribution schedule to the fields.

g) Infrastructure facilities available/planned for collection and analysis of samples collected as per item 3 i.e. Monitoring Protocol;

h) Full-time expert and other manpower employed for the purpose of managing the IMP and;

i) The fresh water may not be allowed for dilution of spent wash treated or partially treated.

2. SAFETY PROTOCOL

vi. Thought the crops normally cultivated in the area can be grown under the scheme the rotation of wheat, rice and sugarcane crops is preferable.

vii. Effluent application during the germination and seeding growth shall be avoided.

viii. Any concurrent of fertilizers and pesticides shall be done judiciously to avoid super-imposed effect.

3. MONITORING PROTOCOL

ix. The physic-chemical characteristics of the soil under irrigation by distillery effluent shall be regularly monitored for Ph and Electrical Conductivity (EC). One representative sample per 10 ha at depths of 30 cm and 60 cm shall be collected at least twice a year, for this purpose. The Ph and EC of the extra of the mixture of 2 parts of soil with 5 parts of water shall exceed 8.5 and 4 milliohms/cm respectively.

x. The ground water quality shall be monitored by installing one hand pump for covering 10 ha area of land and one bore well for 20 ha area of land. Groundwater for BOD, Nitrates and TDS. The net addition to the groundwater quality in terms of (i) BOD shall not exceed 3 mg/1, (ii) Nirtates, expressed as ‘N’ shall not exceed 10 mg/1, and (iii) TDS shall not exceed by 10% or 200 mg/1 whichever is less.

xi. The records of soil and groundwater quality monitoring data so collected shall be properly maintained for verification by the State Pollution Control Board, at least once after every cropping season, for cross-verification by the State Pollution Control Board, at least once after every cropping season, for cross-verification.

xii. In the event of first observation of any of the soil and groundwater monitoring parameters exceeding the prescribed limits, effluent application shall be stopped immediately and the distillery shall communicate the matter to the State Pollution Control Board about such observation. The industry would be solely responsible for reclamation of soil and groundwater quality at their own cost and expense, in case of damage.

PROTOCOL FOR CONTROLLED LAND APPLICATION OF TREATED POST BIO-METHANATED DISTILLERY SPENT WASH AS LIQUID MANURE

I. Basic Requirements :

1. Any distillery desirous of utilising the spent wash for pre-sown controlled land application should use treated post bio-methanated spent wash only.

   The effluent to te utilized for one time controlled application after post bio-methanation shall have a BOD3 270 C value not exceeding 7000 mg/1 and Ph should be more than 7.

2. The distillery shall engage a full time expert and other required manpower for the implementation and monitoring of controlled land application of spent wash.

3. The distillery shall construct pucca an lined storage tanks with a maximum holding capacity of 30 days for storing the spent wash during the monsoon and / or non-application period.
4. The command area for spent wash application shall be within a distance of 20 km from the distillery unit in order to facilitate easy monitoring and effective control over land application of spentwash.

5. The distillery shall either provide pipeline network or engage tanker lorries for spent wash transportation based on the location and distance of the command area meant for spent wash land application.

6. The distillery should maintain pucca records and data regarding spent wash land application. In case, tanker lorries are engaged for spent wash transportation to the field, they should carry a 'Transit Card' with the following details

   a) Tanker lorry number
   b) Date/Time of loading & unloading
   c) Field address
   d) Receiving person
   e) Distance travelled

7. Infrastructure facilities should be arranged for collection and analysis of samples drawn from the application zones.

8. The distillery after fulfilling the above basic requirements shall maintain a comprehensive ‘Controlled Land’ for utilisation of treated post bio-methanated spent wash. The plan includes the details on

   a) Survey No./ Plot No./ Field Name of land for controlled land application along with their area/extent.
   b) The distillery shall obtain the acceptance of the farmers in the form of ‘Spent wash Request Application’ before the application of spent wash to their land.
   c) Agronomic plan for effective utilisation of land by crop rotation.
   d) Spent wash application schedule to the fields.

9. Controlled Land Application of Treated (post bio- methanated) Spent Wash shall be carried out as described below;

   Pre-sown Controlled Land Application as basal manure:

   Treated (post bio-methanated) spent wash should be applied uniformly on land at least 20 days prior to the sowing of the crop and ploughed before raising the crops.

   The dosage of treated (post bio-methanated) spent wash for various crops is furnished in Annexure-A.

