International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **2(11),** 23-45, November **(2013)** *Int. Res. J. Environment Sci.*

Innovative Methods for Optimization of Surface Aerobic Bio-composting (SABC) Technique in Managing Molasses based Distillery Wastewater, MS, India

Ghugare Sangram P.[1*] and Samant Jay S. [2]
[1]Department of Environmental Science; Shivaji University, Kolhapur, MS, INDIA
[2]Development, Research, Awareness and Action Institute (DEVRAAI), Kolhapur, MS, INDIA

Available online at: www.isca.in
Received 29th August 2013, revised 5th September 2013, accepted 14th October 2013

Abstract

The distillery wastewater - spentwash - is a highly polluting effluent generated in considerable quantities subsequent to alcohol manufacturing from molasses (a by-product of a sugar factory). So far, number of systems such as anaerobic / facultative lagoons and ponds, anaerobic digesters, solar evaporation and drying, incineration, DIEG (drying after concentration; incineration and energy generation), concentration and incineration by using supportive fuels, aquatic treatment system (ATS) etc. have been tried for spentwash treatment and disposal. Most of them suffered serious limitations while offering limited or no success. Huge land requirements, enormous energy inputs, unhealthy economics, ground water and air pollution, non-consistent working were the prominent limitations faced by most of the treatment methodologies tried. Eventually spentwash composting option came forward as it was felt promising and economically viable. Though initially pit composting was practiced by many distilleries, due to some major disadvantages, it was discontinued. Later on, the on ground composting practice was adopted subsequent to directions and guidelines from Ministry of Environment and Forests (MoEF), and Central Pollution Control Board (CPCB); New Delhi. The bio-composting of spentwash along with filler materials such as pressmud, ash, waste bagasse and agro residue seemed a viable alternative towards treatment and disposal of the distillery waste. However, while working on same, almost all of the effluent treatment facility operators relied on personal judgments while carrying out the composting mostly through trial and error methods. This was due to non-availability of precise mass balance for the substrate materials, lack of understanding of their properties and inability in exercising control on the process parameters due to paucity of appropriate data. The operators were obsessed by the sole objective of disposal of entire spentwash by consuming it totally on available filler materials. The composting operation thus lacked proficient controls, experienced judgments, skilled supervision and adoption of best management practices (BMPs). In light of above facts and modest experience in distillery wastewater management, it was planned to study and evaluate the spentwash composting process being practiced conventionally, at a number of distilleries. For the same detailed laboratory scale experimentation, pilot studies and field scale trials were conducted, in phases, over five years during summer and winter seasons. Under the characterization studies, for each phase, physico-chemical parameters viz. pH, total solids (TS), moisture contents, bulk weights (densities), N, P, K, TVS, ash contents, organic contents, sulphates and C/N ratio for all individual substrate materials were analysed. Tests were also conducted for mixing and blending of the individual solid feed materials in various proportions to observe effects on pH, TS, moisture contents, bulk weights, porosity and free air spaces (FAS) of the resultant feed mix. Further conditioning of pressmud was done through compost recycle and introduction of an amendment in the form of cane trash to improve the solids loading in the in-feed to a compost system. Evaluation of biodegradability, porosity and FAS in the substrate matrix were also done. Performances of composting systems, while changing spentwash loading under various phases, were studied with varied porosity and FAS. Also, the single step and two step composting process configurations for spentwash treatment and disposal were studied and evaluated. It was noted that the losses of biodegradable volatile solids were directly proportional to TS contents of a compost system. Further, from the mass balance, it was also observed that when the quantity of spentwash to a composting windrow was reduced, the overall system TS were found to be increased. The feed conditioning offered distinct advantage towards improvement in the in-feed TS thereby resulting in to enhanced performance. Also, it was revealed that bulk weights of in-feed and compost product decreased with increase in TS to the system which proved that there was improvement in interstices and air spaces in body matrix of both. Thus feed mix could absorb more moisture due to decreased bulk weights and hence could sustain more spentwash loading without leaching. For compost product, bulk weight reduction was nothing but decrease in water (moisture) in the matrix which could lead to an easy and efficient handling, transportation and land application of the product. Eventually, the two step composting proved to be better than single step process due to certain distinct constructional and operational features offering best performance towards biodegradability and BVS losses.

