CHALLENGES OF ZERO POLLUTION IN DISTILLERY INDUSTRY

A Report submitted to

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EDUCATION AND RESEARCH, KOLHAPUR

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2022

DECLARATION

I hereby declare that, the research project entitled **CHALLENGES OF ZERO POLLUTION IN DISTILLERY INDUSTRY** completed and written by me has not previously formed the basis for the award of any Degree or Diploma or other similar title of this or any other University or examining body. I have not received any grant for this research project from any funding agency.

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ACKNOWLEDGEMENTS

It is with a deep sense of gratitude, I would like to express my sincere thanks to Dr. R. A. Shinde Sir, Secretory and Managing trustee CSIBER, Kolhapur for giving me an opportunity and funding to carry out the present work under his able guidance and encouragement during the research period.

The author is thankful to Director CSIBER, Kolhapur for his valuable suggestions from time to time, advice in experimental work and report preparation. The author is thankful to Environmental Engineers of Shri. Datta S. S. K. Ltd., Shirol, Shri. Rajarambapu Patil S. S. K. Ltd., Rajaramnagar, chief chemists and effluent treatment plant personnel of these organizations are hereby acknowledged for their help and co-operation in carrying out research.

I am thankful to Mr. S. S. Gaddi and Mr. Rajeev Hunshal for assistance in experimental work.

Last, but not the least, the author wishes to thank all those who helped directly or indirectly to prepare the report in the present form.

Er. D. S. Mali

ABSTRACT

Project Title

Challenges of Zero Pollution in Distillery Industry

Themes and Objectives

I. To study the production process of distillery industry.
II. To characterize the spent wash, press mud, bagasse and sugarcane trash.
III. To Study the controlling parameters of composting process of spent wash by using press mud, bagasse and sugarcane trash as a filler material.
IV. To check the feasibility of using sugarcane trash as filler material.
V. To find out the proper ratio of press mud, bagasse and sugarcane trash to have good quality compost.
VI. To find out the optimum time period of composting.
VII. To carry out economic study of this treatment method.

Relevance to Professional or Academic Field

Molasses from the sugar industry, which is one of the by-products, is used as a raw material for the production of alcohol in distillery. The process water from distillery is known as spent wash. The spent wash from distillery creates a very serious problem by the way of threat to the environment. Its volume is as large as 10-15 litre / litre of alcohol produced depending on the type of distillery.

Spent wash is one of the strongest wastes and is highly acidic in nature with higher Chemical Oxygen Demand (COD) and BOD values having very dark colour. The wastewater is hot with temperature range of 95-105 ^{O}C at origin. Methods usually used to treat wastewater are physical, chemical and biological processes. Physical processes widely used are screening, grit removal etc. Chemical processes are not usually very widely used. Biological processes are most widely used which can be classified as aerobic biological treatment process and anaerobic biological treatment process.

The spent wash with low pH (negative logarithm of Hydrogen ion), high dissolved solids, high temperature, high sulfates and high BOD and COD is not amenable to aerobic biological treatment. Physico-chemical methods are also found to be less effective in the treatment of spent wash or combined distillery wastes. Two-stage biological method of treatment consisting of an anaerobic treatment, followed by an aerobic treatment of the waste, has been widely accepted as the only method of treatment of the waste from the distilleries. This requires huge capital investment for the construction and maintenance of the anaerobic digesters.

A single-stage digester is usually adopted for the anaerobic treatment when land available is limited. Anaerobic lagooning is a low-cost alternative to the digester when land available is in plenty. The only disadvantage of anaerobic lagoons is the evolution of volatile gases and obnoxious odour from the ponds. Establishing a proper anaerobic activity in the lagoons can eliminate this odour nuisance. As the high sulfate content and low pH is unfavourable for the methane formers, neutralization of the waste helps in establishing a proper condition for their activity. Presently it is not allowed by MPCB due to ground water pollution problem and smell nuisance.

Anaerobic treatment is used for treating spent wash, which can be produce biogas. The relative proportion of methane is also higher in the biogas obtained, which in turn will increase its fuel value. This can meet the energy demand of the sugar industry. The sludge extracted is doorless. The optimum temperature and pH for operating the process is 35-37ºC and 7-8 respectively. But the main disadvantage is its high volume and stringent controlling parameters.

Actually, anaerobic treatment is an efficient way of treating organic wastes to reach the pollution control levels accepted by pollution control boards. In most cases, it not only reduces pollution, but also generates biogas, which is a valuable fuel. Anaerobic digestion is a common method of reducing sludge solids for the final disposal. All solids settled out in primary and secondary or other basins are pumped to an enclosed airtight digester, where they are decomposed in an anaerobic environment. The rate of their decomposition depends primarily on proper seeding, pH, and nature of the solids, temperature and degree of mixing of raw solids with actively digesting seed material. Digestion serves the dual purpose of rendering the sludge solids readily drainable and converting a portion of the organic matter to gaseous end product. It may reduce the volume of sludge by as much as 50 % of organic matter reduction. Historically, anaerobic treatment was used for treatment and stabilization of concentrated municipal and industrial sludge with 2-7 % solids concentration. The fact that dissolved oxygen is not needed for the process, the methane is a combustible gas has a commercial value and the biomass production is relatively small. All this makes the anaerobic digestion process ideal for the stabilization of organic sludge, the treatment of concentrated organic industrial waste and the production methane gas from agricultural and organic waste.

The anaerobic treatment should be followed by aerobic treatment and for this aerobic composting of spent wash is the best option.

Technology and research - trends and needs

A review of the present and emerging treatment and disposal alternatives for handling spent wash and allied process wastewaters lead to the following significant trends and observations relevant to planning and organizing this research study.

1. Proven technology is available for primary anaerobic treatment and has been used extensively by several distilleries for energy recovery as biogas.

2. The secondary aerobic oxidation process requires a high energy input for oxygen transfer on a continuous basis, which is generally not economical.

3. Post anaerobic spent wash cannot be used directly for irrigation purpose since it would require large amount of dilution water to reduce BOD to below 100 mg/l to comply with CPCB requirement.

4. In case of disposal of spent wash in to inland surface water (river or stream) BOD level should be below 30 mg/l.

5. Concentration- incineration with energy recovery would be an ideal solution available for complete treatment of spent wash. Apparently, this method is not viable because of the large quantity of auxiliary fuel is required for combustion.

6. The thermal processes have undergone extensive development through pilot scale and full-scale installations. However, the technology is yet to be proven on field scale. DIEG (Drying-Incineration-Energy-Generation) process uses dried spent wash power/ pellets to be burned together with bagasse and coal to recover energy as steam and used for generating power. Detailed data on plant performance and cost benefit analysis are not readily available.

7. Composting process has been considered as zero pollution, gives no odour with a high product value easy to handle. It can be a partial remedy, because press mud is not available throughout the year.

8. Each of the alternatives discussed above can go wrong if a site-specific waste management and monitoring programme is not implemented. The results of monitoring must be reviewed periodically and the management plan may be modified, if necessary.

Research Approach or Methodology

In the present experimentation the aerobic composting of spent wash is tried as aerobic treatment method because it will yield good quality compost, most needed for the agriculture.

The spent wash will be added in the filler material till the moisture content is approximately 70 %. The contents are mixed thoroughly in plastic vats having about 15-liter capacity. Every day the overturning is done to have the aeration. Before over turning the composting mass the temperature should be noted down in accordance with the room temperature. After the temperature is taken the overturning will be carried out and 10 gm well mixed sample is kept in hot air oven at 100 + or – 2 ^{O}C for the further analysis. During analysis if moisture content is found below 50 % then the known quantity of spent wash is added to maintain the desired moisture content.

The sample kept for drying is sieved after taking its dry weight for moisture content estimation, and analysed for physical and chemical parameters. The size of the sieve used is 500 microns. Leachate water is prepared by dissolving 1 gm of sieved sample in 100-ml hot distilled water. The mixing of spent wash and filler material is carried out manually. Weakly samples will be taken from the composting mass for analysis purpose.

- For the aerobic composting of spent wash the press mud, bagasse and sugarcane trash will be used as a filler material.
- The addition of press mud and bagasse will help to maintain desired moisture content to have aerobic condition and it will act as a support for the growth of the microorganisms.
- In these experiments the press mud, bagasse and sugarcane trash will be used in the ratio 5:10:0.5 respectively.
- The proportion will be kept 5:1:0.5 to maintain the C/N ratio close to 30.
- The C/N of press mud is 24 and of bagasse is around 54 therefore addition of 20 % bagasse will make C/N ratio 30.

Methods of Analysis

The physico-chemical analysis will be carried out by the procedures described in-

1. Standard Methods for the Examination of Water and Wastewater, American Water Works Association (A. W. W. A.) and American Public Health Association (A. P. H.

A.), Washington, 20th Ed., (Lenore S. Clesceri, Arnold E. Greenberg and Andrew D. Eaton, 1998)

2. Chemical and Biological Methods for Water Pollution Studies, Environmental Publications, Karad (R. K. Trivedy and P. K. Goel, 1986)
3. Laboratory Manual for Environmental Quality Testing, EPRF, Sangli (Rao, B. S., *et al*, 1991)

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CHAPTER-I

INTRODUCTION

CHAPTER - I

1.1 Introduction

Sugarcane, Saccharum officinarum L., an old energy source for human beings and, more recently, a replacement of fossil fuel for motor vehicles, was first grown in South East Asia and Western India. Around 327 B.C. it was an important crop in the Indian sub-continent. It was introduced to Egypt around 647 A.D. and, about one century later, to Spain (755 A.D.).

Sugar industry is one of the major industries in India; usually these sugar industries are accompanied with distilleries and other allied units. Cuba is the major sugar producing country in the world. India enjoys the third place in the world. There are 514 sugar industries in India. Sugarcane is the source of the sugar produced in India. In some other places the raw material used for the production of the sugar are the beetroots.

In India, U. P. is the major sugar producing state whereas; Maharashtra is the second major sugar producing state. In Maharashtra, sugar industry is one of the major industries and is often accompanied with a distillery and other chemical units. Most of the sugar mills operate for about 4 to 8 months just after the harvesting of the sugarcane. A large volume of waste of organic nature is produced during the period of production, and normally this waste is discharged directly on to the land, or into the nearby watercourses, usually small streams. Condition of the stream becomes worse as the stream flow will be very low and eventually enough dilution water is not available during the period of operation of the sugar mills. Thus Maharashtra Pollution Control Board (MPCB) has imposed a strict ban on the discharge of such effluents in the steams. The huge mass of effluent with highly objectionable organic matter renders it unfit for direct discharge on land for irrigation as well as in rivers. Therefore, proper treatment of this effluent is necessary. One of the solid wastes from sugar industry is the press-mud. The quantity of press-mud generated is about 3 - 4% of total sugarcane crushed.

At present farmers in their sugar fields use it as manure. Aerobic composting of the treated spent wash from distillery, and press mud can increase the fertility value of the compost.