10. The rate of application of spent wash shall be quantified by the following techniques

    i) Horizontal open discharge method
    ii) Measuring container
    iii) V-notch

II. Safety Protocol :

1. Though the crops normally cultivated in the area can be grown under the scheme, the rotation of crops is preferable.

2. Any concurrent use of fertilizers shall be done judiciously to avoid super imposed effect.

III. Monitoring Protocol

1. The unit shall form an internal monitoring cell under the supervision of an agricultural graduate to closely monitor the application of treated (post bio-methanated) spent wash for controlled land application.

2. The farmers should be educated about the application of treated (post bio-methanated) spent wash for controlled land application.

3. The application of treated (post bio- methanted) spent wash on the soil should be with farmer's acceptance and transport through tankers should not cause any environmental concern.

4. Short-term and long-term monitoring must be carried out with agricultural experts. The distillery units should have their own monitoring team with renowned agricultural experts to assess the compliance status of protocol on controlled land application protocol for treated (post bio-methanated) spent wash.

5. The physic-chemical characteristics of the soil under treated (post bio-methanated) spent wash application shall be regularly monitored for Ph, electrical conductivity (EC), Nitrogen (N), Sodium and Potassium (K). One representative sample per 50 ha at depths of 30 cm and 60 cm shall be collected at least twice a year, for this purpose. The Ph and EC of the extract of the mixture of 2 parts of soil with 5 parts of water shall not exceed 8.5 and 4 millimhos/cm, respentively.

6. The ground water quality shall be monitored for BOD, TDS and NO3 by collecting one representative sample from open wells / bore wells situated in every 50 ha area of land under spent wash application at least twice a year. The increase in BOD, TDS and NO3 shall not exceed 3mg/1, and 10 mg/1 over the initial results.
7. Piezometers shall be installed to study the long-term nutrient mobility in soil and its impact on ground water quality, at minimum 5 zones in the command area for continuous monitoring.

8. In the event of first observation of any of the soil and ground over monitoring parameters exceeding the prescribed limits, the treated (post bio-methanated) spent wash application in that particular location shall be discontinued immediately and the distillery should implement corrective measures for remediation.

9. The records of soil and ground water quality monitoring data collected shall be properly maintained for verification by the State Pollution Control Board/Central Pollution Control Board.

10. A MoU with nearby reputed agricultural university shall be entered into (prior to application of post methanated spent wash on land) for monitoring of required dose of spent wash, quality of spent wash used, monitoring of soil, ground water and productivity of crop.

11. The findings of minimum one year study by the concerned agricultural universities shall be made available by distilleries to SPCB/CPCB prior to one time controlled land application of post methanated spent wash. The report on findings will be reviewed also by the Sub-committee.

It was also decided that:

(i) The unit should obtain consent for utilization of post-methanated spent wash for one time controlled land application.

(ii) The unit should sign MoU with reputed agricultural university.

(iii) The agricultural university should also monitor the soil and ground water quality during the application phase.

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Enclosure-A

Spent wash (bio-methanated) Dosage for Various Crops based on Nitrogen Requirement

Crops	Spent wash (Post bio- methanated) to be applied based on Nitrogen requirement (m3 /ha)		
	Loamy Soil	Clay Soil	Sandy Soil
Sugarcane	90-125	80-115	70-95
Paddy	80-150	70-135	60-115
Maize	100-150	90-135	75-115
Sunflower	35-90	35-80	25-70
Turmeric	30-50	30-45	25-40
Banana	125-250	115-225	100-190
Cotton	70-80	65-75	55-60
Tobacco	60-70	55-65	45-55
Sorghum	35-90	30-80	25-70
Groundnut	35-90	30-80	25-70
Ragi	60-80	55-75	45-60
Gingelly	20-30	20-30	15-25
Chillies	70-90	65-80	55-70
Brinjal	60-70	55-65	45-55
Tomato	90-100	80-90	70-75
Onion	40-60	35-55	30-45

- Derived from the experimentals conduct by Tamil Nadu Agricultural University, Coimbatore at different locations of Tamil Nadu.