Keywords: Spentwash, SABC, compost recycle, amendment, single and two step composting.

Introduction

The molasses based distilleries, manufacturing alcohol, generate wastewater called ‘spentwash’. It is a dark brown coloured (caramelized) effluent with very low pH, high BOD, COD, total dissolved solids (TDS), sulphates, chlorides and potash i.e. the complex inorganic and organic constituents[1,2]. Treatment and disposal of spentwash is an extremely challenging task due to its highly polluting nature and enormous generation (about 10-12 litres per litre of alcohol for batch fermentation process and 6 to 7 litres for continuous process). Till date, out of number of treatment methods tried for spentwash, only composting felt somewhat promising. The others namely open anaerobic lagooning, in-vessel bio-methanation, concentration and drying, drying after concentration and incineration for energy generation (DIEG), aquatic treatment system (ATS) etc. did not become much popular as they could not offer a full-proof solution and hence many of them eventually got discouragement owing to process limitations, high energy costs, problems of seepage; infiltration and odours. In the end, the bio-composting evolved as a viable alternative for spentwash treatment in view of good organic contents and N, P and K in it[3]. Earlier, pit composting was tried but later on due to some prominent disadvantages associated with it, the same was discontinued and above ground windrow composting process came in to practice[4]. Thereunder, spentwash was composted with pressmud, ash, waste bagasse, agro residue etc. as the filler materials. Subsequently, a number of distillery units went for this type of spentwash treatment. However, achievement of desired performance for process parameters of the windrow composting on field and development of a prototype system where all the aspects in the system have been optimized was yet to come forward. Thus, the up to mark performance and overall economic viability of the windrow composting process always remained unsatisfying. In light of above, it was felt that outcome of investigations with respect to 'Surface Aerobic Bio-composting (SABC) Process' could overcome the aforesaid limitations. As such, it was envisaged to take up a thorough study on different aspects of the conventional windrow bio-composting process for spentwash treatment and disposal.

Methodology

The field scale effluent treatment facility (ETF) setup at the distillery unit of Vishwasrao Naik Sahakari Sakhar Karkhana Ltd. (VNSSK Ltd.), Yashwantnagar, Chikhali, Tal.:Shirala, Dist. Sangli, Maharashtra was selected for experimentation. The sugar factory with cane crushing capacity of 5 Lakh MT per annum has the 30 KLPD distillery unit established during the year 2001-2002. Through onsite composting study during three distillery working seasons (2003-2005), certain discrepancies and limitations were noted especially towards spentwash consumption, quality of final compost product (moisture and odours) and overall mass balance in the process. As such from viewpoint of understanding the science and mechanics of the process, actual laboratory and field testing were undertaken. For this, infrastructure of ETF at the distillery was utilized which included spentwash storage; conveyance; spraying and application arrangements, filler material handling and transportation equipment, windrow forming; turning and mixing machines. The, assistance of field staff and workers also proved vital. The experimentation, divided into various phases, was carried out during the distillery working season (December – May) and crushing season of the sugar factory (November – April) to ensure consistent and adequate supply of fresh pressmud, spentwash and microbial culture for composting.

In the beginning, during 2004.05, laboratory scale experiments were conducted to evaluate pH, TS, moisture contents, bulk weights (densities), free air space (FAS) of the feed materials namely pressmud, boiler ash, compost, cane trash and spentwash. Further, mixing of the solid feed materials; in certain proportions, was done and again the above parameters were determined to see effects of blending on resultant feed mix. Also, studies were carried out by utilization of spentwash to see maximum initial moisture carrying capacities of the solid feed mix as per the proportions of feed mix and spentwash @ 1:1, 1:2, 1:2.5, 1:3 etc. This was done under the assumption that the spraying period on a windrow during actual composting would be of 5 weeks. Subsequently, certain proportions were decided with respect to pressmud and spentwash for actual composting which were 1:2.5; 1:3.5 and 1:2.0 tried under Phase-I, Phase-II and Phase-III respectively. The experimentation under these phases was further divided in to two parts viz. 'First Part' (summer season) from March to May and the 'Second Part' (winter season) from December to February. During the months of June through October, the composting was stopped due to rainy season.