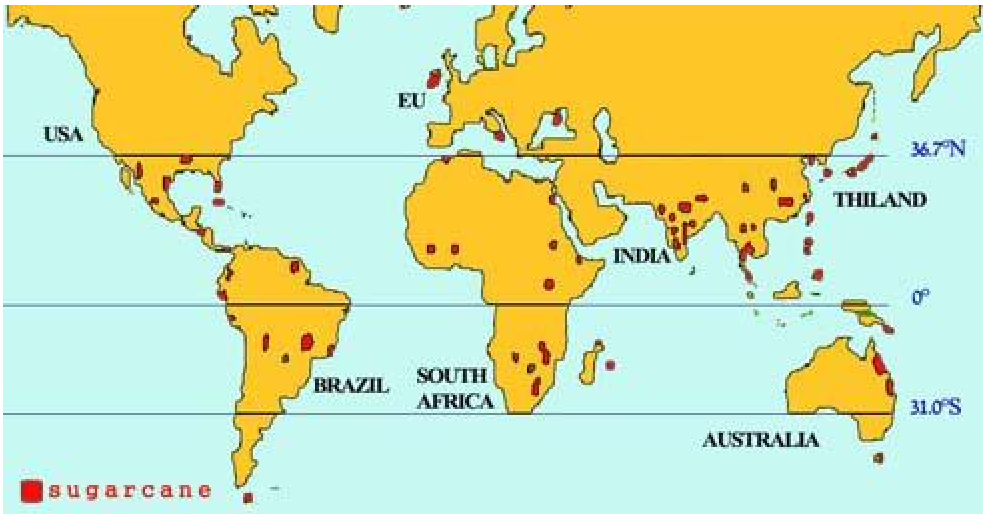

Fig. 1.1: World map showing location of countries producing sugar

Fig. 1.2: Map showing the locations of sugar factories in Maharashtra

1.2 Distillery

Molasses from the sugar industry, which is one of the by-products, is used as a raw material for the production of alcohol in distillery. The process water from distillery is known as spent wash. The spent wash from distillery creates a very serious problem by the way of threat to the environment. Its volume is as large as 10-15 liter / liter of alcohol produced depending on the type of distillery.

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The spent wash with low potentiometric hydrogenium (pH), high dissolved solids, high temperature, high sulfates and high BOD is not amenable to aerobic biological treatment. Physico-chemical methods are also found to be ineffective in the treatment of spent wash or combined distillery wastes. Two stage biological method of treatment consisting of an anaerobic treatment, followed by an aerobic treatment of the waste, have been widely accepted as the only method of treatment of the waste from the distilleries.

A single-stage digester is usually adopted for the anaerobic treatment when land available is limited. Anaerobic lagooning is a low-cost alternative to the digester when land available is in plenty. The only disadvantage of anaerobic lagoons is the evolution of volatile gases and obnoxious odor from the ponds. Establishing a proper anaerobic activity in the lagoons can eliminate this odor nuisance. As the high sulfate content and low pH is unfavorable for the methane formers, neutralization of the waste helps in establishing a proper condition for their activity.

Anaerobic treatment is used for treating spent wash, which can be produce biogas. The relative proportion of methane is also higher in the biogas obtained, which in turn will increase its fuel value. This can meet the energy demand of the sugar industry. The sludge extracted is odorless and the filtration is easy through a better mineralization. The optimum temperature and pH for operating the process is 35-37°C and 7-8 respectively.

Actually, anaerobic treatment is an efficient way of treating organic wastes to reach the pollution control levels accepted by pollution control boards. In most cases, it not only reduces pollution, but also generates biogas, which is a valuable fuel. Anaerobic digestion is a common method of reducing sludge solids for the final disposal. All solids settled out in primary and secondary or other basins are pumped to an enclosed airtight digester, where they decomposed in an anaerobic environment. The rate of their decomposition depends primarily on proper seeding, pH, and nature of the solids, temperature and degree of mixing of raw solids with actively digesting seed material. Digestion serves the dual purpose of rendering the sludge solids readily drainable and converting a portion of the organic matter to gaseous end product. It may reduce the volume of sludge by as much as 50% organic matter reduction. Historically, anaerobic treatment was used for treatment and stabilization of concentrated municipal and industrial sludge with 2-7% solids concentration. The fact that dissolved oxygen is not needed for the process, the methane is a combustible gas has a commercial value and the biomass production is relatively small. All this makes the anaerobic digestion process ideal for the stabilization of organic sludge, the treatment of concentrated organic industrial waste and the production methane gas from agricultural and organic waste.

1.3 Pollution Standards

The pollution standards stipulate that BOD of effluent should be less than 30 mg/liter for disposal into inland surface waters and less than 100 mg/liter for disposal on land. BOD can be 500 mg/liter, in case land application, which is envisaged as a secondary treatment system for further removal of BOD. Regarding water consumption and effluent generation, specified standards are 1,000 liters and 400 liters respectively for per ton of cane crushed.

1.4 Pollution Control

There is scope of recycling and reuse of water in sugar mills thereby minimizing water consumption and ultimately effluent quantity. The recycling and reuse of hot condensate water can reduce the water consumption to as low as. 100-200 liters, as against 1,500-2,000 liters per ton of cane crushed. Proper housekeeping, periodic checking and maintenance of pipe joints, valves and glands further reduces the water consumption and effluent quantity. The effluents from the sugar industry can be treated by conventional biological treatment systems. General, anaerobic biological processes (oxidation ponds and bio-methanation) have several advantages over aerobic processes (aerated lagoons, activated sludge process). Anaerobic processes are easier to control and operate, produce a lower quantity of sludge and their costs are lower. Anaerobic processes decompose the organic compounds in an atmosphere free of oxygen and consequently require significantly less energy as compared to aerobic processes.

Among the air pollution control of treated equipments; wet collectors and multi-cyclones, can reduce particulate matter in boiler emissions by 90% or more. These equipments can reduce. The concentration of particulate matter to 450 mg/ Normal cubic meter.

Double Sulphitation Process, already adopted by most of the sugar industries, reduces the quantity of lime sludge and press mud to a great extent. The lime sludge is usually dumped in low-lying areas, whereas press mud is sold to farmers as it can be used as manure. Bagasse is either used as fuel or sold to pulp and paper industry, which use them as raw materials. Molasses produced in sugar industry is raw materials for fermentation industries.

CHAPTER-II

LITERATURE REVIEW

CHAPTER II

2.1 Literature Review

This chapter presents a review of literature on production process, sources and treatment of different high strength process wastewaters from sugar, distillery, paper, tannery and textile industries by novel physico-chemical, chemical, electro-chemical and biological processes. This chapter also gives a brief discussion on the generation of spent wash during the production of alcohol from molasses, color constituents of molasses, general characteristics of spent wash and merits/ limitations of different treatments currently adopted.

2.2 Distillery waste treatment and disposal options

The best way to minimize wastewater quantity appears to be process modifications. The recycling of spent wash as dilution water can minimize the effluent quantity to around fifty percent. The use of reboilers and multiple effect evaporators can further reduce the effluent quantity to around one third to one fourth.

The treatment technologies such as anaerobic digestion followed by secondary and tertiary treatment may not be the effective solution for the disposal of the treated effluent either into water bodies or on land for irrigation due to high inorganic dissolved solids concentration (i.e. 20,000–30,000 mg/l). The requirement of land is high and the groundwater pollution cannot be ruled out due to continuous application of diluted water for irrigation.

“Composting” and “Controlled Land Application” appears to be one of the viable alternatives. However, these technologies are useful only for the small and medium sized distilleries (i.e. R.S. production up to 45,000 liter/ day).

Distilleries having production capacities more than 50,000litres per day may have to opt for only concentration and incineration.

2.3 Process modifications

Spent wash recycling as dilution water in fermenters can reduce the effluent quantity to around 7-8 liters per liter of spirit production as against 12-15 liters per liter of spirit production in conventional Batch and Continuous Fermentation processes. If the effluent is passed through a single stage reboiler, the effluent quantity can be further reduced by another 15 percent. Subsequently if multiple effect evaporators are used, the effluent quantity can be brought down to 3-4 liters per liter of spirit production. The scale formation problems in evaporators and distillation columns can be avoided considerably if pre-clarification of molasses is followed.

Special yeast strains would increase the brix in wash and thus help to reduce the effluent quantity besides improving the fermentation efficiency.

The reduction of spent wash quantity to 4 – 5 liters per liter of spirit production has been already achieved successfully at Sahyadri S.S.K. Ltd., Yashwantnagar, Tal- Karad, Dist. - Sangli, Maharashtra State by using spent wash as dilution water in fermenters and passing the spent wash through the re-boiler. It is suggested that an expert committee be appointed to study this unit and evolve the guidelines for the benefit of other industries. The dilute streams such as floor washings and spent lease should be segregated and given appropriate treatment. The fermenter cooling waters shall be recirculated. The fermenter washings can be directly used as manure.

2.4 Treatment technologies

2.4.1 Anaerobic treatment followed by secondary treatment

Anaerobic digestion process can be used for the treatment of wastes having high organic contents. The chemical composition of the spent wash mainly contains carbohydrates and some proteins and therefore it is suitable for anaerobic decomposition. The formation of methane is considered as an alternative source of energy, since methane has high calorific value. Hence this process becomes economical and effective for high BOD wastes.

In the anaerobic digestion process, the organic material in mixtures of primary settled and biological sludge under anaerobic conditions is biologically converted to methane and carbon dioxide. The process is carried out in an airtight digester. Sludges are introduced continuously / intermittently and retained in the reactor for varying periods of time. The stabilized sludge, which is withdrawn continuously or intermittently from the process, is non-putrecibile, and its pathogenic content, is greatly reduced.

Anaerobic digestion exploits the ability of various populations of bacteria to perform different steps in a degradation process to break down large organic molecules to water, carbon dioxide and methane. This process provides chemical building blocks for the growth and maintenance of the bacterial population. The core biochemical steps in anaerobic digestion are summarized in Table 2.9

Table 2.1 Core biochemical steps in anaerobic digestion (Wheatly *et al.,* 1997)

Step	Core reactions	Process	Type of bacteria
1	Hydrolysis	Fermentation of complex Fermentative organics to soluble organics	
2	Acidogenesis	Soluble organics converted to volatilefatty acids (VFAs) and alcohols.	Acidogenic
3	Acetogenesis	VFAs and alcohols converted	Acetogenic

		to acetic acid (i.e. ethanoic acid), carbon dioxide and hydrogen	
4	Methanogenesis	Acetic acid converted to methane and carbon dioxide Carbon dioxide and hydrogen converted to methane and water.	Methanogenic

A wide range of microbial species are responsible for the above conversions and each reaction is catalyzed by a distinct group of bacteria/ enzymes.

STEP 1: In Step 1 hydrolysis reactions are carried out by a group of hydrolytic bacteria, which convert complex organics into simpler molecules by means of extra cellular hydrolytic enzymes. Until recently this hydrolysis step was not accorded significant attention mainly because of the complexity of the reactions. Recently this process has been shown to be potentially rate limiting (Pavlostathis and Giraldo-Gomez, 1991) apart from the traditionally acknowledged slow methane formation step.

STEP 2: Step 2 is mediated by a general class of acidogenic bacteria which ferment monosaccharides and amino acids to acetic, propionic, butyric and valeric acids generally termed as volatile fatty acids (VFA). Acetic acid formation is the most preferred since it offers the bacteria with the largest energy yield for growth and it provides the substrate for the methane formers as shown in Step 4. (Mosey, 1983).

STEP 3: Acidogenic bacteria convert propionic and butyric acids to acetic acid. Enrichment cultures of these bacteria indicate that they grow relatively slows even under optimum conditions of low concentration of hydrogen (Lawrence and Mc Carty, 1996).

STEP 4: This is the last step in the entire chain of events leading to the generation of methane. Formation of methane is postulated to occur by two mechanisms.

The bacteria catalyzing this reaction are slow growing and control the pH value of the fermentation medium by the removal of acetic acid and formation of carbon dioxide. They are responsible for most of the methane produced by the anaerobic digestion process (Mosey, 1983). Methane generation (Step 4) can also occur According to equation (2.2) in the presence of hydrogen utilizing methane bacteria. These bacteria grow relatively rapidly with minimum doubling time of six hours and they utilize the H2 produced during the hydrolysis and carbon dioxide produced during acetogenesis to form methane and water.