Requirement for surface Compost Process utilizing distillery spent wash and press mud

Sl.No.	Description	Requirements
1.	Working days of distillery	Maximum 270 days (rainy season shall be avoided and the entire compost area shall be kept dry before starting of the rainy period)
2.	Spent wash storage capacity (duly lined with 250 micron HDPE sheet and pitched by stone/bricks with cement mortar to	<30 days

	prevent leachate)	
3.	Press mud (PM) to Spent Wash (SW) ratio	1:2.5 – 1:3.5
4.	Land required for Compost Plant Specification of floor of compost yard should be as under- (with arrangement of leachate collection lagoon and laying of pipe net work for automatic spraying of spent wash) i)Compaction of soil ii)5 cm local and cushion (bottom) iii)250 micron HDPF sheet (as per BIS specification) iv)5 cm sand cushion (top) v)Bricks/stone soling (not less than 6 cm in case of bricks & 3 cm in case of stone soling) In case the co-efficient of permeability in less than 10-8 cm/sec. (as in black cotton soil), 30 cn depth of murum at the top may also be used.	850 MT/acre/cycle
5.	No. of days required to complete one cycle	i. 45 days for 1:2.5 (PM to SW ratio) ii. 60 days for 1:3.5 (PM to SW ratio)
6.	Maximum allowable cycles/annum	i. 5 cycles, in case of 45 days compost period ii. 4 cycles, in case of 60 days compost period
7.	Land required for Storage of press mud In case, storage area is not leakage proof (by lining with HDPE or less permeable compacted soil as specified in Para 4). Press mud should be transferred to compost yard before onset of rainy period and covered with HDPE/PVC sheet/tarpaulin,	Equivalent to one cycle
8.	Land required for storage of finished product Land area will be raised by about 30 cm above ground level. The maximum height of storage shall be 4cm. The finished compost shall be kept sheds or covered with PVC/HDPE Sheet/Tarpaulin to prevent soaking from rain water	Equivalent to 33% of the total production of finished product/annum

9.	Compost quantity (digested spent wash)	3.0– 3.5 MT/kld of alcohol production
10.	Compost quality	Moisture content : <35% Organic carbon : 20-25% Phosphorous : 1.5-2.0% Nitrogen : 1.5-2.0% Potassium : 2.0-3.5% C : N ratio : <17
Equipment's and Machinery Required		
1.	Tractor for transportation of press mud from storage site to composting area	One
2.	Homogenizing Machine along with auto spraying system with 70 HP tractor (for churing upto the bottom)	One
3.	Front and loader with tractor or JCB of bucket capacity of 600-1000 Kg	One
4.	Sieving machine	One
5.	Sewing machine in case compost is to be bagged (finished product)	One

Annexure - 2

Improved Technologies

1. Distillation system with reboilers:

To concentrate spent wash and reduce effluent generation, reboilers along with distillation column have been installed by some of the old atmospheric distillation based distilleries as well as all new MPR distillation based distilleries. Use of reboilers results in indirect heating of distillation columns and restricts the mixing of steam condensate with spent wash. Steam condensate can be recycled as boiler feed water or can be used as process water. Reboilers coupled to multipressure distillation systems have resulted in direct reduction of spentwash quantity by about 2.0 liters per liter of alcohol produced.

2. Distillation with integrated evaporation system:

To concentrate the spent wash as per the requirement of downstream bio-methanation or bio-composting systems, Integrated evaporation plants are now being installed in distilleries. Integrated evaporation system uses alcohol vapours as heating media for heating the spent wash thus saving good amount of steam. Integrated evaporation concentrates the spent wash to about 22-27 % solids from initial concentration of 12-14 % solids depending on the type of fermentation system used, final alcohol concentration in wash and heat integration concept adopted.

3. Biomethanation

More than 70 % of the distilleries in the country have adopted biomethanation of distillery SW as the primary treatment method. Molasses based distillery effluent treatment through the biomethanation route offers several advantages. The most important advantages include recovery of energy in the form of biogas produced and neutralization of acidic spentwash. Sludge production is significantly lower under anaerobic conditions with the net amount of cell produced being 20-150 g per kg of COD destroyed as compared to 40-600 g during aerobic degradation.

4. Aerobic Bio-composting

Scientifically operated bio-composting can result in Zero Liquid discharge (ZLD). It is used either as a primary treatment, secondary treatment after anaerobic digestion or tertiary treatment after concentration of SW. The mixing of SW and press mud (PMC) (50-70% moisture) has to be carried out (2.5:1 proportion for 45 days cycle and 3.5:1 proportion for 60 days cycle) in surface windrows with the help of an aerotiller machine (Self-propelling) for spraying, mixing, turning and aeration of compost material. Addition of special blend of cultures or cow dung provides microbial inoculum required for composting.

5. Membrane filtration /Reverse osmosis

RO process has been used commonly for advanced treatment of wastewaters to remove dissolved inorganic solids and some recalcitrant compounds. Its use to recover good quality water from polluted waste such as SW is recent in India. This has been made possible due to development of new membranes and membrane module configuration, which allow easy accessibility for cleaning and replacement of membranes.