Distillery spent wash is a complex substrate having high COD (90,000 – 1, 00,000 mg/l), BOD (45,000 – 50,000 mg/l) and low pH (4.2 – 4.5). The major constituents of distillery spent wash are carbohydrates, organic acids, proteins, nitrogenous compounds and minerals. (Bardiya et al, 1995). Clostridium, proteus and peptococcus group of bacteria hydrolyse (Step 1) proteins to amino acids and sugars. Clostridium, acetovibrio celluliticus and staphylococcus hydrolyse carbohydrates to amino acids and sugars. Also, lipids are hydrolyzed to amino acids, sugars, higher fatty acids and alcohol by clostridium and syntrophomonas wolfei in first step of hydrolysis reaction of spent wash.

During fermentation process (Step 2) amino acids and sugars are converted to acetate by lactobacillus, escherichia and staphylococcus and intermediates (valerate, isovalerarte and butyrate) are formed due to the action of clostridium, eubacterium limosum. Zymomonas converts the amino acids to higher fatty acids and alcohol. Further in the third step intermediates are fermented to acetate and hydrogen by syntrophomonas wolfei and syntrophobacter wolfei. Finally in the methanogenesis step (Step 4) acetate and hydrogen are converted to methane by a group of methanothrix, methanobacterium, methanosarcina and methanoplanus.

Anaerobic treatment is now a well-established primary treatment methodology for handling distillery spent wash based on different types of reactors (conventional digester, fluidized bed reactor, fixed film reactor and UASB). Each system varies in respect of reactor size and configuration, and arrangements for effluent and sludge recirculation and mixing. The above reactor systems are capable of treating spent wash having BOD in the range of 40,000 to 50,000 mg/l with an efficiency of 80-85% (Veeramani, 1993).

Frequently, process failure would occur when the system is either overloaded or an attempt is made to restart quickly at full load, after a temporary shutdown. The treatment systems produce biogas having a composition (v/v) of 55-60% methane, 40-50% carbon dioxide and 1-1.5% hydrogen sulphide at the rate of 0.4 - 0.5 m3/kg COD removed. The gas is used as a source of energy by the industry for the generation of steam (Bal and Dhagat, 2001).

Comparing this effluent quality with the prescribed effluent standards, it can be seen that the treated effluent must be diluted if it has to be used for the irrigation or meet the CPCB standard for BOD = (100 mg/l). Anaerobic treatment alone will be inadequate and will require additional downstream aerobic or other physico-chemical treatment steps for environmental compliance.

The primary anaerobic treatment can be followed by a secondary biological (aerobic) treatment process. Two-stage activated sludge process (ASP) with intermediate and final sedimentation tanks and arrangements for sludge recirculation is capable of reducing the BOD level to 300-500 mg/l. The energy requirement for the aeration process is directly proportional to the BOD removal from the system (Ramendra and Manisha, 1992). Successful operation of the process depends on the presence of adequate concentration of dissolved oxygen and biomass Mixed Liquor Suspended Solids (MLSS) in the aeration tank.

In case the wastewater is to be disposed in inland surface waters or used for application on land for irrigation effort should be made to treat the effluent to a BOD level of 30 and 300 to 350 mg/l respectively (Arceivala, 1998).

2.5.1 Acid production

Acid production results in formation of acetic acid or in case of instability of higher fatty acid such as propionic, butyric, iso-butyric, valeric and iso-valeric acid are formed. This converts about 35% of the material in to short chain organic acid that is acetic acid and propionic acid and the rest 65% is converted to alcohol, aldehydes and long chain fatty acid. This percentage depends greatly on waste composition of and will markedly for waste containing different organic compounds.

In this stage, there is very little stabilization of organic materials. This is often called the constant BOD stage, because all that occurs is the chemical rearrangement of the organic molecules. Acid fermentation is characterized by a drop in pH from near neutral to about 5.0 however in a balanced system the subsequent conversation of the acids, as they are formed to methane and carbon dioxide results in pH of 6.8 – 7.4.

2.5.2 Methane production

In this phase, the end products of metabolism of the microorganism of the acid fermentation phase are converted into methane and carbon dioxide by a physiologically unique group of strict anaerobes termed as methanogenic bacteria. A wide range of organic compounds could be degraded to methane during anaerobic digestion. Barker commented on the two-stage process in the production of methane from complex organic compounds and suggested that methanogenic bacteria would probably directly ferment lower fatty acids, alcohol and ketones.

Methane fermentation results in marked reduction in the amount of organic material (COD & BOD) in the system. Stabilization of the oxidizable organic matter is accomplished and the amount of stabilization of organics is directly proportional to the amount of methane produced. It is the slow process in general the rate-limiting step of anaerobic decomposition.

2.7 Controlling parameter

Controlling parameters are mainly classified into two groups:

a. Environmental parameters
b. Operating parameters

Environmental parameters include temperature; stirring mechanism, pH etc. whereas operating parameters include COD, BOD loading, volatile acids, etc.

2.6.1 Temperature

As the temperature increases within a relatively narrow band the specific growth rates of the microorganisms also increases. Different species of bacteria will respond to changes in temperature in qualitatively similar but quantitatively dissimilar ways. Consequently, a digester, which has been developed at one temperature, is likely to have a different balance of species than a digester developed at another temperature. Enzyme catalyzed reaction show a temperature minimum, a temperature optimum and a temperature maximum. This temperature dependence of the reactions is called cryophilic (optimum 20 ^{O}C), mesophilic (optimum 20 – 45 ^{O}C) or thermophilic (optimum 45 ^{O}C).

2.6.2 pH

The production of methane indicates pronounced pH dependence and a relatively small optimum. It is consequently very important to maintain the liquid in the digester at a neutral pH. Acidity (pH 6.3 – 6.6) reduced the activity of the methane bacteria oxidizing hydrogen.

Thus, for thermodynamic reason, less fatty acid is oxidized. They accumulate and lower the pH again.

2.6.3 Stirring mechanism

Mixing arrangement is required in high rate digester. This type of digester can be considered as completely mix flow digester without cellular recycle. Mixing permits more effective utilization of digester capacity, thus allowing higher organic loading rates. Mixing of digester increase the rate of stabilization substantially.

2.6.4 BOD

It is most widely used parameter of organic pollution applied to wastewater. This determination involves the measurement of dissolved oxygen used by microorganisms in the bio-chemical oxidation of organic matter. In order to make the test quantitative, the samples must be protected from the air to prevent re-aeration as the dissolved oxygen level diminishes. Since this is a biological procedure, it is extremely important that environmental condition be suitable for the living organisms to function in an unhindered manner at all times.

2.6.5 COD

This test is widely used as a means of measuring the organic strength of domestic and industrial wastes. This test allows measurement of waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water.

2.6.6 Volatile acids

The volatile acids determination is widely used in the control of anaerobic waste treatment process. In the biochemical decomposition of organic matter that occurs facultative and anaerobic bacteria of wide variety hydrolyze and convert the accumulation of volatile acids can have disastrous effect upon anaerobic treatment if the buffering capacity of the system is exceeded and pH falls to unfavorable levels. Volatile-acids determinations are extremely important in detecting the presence of unbalanced condition in anaerobic treatment units.

2.7 Composting

Even though "composting" appears to be yet another popular method; it has limited application due to non-availability of sufficient filler materials. As such the use of this method needs to be carefully evaluated. The present practices indicate that only one third to one half of the effluent quantity can be consumed except in few exceptional cases where the effluent quantity is reduced by process modifications and inclusion of additional equipment such as reboilers etc. The dosage of "compost" is now well established depending on the type of the crop and soil conditions.

Composting is an aerobic biological process in which organic matter is degraded and mineralized under controlled conditions. When distillery effluent is sprayed over press mud the aerobic bacteria converts the organic matter into humus after 30 days (Deodhar and Shingare, 1989). Alfa-Laval (India) Ltd., have introduced a new technology known as BIOEARTH composting. In this process distillery effluent along with press mud and special type of microbes is arranged in windrows (2m high, 3.5m wide at the base and 300 to 400m long). The windrows are sprayed with a measured quantity of spent wash, usually in the ratio of 2.5–3.0:1 spent wash to press mud (w/w). The ratio will change depending upon the moisture content of the press mud. Special mixing machines traveling along the length of the windrows are used to mix and aerate the decomposing mass, about once in three days. The moisture content during composting is maintained at 50-60% by periodic spraying of the spent wash (CPCB, MoEF, 2002). The composting process has several salient features like zero pollution, no odor or flies nuisance, high product value and a dry product easy to handle and transport. Composting has been adopted by a few distilleries in the country for handling raw or post an-aerobic spent wash as a partial remedy.

2.7.1 Composting system

Broadly the composting systems can be grouped in two headings.

1. Aerobic composting.
2. Anaerobic composting.

The combination of aerobic and anaerobic composting is known as Beccari method. Composting in pits an aerobically is called as Bangalore method. Aerobic system of composting can be operated either manually or mechanically in open windrow, pits or enclosed digesters. Open windrow system is preferred in tropical region, while in temperate region closed digester system is used. The pit method of composting is known as Indore method.

2.7.2 Bangalore and Indore methods

India can take credit for developing systematic manual composting. In 1925 Sir Albert Howard, a British agronomist and his Indian associate Acharya and Subrahmanyam developed the Bangalore and Indore methods of composting.

2.7.3 Bangalore method (Anaerobic method)

A layer of course material is first put at bottom of pit having a depth of 15 –25 cm which is 7.5 cm deeper for a 25 cm width at the pit edges. Now the liquid devoted waste is poured to the thickness of 5 cm in the depressed portion and the elevated edges prevent its draining to the side. On the top of this, second layer is given.

Such alternate layers of solid and liquid waste are given till the height of 30 cm above the edges of pit. The top is rounded to avoid the rainwater entering the pit. Sometimes the top layer of soil is given to prevent fly breeding. It is then allowed to decompose for 4 to 6 months; after which the compost can be taken out for use.

2.7.4 Indore method (Aerobic method)

The same procedure as mentioned above is used here except over turning which is done to maintain the aerobic condition. By maintaining aerobic condition uniform decomposition takes placed and files and odor also get controlled. While filling the pit a space of 60 cm is kept vacant for starting the turning operation. First turning is carried out after 4 to 7 days and second turning after 5 to 10 more days. Further over-turning after 5 to 10 more days. Further over-turning will not be necessary and composting is completed within a period of 13 to 27 days. The windrow method of aerobic composting is more popular for composting municipal refuse without night soil (Bhide and Sundareshan, 1983).

In the process of composting bacteria, fungi, molds and other saprophytic organisms are feed upon organic material. To overcome odor nuisance associated with the breakdown of organic matter under aerobic conditions. Jeam Bordas (1931) suggested introducing a forced air in to piles or turning the piles more frequently.

2.7.5 Rate and extent of reaction

Rate of reaction is synonymous with rate of waste decomposition and therefore is control the process performance. Aerobic composting can be represented in general terms as

$$\text{Organic Matter} + O_2 \xrightarrow{\text{Microorganisms}} \text{Stable organic matter} + CO_2 + H_2O + \text{Heat} + \text{New Biomass}$$

There are some reasons for maximizing the rate of decomposition.

a. The problem of odor nuisance is overcome by rapid decomposition of organic matter through aerobic degradation. For this proper supply of air i.e. frequent overturning is to be done.

b. If the rate of reaction is high then the space, power and energy required is less.

c. The rate of waste decomposition is directly proportional to water vaporization.

2.8 Factors governing the composting process

There are various factors, which governs the composting process. They are as follows:

1. Temperature
2. pH
3. Moisture content
4. Carbon to Nitrogen ratio (C/N)
5. Inoculums
6. Oxygen supply / Aeration
7. Insect control
8. Odor
9. Microbial aspect of composting
10. Time required for composting.

2.8.1 Temperature

The process of composting is exothermic and the filler material is good heat insulator. Hence the temperature of composting mass is increased. The main heat loss from composting mass is taken place from the open surface area at top. So, if surface area is large then heat loss is high. During the process of overturning, drop in temperature is observed; while the decomposition is going on the temperature will go up to 70 ^{O}C. The addition of water will also reduce the temperature of the mass. When the degradation of organic matter is completed then the temperature goes down to room temperature.

Temperature mainly affects the growth and activity of microorganisms and consequently determines the rate at which organic materials are composted. Degradation also proceeds much more rapidly in the thermophilic temperature range (40 to 60 ^{O}C). The optimum temperature range is 50 to 70 ^{O}C usually around 60 ^{O}C is the most satisfactory.

From the study of University of California (1954) it can be said that, when moisture content is high, the temperature near the surface will be higher and high temperature zone will extend nearer to surface, when the moisture content is low.

The United State Public Health Service (1969) has reported on composting experiments (mechanically aerated) that the maximum temperature achieved is 70.6 ^{O}C. The result shows a remarkable increase in the degree of decomposition obtaining at the higher thermophilic temperature. The prolonged high temperatures have avoided because in case of low C/N ratio the nitrogen loss tends to be greater at higher temperature due to the vaporization of ammonia.

Usually in composting process a temperature of 30 to 35 ^{O}C is obtained in first 24 hours of composting and up to 50 to 55 ^{O}C is obtained within 5 to 8 days. The decline in temperature is more gradual than the original rise and indicates that the material has become well stabilized. A sudden drop in a temperature in a pile is the indication of anaerobic condition of pile and then pile should aerate as early as possible. If after 18 to 20 days it is observed that temperature is above atmospheric temperature by several degrees then it is concluded that composting activity is concluding at slower rate.

2.8.2 pH

pH of the composting matter would be 5 to 7 at initial stages. After 2 to 3 days there will be rise in pH and it may go up to 8.5 for remaining degradation. If the overturning frequency is less then the rise in pH will be there. And if drop down in pH for successive three days is observed then it can be concluded that all the organic matter is stable. The pH should be prevented from rising above 8.5 to avoid the nitrogen loss in the form of ammonia. The favorable range of pH for composting process is in the range of 6.5 to 8.0. Nevertheless, initial pH values may extreme as 4.5 or 11 do not see to retard microbial activity for more than one or two days. In aerobic composting the pH is in the range of 6.0 to 8.5. Even the initial pH of spent wash compost is low it will go above 7 within a period of one or two days only.

2.8.3 Moisture content

Moisture replaces the air from the voids, which are in between two particles giving rise to anaerobic condition. On the other hand when the moisture content is too low, then it retards the microbial metabolic activity. It is concluded from various experiments that the optimum moisture content for effective composting is 50 to 60 percent. The filler material used also affects the moisture content. If the bagasse cillo is used as filler material or bagasse is used as filler material then the composting process can be successfully carried out at higher moisture contents (60 to 70 percent).

Fig. : 2.2 View of spent wash being sprayed

The higher moisture content can be used when mechanical aeration is used. In case of paddy straw as filler material the optimum moisture content range may be between 55 and 90 percent. More frequent turning and excess aeration will cause loss of moisture by evaporation. The moisture content of the composting mass can be maintained by adding water or even liquid waste.

2.8.4 Carbon: Nitrogen ratio (C/N)

The carbon to nitrogen ratio can be defined, as, it is the ratio of available nitrogen. The process of decomposition is greatly affected by the Carbon to Nitrogen ratio of composting material. The living biological mass requires thirty carbon parts to one part nitrogen to construct a new cell. That's why the C/N of composting mass should be near to 30 for rapid decomposition.

Research workers have shown that the optimum value of C/N ranges from 26 to 31 depending on other environmental factors.

The municipal waste from developing country has C/N up to 80. Using the sludge of sewage having C/N 5 to 8 can help to reduce it. This also solves the problem of sewage sludge disposal otherwise filter press and vacuum filters are essential. The rate of decomposition reaction is in proportion of C/N. It is reported that if C/N is too great "Robbing" soil nitrogen takes place and if C/N ratio is less then there will be loss of nitrogen from the compost in the form of ammonia. Few scientists are of opinion that an initial C/N of 30 would seem most favorable for rapid composting and would provide some nitrogen in an immediately available form in the finished compost. The ratio of carbon to phosphate must be 100. If the C/N ratio is below 20 then the time required for the degradation will be more.

2.8.5 Inoculums

During the development in process of composting it is reported that the presence of bacteria and fungi is essential for the degradation of organic matter but the effect of enzymes were studied and found that it is unnecessary (Bhide and Sundareshan, 1983). As the process is dynamic it involves various types of microorganisms for various purposes and at specific environmental conditions, one group of bacteria will be inactive while other is acting more efficiently so the addition of culture is essential.

The inoculate in composting of garbage, refuse, manure, sewage, night soil, vegetable waste etc. are not necessary since bacteria are always present in such material (Bhide and

Sundareshan, 1983). Bhide and Sundareshan (1983) reported that inoculums in composting of some industrial and agricultural solids are essential which do not have the required indigenous bacterial population.

2.8.6 Oxygen supply or aeration

Aeration by natural methods takes place in top layers of composting material. But at the same time the bottom layer are anaerobic as the present oxygen is utilized in degradation process. Therefore, it is essential to overturn the mass to maintain aerobic condition and increase the oxygen content. This can be achieved by supplying a compressed air at a rate of 1 - 2 cum/day/kg of volatile solids.

Fig. : 2.3 Composting mass is being aerated

In tropical region the temperature is much higher and aerobic condition can be maintained by only overturning the mass frequently.

The optimum level of oxygen required for the aerobic microorganism's range from 5 to 15 percent of the air, with 5 percent being the minimum essential for the growth of mesophiles. The oxygen consumption depends upon the following factors.

- The stage of process
- The temperature
- The degree of agitation of the mass
- The composition of composting mass
- The grain size of mass
- The moisture content of mass

Oxygen consumption appears to increase and decrease logarithmically with change in temperature. Moisture content affects the air space within the composting mass. If air flow (air supplied) is too high than it will cool down the composting system.

2.8.7 Insect control

As far as composting of spent wash using press mud as a filler material there will be no much problem of fly and insect control. This was reported by Gurudatta (1987) in his dissertation and proved on large-scale plant.

In case of refuse composting the problems of fly is much serous. This can be avoided by less frequent overturning due to which the flies are destroyed due to high temperature produced.

The Compost Corporation of America and Gotaas (1956) found that when composting materials which were attractive to flies and which contains larva and pupae then insulating the piles with stabilized compost would produce higher temperature near the surface resulting in control of fly breeding.

2.8.8 Odor

This indicator is not only an index of efficiency of the process, but it also affects public acceptance and support for composting plant. The odor problem is created due to improper aeration and this can be solved by proper overturning of compost mass or if possible by forced aeration.

To overcome odor nuisance associated with the breakdown of organic matter under anaerobic conditions, it is suggested that introduce a forced air into piles or overturn the mixture periodically or frequently. He also defines aerobic composting as under suitable environmental conditions facultative and aerobic organisms principally thermophilic, utilize considerable amounts of oxygen in decomposing organic matter to fairly stable humus.

2.8.9 Microbiology

Bacteria, fungi and other living organisms carry out Aerobic composting process. The activity of each organism is dependent on availability of degradable organic matter, moisture and temperature. In the process of compost the facultative bacteria are active. At initial stages mesophilic type is dominating while after some period as temperature of mass increases the thermophilic type becomes active. If overturning frequency is low then a fungal growth on outer surface imparts a typical grayish white color.

It was not known till today the role of individual organism in the degradation of different organic matter. The thermophilic bacteria are responsible for breakdown of proteins and other readily biodegradable organic matter. The fungi are responsible for decomposition of cellulose and lignin (Bhide and Sundareshan, 1983). The maximum, optimum and minimum temperature ranges for psychrophilic, mesophiles and thermophilic as shown in following Table 2.9

Table 2.6 Favorable temperature range for different types of microorganisms

Type	**Minimum (^{0}C)**	**Optimum (^{0}C)**	**Maximum (^{0}C)**
Psychrophilic	0-5	1-18	20-22
Mesophiles	10 - 25	23 - 35	35 - 40
Thermophilic	25 - 45	50 - 55	75 - 80

The microbial population changes during aerobic composting. The fungi and acid-producing bacteria appear during the initial mesophilic stage. As the temperature increases above 40 ^{O}C these are replaced by thermophilic bacteria, actinomycetes and fungi. Spore forming bacteria are developed at temperature above 70 ^{O}C. Finally mesophilic bacterial and fungi reappear as the temperature falls down. Many aerobic mesophilic bacteria initially present in the composting material multiply and show increased activity. As the temperature increases, their numbers decrease due to change in the environment.

Actinomycetes (Thermomonospora curvata) may be important in cellulose decomposition. T. Curvata was the most frequently occurring actinomycetes in municipal and mushroom composts, because thermophilic actinomycetes can grow at higher temperatures than thermophilic fungi and they become dominant at the warmest stage.

Mesophilic fungi are present at the beginning, as the compost warms up moderately; thermophilic fungi replace them. The mesophilic fungi reappear in large numbers as the heap cools down below 40 ^{O}C. Evidently they persist in outer layers during the thermophilic stage and reappear when the temperature drops down. The mesophilic fungi can utilize cellulose and hemicelluloses but not as efficiently as thermophilic fungi.

The following table shows number of different organisms present in various stages of composting. The efficiency of the process depends on the temperature.

Table: 2.7 Micro- flora population during aerobic Composting

(Number per gram of wet compost)

Type of Microorganism	**No. of Microbes**	**Mesophilic Initial 40 ^{O}C**	**Thermophilic 40 –70 ^{O}C**	**Mesophilic Initial 70 ^{O}C**
Bacteria				
Mesophilic	6	10^8	10^6	10^{11}
Thermophilic	1	10^4	10^9	10^7
Actinomycetes				
Thermophilic	14	10^4	10^8	10^5
Fungi				
Mesophiic	18	10^6	10^3	10^5
Thermophilic	16	10^3	10^7	10^6

2.8.10 Time required

The time required for composting is nothing but time period of stabilization and maturation. The factors which govern the time of composting are as follows,

a. Initial C/N Ratio.
b. Particle size.
c. Moisture content.
d. Maintenance of aerobic condition.
e. Inoculum.

When the C/N ratio is near 30 then the time required is comparatively less. It can be seen from following Table: 2.11

Table: 2.8 Initial C/N ratio and time required for composting

Initial C/N ratio	Time (Days)
20	9 to 12
20 to 50	10 to 16
78	21

The moisture content of the system should be in the range of 50 to 70% for optimum time of degradation (Bhide and Sundareshan, 1983). Inoculation is another factor, which governs the time required for composting. If inoculation is done then the time required is less and on other hand if it is not done the time required will be more. Therefore, to accelerate the degradation process the inoculation is essential (Bhide and Sundareshan, 1983).

2.9 Controlled land application

The application of spent wash at a rate of 40,000 to 50,000 liters per hectares of land as manure is an accepted method of treatment in Australia and Brazil. The studies made in few places in India also have indicated encouraging results. However, the Regulating agencies do not accept this method as they feel that the monitoring mechanism is difficult. A serious thought may be given to this method of disposal as it would enrich the soil with organic manure as well as inorganic macro and micro nutrients.