The majority of the dissolved salts, low molecular weight organic materials, heavy metals, bacteria, viruses and suspended solids etc. are retained by the membrane and are discharged from the system with the brine. A RO membrane typically will reject 99% of most ions and most organics over 150 Molecular weight cut off (MWCO). High pressure of about 35 to 100 atmospheres is required in order to overcome the high osmotic pressure across the membrane for brackish and seawater. For distillery effluent treatment, the disc and tube type membranes have been quite successful.

6. Multiple effect evaporation (MEE)

This is a cost effective method of removal of moisture. Both biomethanated spent wash (BMSW) and raw SW can be fed to the evaporator. Steam used in the evaporation process and the evaporated water from the SW feed form the condensate or the recovered water. In case of MEE's, steam jet ejectors or Themo vapour comptessors (TVR) are used to increase the thermal efficiency. Types of MEE's used in distillery industry are: Falling film evaporators, Forced circulation evaporators, Fluidised bed evaporators, Combination of falling film and forced recirculation evaporators, Integrated evaporators (in which ethanol vapours are used as heating media).

7. Aerobic treatment (Secondary or tertiary treatment)

Extended aeration/diffused aeration methods for oxidation of spentwash by aerobic microorganisms has been also tested by distilleries in India. This process is energy intensive and involves high capital and operating cost. Substantial quantity of sludge is also generated in this process and its disposal is also a problem. Going below 1500-1000 ppm BOD is really difficult by aerobic treatment method and therefore, this method has been now abandoned by many distilleries.

8. Ferti-irrigation

This method is allowed only after primary biomethanation followed by secondary aerobic biological treatment. The BOD of the secondary treated effluent should not exceed 500 mg/L. The treated effluent is diluted prior to irrigation such that the concentrations of BOD may not exceed 100 mg/L. The application rate of the diluted effluent is decided on the basis of the nitrogen content of the diluted effluent, the nitrogen requirement of the crop and the type of soil of the field. The nitrogen requirement of the crop may be met in one or more irrigations. Once the nitrogen requirement is met and if further irrigations are required, these will be done using fresh water. The proper monitoring and supervision of ferti-irrigation system is very difficult. It requires large land area and water for dilution. It has to be carried-out as per the protocol of CPCB under the guidance and supervision of collaborating Agricultural University. However many state pollution control boards are now not allowing this method of spentwash disposal.

9. Controlled land application

This method is allowed only after bio-methanation of spent wash. It has to be carried-out as per the protocol of CPCB under the guidance and supervision of collaborating Agricultural University. The rate of application is based on nitrogen content of SW and the nitrogen requirement of the crop. Extensive work on this aspect has been carried-out by Agricultural Universities in Tamilnadu, Karnataka, UP, Bihar and Maharashtra and most of them have reported encouraging results on crop growth and productivity. These universities have monitored continuously for last 10 to 15 years the effect of one time application of BMSW as organic liquid manure. The results have shown that there are no harmful effect on soil fertility and ground water quality. Similar type of treatment has been also extensively used in Brazil, Thailand and Australia. Due to concerns of salt salinity CPCB and some of the state pollution control boards are now not encouraging this method.

10. Turbo-Mist evaporation

As the name implies, the mist evaporator creates a mist of small droplets by pumping SW through small diameter nozzles placed around the periphery of a duct through which air is blown. The unit is placed at the edge of a lagoon and the SW is pumped. The resulting mist forms a trajectory reaching as high as 18 m and going up to 55 m in horizontal direction. The large surface area of the mist results in evaporation depending on temperature, humidity and wind speed. Turbo-Mist evaporation has been used in some states for evaporation of SW. On an average a single turbo-mist evaporator unit can evaporate about 100 to 150 m^3 of SW/day. This can be a low cost technology for disposal of primary treated SW. Since there are chances of suspended particles getting carried over in the nearby area depending on wind velocity and other factors, many state pollution control boards are not allowing this method of SW disposal.