2.10 Solar evaporation

It is an accepted method of treatment for salt laden effluents. However, great restrain shall be exercised for the adoption of this technology when organic matter is also present. Solar evaporation pits shall be located at least three kilometers away from the habitation. They shall be constructed preferably in impermeable soil or lined with PVC and suitable protective materials. They shall be situated at least three to five kilometers away from the river banks. Proper monitoring schedule shall be evolved to keep track on ground water quality in the surrounding of solar evaporation pits and also the river water quality on the upstream and downstream. Many of the distilleries are following this technology in many parts of the country. This method of disposal may be abandoned as it creates odor problems even up to five-kilometer distance.

2.11 Concentration and power generation

A lot of input is required to establish the techno-economic viability of concentrating spent wash to fifty to sixty percent solids and use it as a supplementary fuel in boilers. A time bound schedule may be drawn for the distilleries having a capacity more than 50,000 liters per day for implementation.

2.12 Irrigation

The land requirement even after achieving the BOD concentration of 100 mg/l would be 270 hectares for a distillery of 30,000 liters capacity as per the report of IARI. These calculations are based on total dissolved solids concentration of 10,000 mg/l and if the concentration is taken as 30,000 mg/l, which is in reality, the land requirement may be 810 hectares; which appears to be most rational and scientific approach. At Ugar Sugar Works Ltd., Ugar Khurd, Belgaum (dist.), the distillery effluent of 450 cum. per day is being applied on 750 hectares of land and there is no significant effect either on soil characteristics or ground water quality. This can be attributed due to the soil strata which are black cotton and the effluent is applied on sufficient land.

However, the experience of using the treated effluents for irrigation purpose is not very encouraging at many places and in fact most of the irrigation schemes are to be abandoned as the farmers have started resisting due to ground water pollution problems.

2.13 Spent wash from molasses-based alcohol distilleries

In sugar mills the cane is crushed and juice obtained is clarified, filtered, evaporated and centrifuged to get sugar. The main by-products of sugar production are bagasse and molasses. Bagasse is a solid fibrous material and is a valuable by-product with a calorific value of 3000 Kilocalorie (kcal)/kg (moisture 47-50%) and used as boiler fuel (Mall, 1995). Molasses is the syrupy liquid substance remaining after the separation of sugar crystals. It is a heavy viscous liquid with several constituents dissolved in water-sugar like sucrose, glucose, fructose and other reducing substances, carbohydrates as gums and starch, ash as carbonates, sulphates, nitrogenous compounds like proteins, amino acids, glutamic acid, waxes and sterols. It is utilized as the feedstock for the manufacture of alcohol in distilleries (Chen, 1985).

Ethyl alcohol can be produced from molasses, by fermentation. Distillery molasses is first diluted to 10-15% sugar and then acidified with sulfuric acid to pH 4 -4.5. It is supplemented with nitrogen and phosphorus nutrients and seeded with yeast in batch fermenters. After fermentation for 30 to 40 hours at 35-37 ^{o}C, the broth will contain 7 to 10% (w/v) ethanol. The beer then enters a three-column distillation system to yield a final concentration of 95 %(v/v) of ethanol. The first distillation unit is a stripping column, which separates bulk of the alcohol as overhead product and an aqueous bottom product containing all the other constituents as a waste stream (spent wash). The overhead stream containing alcohol, some water and aldehydes passes through heat exchangers and condenser to aldehyde's columns where the low boiling point impurities such as aldehydes are separated as an overhead product. The bottom stream then flows to the third column i.e. rectifying column where alcohol is obtained as the desired final product. Figure.2.1 shows a schematic of the molasses fermentation and distillation units and generation of spent wash as a process wastewater stream.

In the continuous process, yeast is recycled and fermentation and distillation stages are coupled to get a continuous supply of fermented beer for the distillation column. The advantage of the process is that a high active yeast cell density initiates the fermentation rapidly and the alcohol yield is also much higher compared to the batch process.

Bio-still process is one of the commercial continuous processes, in which molasses flow rate to the fermenter is controlled at a constant flow rate to maintain the sugar and alcohol concentrations in the broth at 0.2%(w/v) or lower and 6–7%(v/v) respectively. Only about 10% of molasses is utilized in the processes and the major remaining part ends as an effluent in the process (Vijayaraghavan et al., 1999). The liquid wastes from the process mainly consist of spent wash, besides yeast sludge and floor washings. The resulting spent wash is highly coloured and high in total solids and organic matter. Table 2.5 gives the average characteristics of spent wash generated from batch and bio- still processes.

The dark (black/brown) colour of spent wash is caused by the presence of several constituents of molasses during processing. Some colour constituents are naturally present as plant pigments and some are formed during sugar processing (caramel and melanoidin). There are four major classes of compounds contributing to colour of molasses (Chen, 1985).

1 Phenolic, polyphenolic and flavonoid compounds derived from cane plant mostly are yellow to brown and exist in the plant as non-coloured compounds and are oxidized to coloured state in juice either by enzymes or by chemical oxidation.

2 Caramel compounds formed by decomposition of sucrose.

3 Melanoidin type of compounds formed by the reaction of sugar with amine compound contributing to dark and brown colour besides hydroxymethyl furfuarl (Colourless) rapidly decomposing to dark when sugar is heated in acidic condition.

4 Degradation of fructose.

Distillation of fermented broth for alcohol recovery may also intensify the colour of bottom product- spent wash.

Table: 2.9 General characteristics of spent wash from batch and bio-still process (Dhananjay S. Mali, 2002)

Sr. No.	Characteristics	Batch process	Bio-still process
1	Color	Dark brown	Dark brown
2	Odor	Jaggery smell	Jaggery smell
3	PH	4.3 – 4.5	4.3 – 4.5
4	COD	85,000 – 95,000	2,00,000 – 2,20,000
5	BOD_5 at 20 ^{0}C	35,000 – 45,000	90,000 – 95,000
6	Total Solids	80,000 – 90,000	2,70,000 – 2,80,000
7	Chlorides	3,000 – 5,000	13,000 – 15,000
8	Sulfate as SO_4	2,000 – 5,000	15,000 – 18,000
9	Nitrogen (TKN)	1,000 – 2,000	2,000 – 2,500
10	Potassium (K)	8,000 – 10,000	18,000 – 20,000

11	Sodium (Na)	150 – 200	300 – 500
12	Calcium (Ca)	500 – 600	2,600 – 2,700
13	Phosphorus (PO_4)	800 – 1,200	1,000 – 1,500

Note: All values except pH are in mg/l

Table: 2.10 General characteristics of press mud
(Dhananjay S. Mali, 2002)

Sr. No.	Parameter	Range of Value %
1	Moisture Content (%)	65-75
2	COD of Leachate (mg/lit)	1100-1500
3	Mineral ash (%)	22.1 – 32.1
4	pH	6.82 – 7.2
5	Organic carbon (%)	30 – 42
6	Nitrogen (TKN) (%)	1.05 – 1.5
7	P as P_2O_5 (%)	2.21 – 3.01
8	K as K_2O (%)	0.5 – 0.9
9	Calcium (%)	0.83 –1.98
10	Magnesium (%)	0.05 – 0.25
11	Sodium (%)	0.31 – 0.92
12	Sulfate (%)	0.22 – 0.31

13	Iron (PPM)	2250 – 9500
14	Manganese (PPM)	163 – 625
15	Zinc (PPM)	47 – 225
16	Copper (PPM)	35 – 200
17	Density (t/cum)	0.17 – 0.18

Note: All values are on dry basis

Table: 2.11 General composition of bagasse
(Dhananjay S. Mali, 2002)

Sr. No.	**Parameter**	**Value (%)**
1	Fiber (Including pith, clay and sand)	47
2	Water	50
3	Soluble matter	03
4	Gross calorific value (Kcal / Kg)	2300
5	Minor constituent’s	00.5

Table: 2.12 General separation of sugarcane

Sr. No.	**Parameter**	**Value (% of cane crushed)**
1	Sugar recovery	09.5
2	Bagasse	33.3
3	Molasses	04.5
4	Press mud	3.5 - 4

5	Boiler ash	00.3

2.14 Thermal (concentration- incineration) process

Incineration can be developed as the best method available for complete treatment of spent wash. The total system and accessories can be integrated and developed to operate as a compact facility with efficient energy recovery and by product potash. The system can be targeted for total control of atmospheric emissions and residual pollutants.

A zero-pollution system for the incineration of spent wash named as "SPRANNIHILATOR" was commissioned at Gadhinglaj Sahakari Sakhar Karakhana, Kolhapur based on know-how from Praj consultech, Pune. Inamdar (1989) reported the uniqueness of this process in concentrating the raw spent wash to 60% solids for incineration in a refractory lined furnace at 800 -900 ^{o} C. subsequently similar facility with modified feature was adopted by Polychem Ltd, Nira, Maharashtra. Both these projects were apparently were not viable owing to the need for a significant quantity of auxiliary fuel to sustain the combustion reactions.

Basargekar (1989) reported a similar incineration scheme developed by Thermax, Ltd, Pune. The pilot plant trials at a government distillery, Chitali (Maharashtra) gave satisfactory results and a full scale scheme was planned for 45 KLD distilleries to produce ash (700 kg/h) and steam (11.5 tons/h).

Drying-Incineration-Energy-Generation (DIEG) process developed by Vasantdada Sugar Institute, Pune was adopted by Krishna SSK Ltd, (30 KLD distilleries). The dried spent wash will be burned together with bagasse and coal in the ratio of 45: 50: 5 respectively as a boiler fuel to recover energy as steam, to be used for generating power. Detailed data on plant performance and cost benefit analysis are not readily available CPCB MoEF, (2001).

Technology Evaluation & Norms Study in Industrial Alcohol Industry, a study prepared under Programmes Aimed at Technological Self Reliance (PATSER) prepared by Ministry of Science & Technology, Department of Science & Industrial Research (DSIR, 1993) reported that the Banghikhan distillery located at Pathum Thani in Thailand started alcohol production in the year 1981 with capacity 90 KLD leading to 2000 KLD spent wash as effluent. Tate & Lyle Ltd, U.K. designed and supplied the entire plant. The distillery effluent is evaporated to 60% solids and burned in furnace at 1000 º C. The hot flue gases used for generating steam in the boiler and potassium rich ash is discharged from furnace as a by-product.

The treatment of distillery wastewater to the extent that would make it safe to dispose in the environment has not been possible. In most cases, a partial biological treatment is given through primary anaerobic followed by an aerobic secondary treatment step, such as the activated sludge processes. The secondary effluent will require dilution to meet the effluent standards for disposal on land for irrigation or in an inland surface water body. The thermal processes have undergone extensive development through pilot scale and full- scale installations. Additional efforts are necessary to make these ventures commercially viable.

2.15 Physico - chemical options

Several distilleries in the country have adopted full-scale primary anaerobic treatment of spent wash as an immediate remedy for effecting a large reduction (up to 85% BOD or 70% COD) of the pollution load and to benefit from biogas generated as a valuable alternate boiler fuel. The spent wash after anaerobic treatment still has a very high concentration of all the objectionable pollutants, since only the biodegradable organic constituents are removed as methane and CO2 besides sulphate as H_2S in biogas (CH_4: 50-70, CO_2: 30-50, H_2S: 1-3%). Conventional multi-stage aerobic biological methods for downstream treatment are considered to be costly and not favoured by the Indian distilleries. Instead, they prefer to use the partially anaerobically treated spent wash for irrigation after some dilution. Consequently, there is still an urgent need for downstream processing for environmental compliance. Physico-chemical methods appear relevant for tackling some of the residual pollutants like COD and colour. Potentially promising techniques includes coagulation-flocculation, Fentons oxidation, ozonation, electro-oxidation etc in conjunction with aerobic biological oxidation. Some recent related developments in allied applications are considered to highlight potential relevance of study.

2.16 Coagulation and flocculation

Coagulation/flocculation is a very effective method for the removal of color and suspended matter present in wastewaters. Common coagulants like lime, alum, ferric chloride and ferrous sulfate are generally recommended for industrial wastewater treatment. Gupta and Bhattacharya (1985) have reported 90% color removal from bleach plant effluent of a Kraft Pulp mill (initial color =1216 Pt-Co units) by coagulation with lime (10,000 mg/l).

Oldham and Rush (1978) also had achieved 90% color removal from a Kraft mill effluent having initial color concentration of 2285 Pt-Co units with a lower lime dosage (500 mg/l) and by using magnesium (Mg^{++} = 60 mg/l). Subsequent re -carbonation of the sludge and solid calcining in a kiln enables lime recycling.

Rapson *et al,* (1975) reported 80% of color and suspended solids removal by using 5 - 10% of seawater and lime from Kraft mill effluent. Sea water (5-10%) first added to the combined mill effluent and the mixture was aerated to remove bicarbonates as CO_2. This was followed by the addition of lime (250 mg CaO /l) to produce the flocculent precipitate of $Mg(OH)_2$. As the floc settles it removes color and suspended solids from the effluent. Although coagulation/flocculation is a very effective method for the removal of color, suspended solids, BOD and COD, the major disadvantage of this process is the generation of large amount of sludge posing disposal problems.

2.17 Ozonation

Ozonation is relatively simple in operation and excellent in removal of color and dissolved organic and requires compact equipment. Ozone treatment will give better color removal efficiency for low strength wastewater compared to medium and high strength wastewaters (Lin and Lin, 1993). The reaction rate constant decreases with increase of initial concentration of reactant (Gahr et al., 1994).

Ozonation can give better removal efficiency under alkaline condition ($pH > 8.5$) compared to acidic range ($pH < 6$) (Agnihotri, 1997). Perkins *et al.,* (1995) have reported no effects of pH (range of 2.5-11.2) during ozonation of reactive Red 195, reactive Blue 221, and reactive yellow 145 dyes in terms of color removal efficiency.

Gahr *et al.,* (1994) have observed only 5-20% COD removal with concurrent 95- 100% color removal during ozonation of a mixture of reactive dyes CI: reactive Red (2, 35, 120 and 123), CI reactive Orange 82, and CI reactive Blue 29 dyes with colour concentration of 100 to 2000 mg/l each at pH = 10-12 and run time of 180 min. Specific ozone consumption was 0.25 to 0.4 g O3 for the decolourisation of 1000 mg/l reactive dye and the decolourisation at lower concentration was observed faster than at higher concentration. Beltran *et al.,* (1997) have reported rather low COD removal (22%) during ozonation of distillery wastewaters (COD = 636 mg/l) at 18 ^{o}C and pH = 4 with average ozone rate 1530 mg/h.

2.18 Fenton's oxidation

Hydrogen peroxide with a small amount of ferrous (Fe2+) catalyst has been used to treat organic pollutants in many industrial wastewaters. The hydroxyl radicals formed by Fentons will react with target organic compounds oxidizing them completely with the formation of carbon dioxide and water as end products. Literature review (Lin and Lo, 1997) indicates several studies on chemical oxidation of different recalcitrant and toxicant organic chemicals and some actual industrial wastewaters (Kang *et al.,* 1999). Hydrogen peroxide in combination with ozone has also been used in some of the studies to achieve complete oxidation or an increase in biodegradability (Carbarry and Yang, 1994) or reduction in toxicity through structural modification of the target compounds. It can also be used for pre-treatment of industrial wastewaters prior to biological treatment, or as a post treatment to reduce the residual toxicity of the final treated effluent. Review of existing literature adequately validates the potential of hydrogen peroxide for treating toxic or refractory organics for the treatment of several industrial wastewaters.

Ferrous sulphate is used as a catalyst (H2O2 : Fe2+ = 5 :1) to produce hydroxyl radical from peroxide in all studies based on Fentons oxidation. An optimum pH of 3 -3.5 is maintained for Fentons oxidation for the better removal efficiency and the highly reactive hydroxyl radicals are generated at this range of pH (Park *et al.,* 1999 and Solozhenko *et al.,* 1995).

Beltran *et al.,* (1997) have reported up to 38% COD removal during oxidation of distillery spent wash (COD = 850 mg/l) by hydrogen peroxide (0.1 M) in the presence of UV radiation Park et al., (1999) have reported an improvement in biodegradability of pigment wastewater (COD: 336-28, 621 mg /l, pH= 3-5) by Fenton's oxidation with H2O2: Fe2+ molar ratio 5: 1 with an increase of BOD/COD ratio from 0.04 to 0.36, the COD removal efficiency was observed to be 53-59% during downstream extended aeration treatment.

2.19 Electro-oxidation

This section presents a review of the literature dealing with electrochemical oxidation and electro-coagulation for the treatment of high strength wastewaters. Several electrochemical processes have been reported for the oxidation of different chemical pollutants such as phenol

(Smith 1981), aliphatic and aromatic acids and alcohols (Murphy 1992), dye house effluent and textile wastewater tannery wastewater (Szpyrkowicz *et al.,* 1995) and leachate (Chiang, 1995). The industrial effluents in general consisted of several natural and synthetic compounds like sugars, proteins, amino acids, organic acids, alcohols, aliphatic/aromatic hydrocarbons and mineral constituents.

The electrochemical treatment of organic compounds in wastewater can be potentially a powerful method of pollution control. Oxidizing agents such as hypochlorite, oxygen-based radicals, ozone and nitrogen oxides can be generated *in -situ* in an electrochemical reactor. These oxidizing agents can be utilized for oxidation of the organic pollutants (Rao *et al.,* 2001).

According to Oehr (1978) electrochemical decolorisation of Kraft mill effluent can be achieved using lead dioxide anode and stainless-steel cathode at a low cell current density with sodium chloride added (600 to 1600 mg/l) to the medium.

Berchmans and Vijayavalli, (1989) have conducted laboratory studies on electrochemical treatment of distillery spent wash (200 ml) using graphite electrodes. The trials were conducted with a ten-fold diluted sample and a high dosage of sodium chloride (50,000 mg/l) and current density of 0.5 to 10 A/dm2. Complete removal of color and BOD was reported together with 87% COD removal (initial COD 8000 mg/l) efficiency.

Distillery spent wash effectively treated by Vijayaraghavan (1999) using electrolysis in the presence of sodium chloride. Chlorine produced during electrolysis process forms hypochlorous acid and oxidizes the organic pollutants present in spent wash. Vijayaraghavan have reported 99% COD removal efficiency during electrolysis of distillery spent wash containing (COD 15000 mg/l) in the presence of 3% (w/v) sodium chloride and current density of 34 mg/cm sq.

Wilcock *et al.,* (1992) have reported efficient removal of colour from effluent containing disperse dyes using soluble anodes like iron and aluminium to generate a porous mass, for adsorbing the colour species. Aluminium was found to be the most effective electrode material based on the analysis of residual colour of the effluent, using non-ionic, cationic and anionic polymers as flocculating agent's Non-ionic polymer was found to have better flocculating capacity compared to other polyelectrolyte since the former gave a coarser and readily settling floc.

Lin and Peng (1994) have studied electrochemical treatment of textile wastewater. The organic dye molecules were reduced at the anode and suspended solids were captured by ferric hydroxide Fe (OH)3 flocs to be removed by sedimentation. The iron electrode worked as a sacrificial anode in electrochemical reaction and gave up to 50% removal for an initial COD concentration of 800 to 1600 mg/l after 240 seconds electrolysis. The addition of a small amount of PAC (poly aluminium chloride, 40 mg/l) gave 54% COD removal with 30% less power consumption. Batch electrochemical oxidation trials were carried out by Allen *et al.,* (1995) with sodium chloride as the electrolyte to reduce the concentration of acid dyes (200 mg/l) and COD of effluent. The results showed efficient colour reduction with the complete elimination of organic dyes with a pseudo-first order reaction kinetics.

Tsai *et al.,* (1997) have reported concurrent electro-oxidation and electro-coagulation during treatment of municipal landfill leachate in Taiwan. Electrolysis was carried out in a batch reactor (2L capacity) with copper anode and iron cathode (80 cm2 each). Electrolysis was conducted at 10 volt and COD concentration was reduced from 2107 to 1158 mg/l (45 %) in 20 min. Electro-chemical oxidation of landfill leachate conducted with current density of 15 A/dm2 and added chloride (7500 mg/l) gave 92% COD removal at the end of 240 minutes of reaction (Chiang *et al.,* 1995).

Mameri *et al.,* (1998) used bipolar aluminium electrodes (A single electrode to act as anode and cathode on two opposite surfaces) in an electro-coagulation process for defluoridation. The bipolar electrode is a conductive plate placed between two oppositely charged electrodes without any electrical connection. Bipolar electrode will transform the two neutral sides of the plate to charge sides, which have an opposite charge, compared to the parallel electrode. Thus, on the positive side it undergoes anodic reactions while on the negative side cathodic reactions will occur. The mechanism proposed involves the dissolution aluminium anode to produce Al3+ ions and the latter is transformed to aluminium hydroxide Al(OH)3. Al3+ ions under high concentration of fluoride ions near the anode are induced to form AlF3- which could be transformed to insoluble salt hexafluoro sodium aluminates (Na3 AlF6) by sodium ions as given by equation (2.3 to 2.7). The studies of Mameri showed final fluoride concentration of 0.5 mg/l was achieved in batch mode with (initial fluoride concentration 2.5 mg/l) and aluminium to fluoride weight ratio of 17:1. Optimum values of the parameters such as inter-electrode distance 20 mm, temperature 20 º C, pH 5 -7.6 gave 70% of defluoridation in first 10 min and 90% at the end of reaction (45 min).

Process passivation is one of the common problems in electro-coagulation process, which can considerably reduce the treatment efficiency. One of the approaches to avoid passivation is the use of alternating polarity of the electrodes, which can be achieved by either providing an alternating current supply or by switching the polarity of electrodes periodically. The formation of passivation layers represents a small initial operating cost and can lead to high operating costs as the passivation layer thickness increases (Donini *et al.,* 1994).

Higher concentration of sodium chloride tends to lower settling rate and with a bulky sludge. It also causes a greater amount of aluminium to be dissolved thereby increasing operating cost and the cost of aluminium consumed can represent up to 80% of the total operating cost Donini *et al.,* (1994).

2.20 Technology and research - trends and needs

A review of the present and emerging treatment and disposal alternatives for handling spent wash and allied process wastewaters lead to the following significant trends and observations relevant to planning and organizing this research study.

1. Proven technology is available for primary anaerobic treatment and has been used extensively by several distilleries for energy recovery as biogas.
2. The secondary aerobic oxidation process requires a high energy input for oxygen transfer on a continuous basis, which is generally not economical.
3. Post anaerobic spent wash cannot be used directly for irrigation purpose, since it would require large amount of dilution water to reduce BOD to below 100 mg/l to comply with CPCB requirement.
4. Composting process has been considered as zero pollution, gives no odour with a high product value easy to handle. It can be a partial remedy, because press mud is not available throughout the year.
5. In case of disposal of spent wash in to inland surface water (river or stream) BOD level should be below 30 mg/l.
6. Concentration- incineration with energy recovery would be an ideal solution available for complete treatment of spent wash. Apparently, this method is not viable because of the large quantity of auxiliary fuel is required for combustion.
7. The thermal processes have undergone extensive development through pilot scale and full-scale installations. However, the technology is yet to be proven on field scale. DIEG (Drying-Incineration-Energy-Generation) process uses dried spent wash power/ pellets to be burned together with bagasse and coal to recover energy as steam and used

for generating power. Detailed data on plant performance and cost benefit analysis are not readily available.