11. Incineration of concentrated spent wash

Concentrated SW at 55 to 60 % solids or SW powder can be fired in a specially designed boiler with or without subsidiary fuel. Steam generated can be used to run a steam turbine to generate electricity and exhaust steam can be used for the distillery and evaporation plant operation. It is also possible to concentrate SW upto 40-50 % solids. Concentrated SW (40-50 %) can be mixed with a suitable biomass (rice husk, bagasse etc.) and dried in a rotary dryer to about 75-80 % solids. The dried material can be used as fuel in a specially designed boiler. Presently, there are about 30-35 incineration plants in different distilleries. But the technology is not yet well established in the country and there are some bottle-necks as mentioned below to be overcome before it can be implemented in a successful way.

i. There are inherent challenges of ash deposits and clogging in the heat transfer areas of the incinerator.

ii. Boiler cleaning frequency is ranging between 10 to 25 days. Due to frequent stoppages and the cleaning process, the incinerator undergoes a cyclic thermal shock resulting in reduced life of the equipment.
iii. Preliminary feasibility study indicates that slop fired high-pressure incineration boiler is economical for distilleries above 60,000 liters per day capacity.
iv. Very high capital and operating cost.
v. Can lead to air pollution problems if not properly designed. Possibility of emissions of Dioxins, Furans and PAHs etc.

12. Gasification of distillery spentwash

This is a latest technology being explored for complete destruction (zero pollution) of molasses based distillery spent wash. Gasification of coal or biomass is being investigated all over the world for various applications. The process involves controlled combustion of biomass.

It is possible to gasify concentrated spent wash as such or in combination with other biomass and generate syngas in a specially designed gasification system. Sugar/distillery industry is the most suitable industry to source biomass such as spent wash, bagasse or sugarcane trash in terms of well-established supply chain. First commercial scale plant installed in Maharashtra has encountered several process and operational problems. Techno evaluation of this technology is necessary before adopting.

13. Co-processing in Cement, steel and power plants

Latest guidelines on co-processing of SW in cement plants/kilns have been issued by CPCB. It involves concentration of SW to 30 to 60 % solids at the distillery plant by installing a MEE plant, transporting the concentrated SW to the cement plant and incineration of concentrated SW in the kilns of the cement plants. However, the ratio of cement plants-power plants to distilleries is very less in many states. This makes the technology highly cost intensive due to heavy elements of transportation and storage at both ends.

Annexure – 3

R & D organizations with right expertise and capabilities:

Following institutions have the necessary expertise and capabilities to support distillery industry in Research & development:

1. Indian Institute of Chemical Technology (IICT), Hyderabad, AP
2. Institute of Chemical Technology (ICT), Mumbai
3. Vasantdada Sugar Institute, Manjari Budruk, Tal.Haveli, Dist. Pune, Maharashtra
4. Environmental Protection Research Foundation and International School in Environmental Management Studies, Sangli
5. BRD School of Biosciences, Sardar Patel University, Vallabh Vidyanagar , Gujarat
6. Indian Institute of Technology (IIT), Kharagpur, West Bengal
7. School of Environmental Sciences, Jawaharlal Nehru University, New Delhi
8. Indian Agriculture Research Institute, New Delhi
9. Tamil Nadu Agricultural University, Coimbatore
10. Indian Institute of Technology (IIT), Mumbai
11. Guru Jambheshwar University of Science and Technology, Hisar, Haryana
12. Indian Institute of Technology, Delhi, Hauz Khas, New Delhi
13. University of Agricultural Sciences, GKVK, Bangalore
14. Indian Institute of Soil Science, Nabi bagh, Berasia Road, Bhopal
15. Indian Institute of Technology (IIT), Roorkee, Uttaranchal
16. Industrial Toxicology Research Centre, M.G. Marg, Lucknow, U.P
17. National Institute of Technology, Tiruchirappalli, Tamilnadu
18. National Environmental Engineering Research Institute (CSIR), Nehru Marg, Nagpur, Maharashtra
19. Membrane Separations Division, Center of Excellence in Polymer Science, Karnatak, University, Dharwad
20. National Chemical Laboratory, Pashan Road, Pune
21. Central Salt & Marine Chemicals Research Institute, Bhavnagar
22. Jadavpur University, Kolkata
23. Laxminarayan Institute of Technology, Nagpur
24. Anna University, Chennai

25. Madurai Kamraj University, Madurai
26. IIT Guwahati, Assam
27. Central Drug Research Institute, Lucknow, U.P.
28. Central University of Hyderabad
29. Sant Gadge Baba Amravati University, Amravati
30. IIT Madras, Chennai
31. IIT Kanpur, U.P.
32. Indian Institute of Science, Bangalore
33. National Institute of Interdisciplinary Science & Technology, Trivandrum
34. NIT Warangal & NIT Suratkal
35. Dharmsinh Dessai University, Nadiad, Gujarat