8. Each of the alternatives discussed above can go wrong if a site-specific waste management and monitoring programme is not implemented. The results of monitoring must be reviewed periodically and the management plan may be modified, if necessary.

A review of some potentially promising physico-chemical methods for handling COD, colour and pollution problems of some allied industrial applications leads to the following salient features relevant for this study.

1. Coagulation/ flocculation are a very effective method for the removal of BOD, COD, suspended solids and colour. The major disadvantage is the generation of large quantity of sludge creating handling and disposal problems.
2. Coagulation/flocculation efficiency can be improved significantly by the addition of polyelectrolyte and large amount of sludge generation can be avoided by using small amount coagulants.
3. Ozonation is a clean treatment process without sludge generation. Ozone is one of the most effective oxidizing agents for the removal of COD and colour.
4. Ozonation requires small area compared to other conventional treatment process. One of the recognized demerits of the ozonation is high capital and operational cost for the generation of large quantity of ozone.
5. Ozonation removes colour at faster rate with lower concentration compared to medium and high concentrations. Generally alkaline ($pH > 8$) condition is favourable for better removal efficiency compared to acidic range $pH = 2 – 6$.

6. Fentons oxidation and electrochemical oxidation indicates the feasibility of achieving good efficiency of removing COD and colour from distillery spent wash.

7. pH is the most important parameter for Fentons treatment. The highly reactive hydroxyl radical is generated at pH 3.2.

8. Fentons reagent can break down the higher complex molecule to make the molecule biodegradable and enhance the BOD/ COD ratio significantly.

9. Electro-chemical method is an effective means for the treatment of a wide variety of wastewaters.

10. Electro-chemical reactions are attractive as they can be controlled by varying the applied voltage and can be carried out at ambient temperature and pressure with out any further addition of chemicals.

11. Electro-coagulation and electro-oxidation are the two popular methods for the removal of pollutants from effluents. In the former, an adsorbing matrix produced by anodic oxidation of Al or Fe adsorbs the pollutant. In electro-oxidation method, organic pollutants are oxidized to CO_2 and water at anode.

12. Electro-coagulation treatment process has been widely used for the treatment of dye wastewaters to remove the toxic organic pollutants. Operating variables such as pH, wastewater conductivity, and power requirements determine the treatment efficiency.

13. Single stage treatment with ozone, Fenton’s oxidation or electro-oxidation are not adequate and are not economically viable for the effluent treatment. Two stage processes based on physico-chemical treatment followed by biological oxidation may be economical to get better effluent quality.

Coagulation/ flocculation is most effective method for the removal of COD, BOD suspended solids and colour. Coagulants like lime, alum, ferrous sulphate, ferrous chloride and magnesium sulphate are generally recommended for industrial wastewater treatment. Coagulation/flocculation efficiency can be improved by the addition of polyelectrolyte and large amount of solid waste generation can be avoided by using comparatively less quantity of coagulants together with polyelectrolyte. Gupta and Bhattacharya (1985) have reported 90% colour removal from bleach plant effluent by coagulation with lime (10,000 mg/l). Odum and Rush (1978) also had achieved 90% colour removal from kraft mill effluent using 500 mg/l lime together with 60 mg/l of magnesium sulphate. Therefore, the treatment of post anaerobic distillery spent wash by coagulation/ flocculation option was selected for the removal of COD and colour. The feasibility of the technique was established based upon the maximum COD and colour removal with the application of minimum chemicals.

Reverse osmosis requires absolute removal of suspended solids as a high degree of treatment prior to their applications and it is necessary to remove dissolved organic solids to avoid fouling. The use of activated carbon is limited by the associated high cost of regeneration and ozonation technique has become relatively of more attractive. The other advantages of ozonation include no sludge generation, small area requirement, simple in operation and excellent in colour removal. Ozonation is one of the most effective treatment methods for decolourisation and COD removal in industrial wastewaters used as option for the treatment of distillery spent wash.

Fentons treatment is innocuous, as does not introduce any new contaminants to the wastewater being treated. Due to high oxidation potential (1.78 Volt) hydrogen peroxide would decompose quickly to water or oxygen leaving no residuals. It is evident from the review of the literature that several studies on chemical oxidation using hydrogen peroxide with variety of organic chemicals have been reported in the literature. Most studies have been conducted on laboratory scale using pure chemicals. Hydrogen peroxide has been used with various dosages together with iron (Fe2+) catalyst. Some studies have focused on complete oxidation while others were targeted for achieving an increase in biodegradability. Thus, a review of existing literature adequately indicated the potential of oxidation by Fentons treatment for post anaerobic distillery spent wash for the removal of COD and colour.

Electro-oxidation process involves oxidative degradation of organic pollutants present in the effluent. Large organic molecules are degraded to smaller molecules, which may be further oxidized to carbon dioxide and water. Destruction of organic pollutants can be done by direct or indirect oxidation at the anode surface. Besides oxidative degradation, removal of organic species can occur through electro -coagulation in which high surface area adsorbing matrix is generated by electrode reaction. Small organic molecules are captured in the matrix, which are finally removed by sedimentation. Biological methods have the limited applications over the treatment of effluents containing biologically resistant species whereas electro-oxidation process can offer promising approaches for the removal of bio-resistant pollutants which are present as residue after post anaerobic treatment of distillery spent wash.

2.21 Efforts of CPCB in evolving standards for distillery

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

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

Based on the MINAS developed by CPCB, Ministry of Environment & Forests, through the EPA Notification, dated January 8, 1990; specified effluent standards according to the disposal conditions, i.e., the recipient environment, The BOD (20 ^{0}C, 5 days) standards so specified are as follows:

Disposal on stream/river	30 mg/l
Disposal on land	100 mg/l
Disposal on land when land is considered as a treatment medium (land treatment)	500 mg/l
Land treatment with effective monitoring systems for ground water quality	700 mg/l

The standards also include stipulations regarding net additional contribution to ground water quality in terms of BOD not to exceed 3 mg/1 and nitrate not to exceed 10 mg/l. The method of land treatment, involves designing of the hydraulic loading, nutrient loading, crop pattern etc." after considering the porosity/permeability of the soil.

CHAPTER-III

MATERIAL AND METHODS

CHAPTER - III

3.1 Distillery industry

The production process of batch and bio-still process distillery were studied to know the characteristics and quantity of waste generated by them. Molasses is exclusively used as a raw material in the industrial alcohol industry. The final stages being identical, the preparation of the fermenting medium or mash is slightly different in the beverage alcohol industries. In molasses distilleries, the preparation of mash consists of

1. Dilution by water to a sugar content of about 15%
2. pH adjustment in the range 4 to 4.5 for prohibiting bacterial activities and
3. Nutrient addition

The yeast suspension is prepared separately in the laboratory with part of the diluted molasses and then inoculated into the mash for fermentation under controlled conditions. The fermented liquor containing alcohol is then sent to an overhead tank without separation of the solid materials. The same is then de-gasified and then the alcohol is stripped leaving a spent wash. The crude alcohol is then re-distilled and stored in vats.

3.2 Method of analysis

The physico-chemical analysis is carried out by the procedures described in "Standard Methods of Water and Wastewater Analysis" A. P. H. A., 14th Ed. (1974) and Laboratory manual for environmental quality testing, EPRF, Sangli (1991). The digester out let was analysed for pH, volatile fatty acids, Alkalinity and COD.

3.3 Experimental Set up

Aerobic composting

In the present experimentation the aerobic composting of spent wash is tried as aerobic treatment method as it will yield good quality compost most needed for the agriculture. For the aerobic composting of spent wash the press mud and bagasse are used as a filler material. Fresh press mud and bagasse were used as filler material. Experiments were under taken for sugarcane trash also. The addition of press mud and bagasse will help to maintain desired moisture content to have aerobic condition and it will act as a support for the growth of the microorganisms. In these experiments the press mud and bagasse are used in the ratio 5:1 respectively. The proportion is kept 5:1 to maintain the C/N ratio close to 30. The C/N of press mud is 24 and of bagasse is around 54 therefore addition of 20% bagasse will make C/N ratio 30.

Fig.: 3.1 View of composting mass in the laboratory

The lumps of press mud and bagasse are broken and mixed evenly to have homogenous mixture. Then the spent wash is added till the moisture contentment is approximately 70%. The contents are mixed thoroughly in plastic vats having about 15-liter capacity. The mixing of spent wash and filler material is carried out manually. Sample is taken from the composting mass for analysis purpose.

Every day the overturning is done to have the aeration. Before over turning the composting mass the temperature is noted down in accordance with the room temperature.

After the temperature is taken the overturning is carried out and 10 gm well mixed sample is kept in hot air oven at 100 + or – 2 ^{O}C for the further analysis. During analysis if moisture content is found below 50% then the known quantity of spent wash is added to maintain the desired moisture content.

The sample kept for drying is sieved after taking its dry weight for moisture content estimation, and analysed for physical and chemical parameters. The size of the sieve used is 500 microns. Leachate water is prepared by dissolving 1 gm of sieved sample in 100-ml hot distilled water. As mentioned earlier the physico-chemical analysis is carried out by the procedures described in "Standard Methods of Water and Wastewater Analysis" A. P. H. A., 14th Ed. (1974) and Laboratory manual for environmental quality testing, Environmental Protection Research Foundation (EPRF), Sangli (Rao, B. S., et al, 1991). The analysis of composting mass was done every five days for organic carbon and nitrogen. The daily monitored parameters were pH, EC, COD and temperature.). The pH & COD of composting mass was estimated by using the leachate prepared by using one-gram dry sample and dissolving it in 100 ml of distilled water. pH and COD of saturated water was analysed for batch process spent wash composting. If moisture content goes down than 50% then known quantity of spent wash is added.

3.4 Raw materials

The composition of raw materials (spent wash, press mud, bagasse etc.) differs as per variety of sugarcane, maturity, soil condition and method of harvesting and method of fermentation process in distillery. As the composting of spent wash is done using press mud and bagasse as filler material; the characteristics of the raw material used for experiment are given below.

Table: 3.1 Physico-chemical characteristics of spent wash used for experiment (Batch process)

Sr. No.	Parameter	Value
1	Colour	Dark Brown
2	Odour	Jaggery
3	Density (Kg/M^3)	1,040
4	pH	4.8
5	COD	91,200
6	BOD	40,100
7	Chlorides	7997
8	Nitrogen	873
9	Organic Carbon (%)	2.82
10	Potassium (K_2O_5)	12,500
11	Total Solids	83,000
12	Sulfate (SO_4)	2625
13	Phosphorus (P_2O_5)	920
14	Calcium	24,820
15	Sodium	300

All the values are in mg/l, otherwise stated

Photos of Sugarcane trash being collected.


New Holland


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New Holland

3.8 Press mud

It is soft spongy material having dark brown color. It contains around one percent sugar. The production of press mud will be about 3 to 4% of sugarcane crushed. The characteristics of press mud are shown in following Table: 3.2

Table: 3.2. Physico-chemical characteristics of press mud used for experiment

Sr. No.	**Parameter**	**Value**
1	Colour	Muddy Brown
2	Odour	Jaggery
3	Moisture Content (%)	42
4	pH	7.10
5	COD	840
6	Conductivity (Micro mohs/Cm)	500
7	Sodium	8
8	Chlorides	480
9	Nitrogen (%)	1.23
10	Organic Carbon (%)	30
11	Potassium (K_2O_5) (%)	0.80
12	Total Volatile Matter (%)	78.20
11	Ash (%)	17.4

All the values are in mg/l, otherwise stated.

Leachate water was prepared with the help of distilled water in the 1:5 proportions.

3.9 Bagasse

This is the end product remaining after the extraction of juice from the sugar cane. On an average it is around 30 percent of sugar cane crushed. The characteristics of bagasse are shown in following Table No: 3.4

Table: 3. 4. Physico-chemical characteristics of bagasse used for experiment

Sr. No.	**Parameter**	**Value**
1	Colour	Whitish Brown
2	Odour	Jaggery
3	Moisture Content (%)	5
4	pH	7.3
5	COD	364
6	Chlorides	30
7	Nitrogen (%)	0.83
8	Organic Carbon (%)	45
9	Potassium (K_2O_5)	0.12
10	Phosphorus (P_2O_5)	0.0687
11	Sodium	0.009
12	Total Volatile Matter (%)	86.8
13	Ash (%)	10.2

All the values are in mg/l, otherwise stated.
Leachate water is prepared with the help of distilled water in the 1:5 proportions.

3.10 Dilution method

One-gram wet sample was serially diluted using sterile distilled water to have dilutions 10^8 and 10^{10}. From this 0.1 ml is plated by pour plate technique on PDA and nutrient agar medium separately in triplicate. The plates were incubated at room temperature for 48 hours and numbers of colonies were counted. The total and differential count of the various cultures used for the experiment are also carried out.

CHAPTER-IV

RESULTS AND DISCUSSION

Table: 4.1 Physico-chemical characteristics of composting mass with No Sugarcane trash (5 kg press mud + 1 kg bagasse + spent wash)

Days	Composting Mass						Leachate				Loading ml
	Room Temp.	Comp. Temp.	Moist. (%)	O. C. (%)	N (%)	C/N ratio	pH	COD	EC	Cl	
1	27	27	67	47	1.89	24.86	6.9	1424	2080	250	5000
2	30	39	65.2				7.0	1140	2040		
3	28	41	63				7.2	1000	1800		
4	26	45	61				7.4	872	1400	235	
5	31	47	60				8.3	784	1350		
6	27.5	38	65.7				7.6	1840	2100	270	3000
7	26	51	63.9				8.3	1280	2040		
8	28.5	39	61.8				8.3	896	2010		
9	27	32	59.1				8.6	812	2000		
10	28	31	71	45.8	2.13	21.5	7.9	1166	1920	300	2000
11	28	44	64.3				8.1	1012	1890		
12	28	33	64				8.6	976	2010	295	
13	28	31	63.3				8.9	868	1800		
14	28	30	62				8.9	800	1830		
15	28	28	62				8.7	768	1830	290	
16	28	29	61				8.3	720	1520	305	
17	29	30	60				8.9	664	1740		
18	29.5	29.5	59				8.8	600	1680		

19	29.5	29.5	58.6				8.6	632	1790		
20	29.5	30	56.8	38.8	2.28	17.0	8.7	610	1890	320	
21	28.5	31	55.8				8.7	600	1780		
22	29	29	54				8.6	570	1820		
23	28	28	53				8.7	540	1860	340	
24	28	28	52.1				8.5	560	2070		
25	28.5	27	51				8.6	700	2190		
26	27	27	50				8.6	533	2160	350	
27	27	27	50				8.4	640	2100		
28	27	27	49				8.4	640	2000		
29	26	26.5	49				8.3	630	2080		
30	27	27	48	26.4	2.44	10.8	8.2	630	2080	345	

All the values are in mg/l, otherwise stated. Electrical Conductivity is in Micro mohs/Cm. Temperature in degree Celsius. Leachate water is prepared with the help of distilled water in the 1:5 proportions. Saturated water is prepared by squeezing.

Table: 4.2 Physico-chemical characteristics of composting mass with sugarcane trash (5 kg press mud + 1 kg bagasse + 1 kg sugarcane trash + spent wash)

Days	Composting Mass						Leachate				Saturated Water		Loading ml
	Room Temp.	Comp. Temp.	Moist. (%)	O. C. (%)	N (%)	C/N ratio	pH	COD	EC	Cl	pH	COD	
1	23	23	68.3	42.9	2.13	20.14	6.9	2672	1780	270	6.2	8760	3000
2	25.5	45	65				7.5				7.1		
3	25.5	35.5	63				7.4				7.1		
4	24	30	60				7.6				7.2		
5	24	30	58.5				7.9				7.4		
6	22	30	56	42.28	2.16	19.6	8.2	710	1620	256	7.8	4200	
7	24	28	55				8.2				7.8		
8	24.5	26.5	54.5				8.2	576			7.8		
9	24.5	25	53				8.3				8.0		
10	25	24	52				8.4				8.1		
11	24	23.5	51.5	41.8	2.2	19.0	8.3	492	1600	240	8.2	3000	
12	25	23.5	51				8.2				8.2		
13	25	24	58				7.2				7.0		250
14	25	23	56				7.7				7.1		
15	25	23	55				7.8				7.3		
16	25	23	54	41.9	2.26	18.53	7.8	610	1300	228	7.2	3200	

17	25	24	53				7.9				7.4		
18	24	24.5	50.5				7.9	580			7.6		
19	23.5	24.5	49				8.1				7.8		
20	24	24	48.3				8.2				8.0		
21	23	23	57				7.6				7.2		1000
22	23.5	27	55	40.0	2.3	17.4	7.8	912	1705	272	7.4	4608	
23	25	24.5	52				8.9				7.8		
24	24.5	23	48				8.9				8.2		
25	25	24	62				7.3				7.0		1000
26	24.5	24.5	60.8				7.6				7.0		
27	25	24	57				7.8				7.2		
28	24.5	24	55				7.8				7.5		
29	26	25	54				7.8				7.4		
30	24.5	24	53.5	38	2.31	16.45	7.9	404	1450	263	7.2	1720	

All the values are in mg/l, otherwise stated. Electrical Conductivity is in Micro mohs/Cm. Temperature in degree Celsius. Leachate water is prepared with the help of distilled water in the 1:5 proportions. Saturated water is prepared by squeezing.

Table: 4.3 Physico-chemical characteristics of composting mass with Sugarcane trash (5 kg press mud + 1 kg bagasse + 0.5 kg sugarcane trash + spent wash)

Days	Composting Mass						Leachate				Loading ml
	Room Temp.	Comp. Temp.	Moist. (%)	O. C. (%)	N (%)	C/N ratio	pH	COD	EC	Cl	
1	27	27	66	47	1.89	24.86	6.9	1424	2080	250	5000
2	30	40.5	64.1				7.3	1180	1800		
3	28	43	63.1				7.9	1000	1600		
4	26	51	62				8.5	928	1300		
5	31	40	59				8.7	744	1260	237	3000
6	27.5	35	67.9				8.3	1520	1800		
7	26	46	65.3				8.7	1190	1770		
8	28.5	40	63.8				8.5	984	1720		
9	27	33	61				8.6	813	1810	275	2000
10	28	32	69	43.1	2.21	19.5	7.2	1104	1860		
11	28	46.2	65.8				7.5	1080	1890	280	
12	28	35	64.2				8.0	1852	1800		
13	28	30.5	63				8.4	860	1350		
14	28	31.5	62.1				8.4	810	1785	290	
15	28	29.5	62				8.5	752	1670	310	
16	28	29.5	61				8.4	690	1620		
17	29	29.5	60.8				8.3	544	2100		

18	29.5	30	60.1				8.5	550	2050		
19	29.5	30	59.2				8.4	552	2000	330	
20	29.5	30	58	32	2.58	12.4	8.4	600	1890		
21	28.5	30	57.1				8.4	600	1810		
22	29	29.5	56				8.3	600	1870		
23	28	28	54.8				8.4	600	1860	360	
24	28	28	53				8.3	748	2460		
25	28.5	27	52.1				8.1	660	2220		
26	27	27	51.2				8.1	560	2130	340	
27	27	26	50.8				8.0	540	1860		
28	27	27	50.8				8.0	540	1840		
29	26	26	56				7.9	535	1740		
30	27	27	56	30	2.7	11.11	7.8	535	1850	335	

All the values are in mg/l, otherwise stated. Electrical Conductivity is in Micro mohs/Cm. Temperature in degree Celsius. Leachate water is prepared with the help of distilled water in the 1:5 proportions. Saturated water is prepared by squeezing.

Table: 4.4 Total plate count of microorganisms for composting carried out for thirty days period (x 10^{10} / one-gram wet mass)

Days	**A**	**B**	**C**
1	1.2	2.0	3.4
2	22	31	41
3	33	43	42
4	42.9	51.4	47.4
5	9960	4000	7000
6	3700	2900	4600
7	2840	2350	1530
8	0.195	0.518	0.427
9	0.2	0.401	0.18
10	0.2	0.194	0.76
11	0.49	0.112	0.0764
12	0.24	0.13	0.167
13	0.23	0.116	0.156
14	0.12	0.262	0.098
15	0.11	0.581	0.117
16	0.0622	0.0723	0.0561
17	0.0521	0.0627	0.046
18	0.062	0.626	0.0411
19	0.0619	0.0526	0.041
20	0.0426	0.0481	0.0578
21	0.042	0.056	0.051

22	0.0424	0.0517	0.0414
23	0.0373	0.0516	0.063
24	0.22	0.0468	0.0419
25	0.0717	0.019	0.023
26	0.069	0.018	0.023
27	0.0666	0.018	0.022
28	0.011	0.0569	0.031
29	0.011	0.0517	0.031
30	0.021	0.0466	0.0257

A: **5 kg press mud + 1 kg bagasse + spent wash**
B: **5 kg press mud + 1 kg bagasse + 1 kg sugarcane trash + spent wash**
C: **5 kg press mud + 1 kg bagasse + 0.5 kg sugarcane trash + spent wash**

Table: 4.25 Physico-chemical and biological characteristics of compost

Sr. No.	**Parameter**	**Value**
1	Organic Matter	45 – 50 %
2	Nitrogen	2.0-2.5%
3	Phosphorous	2.0-2.5 %
4	Potassium	3.0-3.5 %
5	Calcium	2.5-3.0 %
6	Magnesium	1.5-2.0 %
7	Sulphur	0.5-1.0 %

8	Iron	1000 -1500 ppm
9	Zinc	150 - 200 ppm
10	Manganese	150 - 175 ppm
11	Copper	35 - 40 ppm
12	Boron	2 - 3 ppm
13	Molybdenum	1 - 2 ppm
14	Humic Acid	4 - 6 %
15	Fulvic Acid	2 - 3 %
16	Microorganisms	3 to 4 billion / gram

CHAPTER-V

SUMMARY AND CONCLUSIONS

CHAPTER V

Summary and Conclusions

1. The aeration of composting mass should be carried out more frequently after the addition spent wash and as well as after reloading of for 3 to 4 days as highest temperature rise is observed during these days. This is going to help in improving the maximum absorption of spent wash.

2. It is seen from the analysis of ready compost that the salts concentration is higher hence it's over dose in the same field should be avoided. The nutrient value is found out very good during the study.

3. The findings of study show that there is no difference in value of controlling parameters of compost prepared with sugarcane trash and without sugarcane trash. The COD reduction efficiency of composting is found in the range of 89 to 91 %.

4. The compost reach in organic matter and organic carbon (due to absorption of COD on press mud and bagasse) can be used as a main or supplementary fuel along with other fuel in boiler as it has good calorific value. It is double of the same for the bagasse.

5. Best option for treatment of distillery waste is Aerobic composting of raw spent wash with bagasse, press mud and sugarcane trash as filler material is a method of treatment of zero waste in distillery.

CHAPTER-VI

REFERENCES

CHAPTER VI

Reference

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