Based on the outcomes of initial studies during Phase-I, Phase-II and Phase-III, later certain modification was tried with respect to the solid feed material going in the composting system. This was done during subsequent Phase-IV and following all the rest phases carried out during course of experimentation. Therein, amendments were introduced in the solid feed material followed by changing of style of composting. Eventually, performance of the most effective system configuration was tested under increased spentwash loading to study effects of increased moisture and variable solids contents simultaneously. After Phase-I to Phase-III experimentation conducted from March-2004 to February 2007, performance evaluation of individual phases was done and further planning was made regarding experimentation under subsequent phases i.e. Phase-IV to Phase-VII. The studies under these phases were carried out from March 2007 to May 2009. During the studies, by using a windrow forming machine, windrows with 25 MT of pressmud were formed with dimensions of 50 X 1.5 X 1.0 M. Actual composting operations involving the experimentation on site lasted for 8 week cycle of windrows spraying and dressing under Stage-I followed by Stage-II of 2 week cycle for windrows curing. The windrows were mixed and homogenized by a particular machine whereas spentwash application was done through 1000 litres capacity calibrated HDPE tanks mounted on a tractor trolley. During actual composting, in the 1^{st} week, the pressmud windrow was left on yard for initial drying when the moisture got reduced up to 40%. Thereafter, the spraying was done so that the moisture of material in the windrow was always in the range of 60% to 70% without any excessive soaking or leaching. Depending up on temperature rise initially, during first 4 weeks (2^{nd}-5^{th} week) more spentwash was applied to the windrows. The rate of spentwash application was reduced in 6^{th} week. No spentwash application was done in the 7^{th} and 8^{th} week where windrows were only turned and mixed. Thereafter, two weeks were given for curing. Activity in the windrows was monitored throughout the 10 weeks' period.

Eventually, moisture dropped to 35% to 40% and temperature went below 50^0C slowing down composting. At the end weight of compost material was taken.

The exercises under all phases were conducted on field as well as in the laboratory by following various procedures recommended by Washington State University, Department of Crops and Soils; USA[5] and Washington Organic Recycling Council; USA[6]. Further the samples of spentwash, pressmud, feed mix and compost were analyzed by using standard methods[7] at a laboratory approved by the MoEF; Govt. of India, New Delhi. During the course of Phase-I to Phase-VII, exercises were conducted on field and in the laboratory to evaluate 13 selected parameters of the substrate materials as well as that of the compost product. The pH; temperature and moisture of substrate were tested weekly before actual mixing and turning operation whereas the bulk weight, organic matter, organic carbon, nitrogen, phosphorus, potassium, calcium, total volatile solids (TVS), total ash and sulphates were determined three times (in the first week, during sixth week and in the tenth i.e. last week).

During the Phase–IV studies which commenced in March-2007, it was decided to increase the solids loading in the composting system over the previously tried TS percentages during Phase-I to Phase-III. Also, the effect of conditioning of the feed (i.e. the substrate material going in the composting system) on the overall performance was decided to be explored. Thereunder, two different sets of simultaneous experimentation were planned namely Phase-IVA and Phase-IVB where it was decided to keep the proportion of feed mix to spentwash as 1: 2, which was concluded from the performance of composting systems under Phase-I to Phase-III. In the Phase-IVA, it was decided to adopt compost recycle for conditioning of the fresh pressmud going in the system and accordingly quantum of compost was worked out. It was thought that the compost product generated could be recycled partly to condition the feed substrate depending up on the nature of feed, its solids content, moisture contents, economics involved in the overall operation as well as the outputs desired. During initial studies up to Phase-III, only pressmud and spentwash were used as substrates to the composting system. However, in light of observations and results of Phase-I to Phase-III, it became necessary to undertake experimentation with increased solids loading in the composting system. Thus for pressmud conditioning, under Phase-IVA, compost recycle was envisaged where compost product from Phase–III was used. Here, an elaborate mass balance in the composting system was established and recycle compost quantum was derived from the wet weight recycle ratio. It was observed that about 30% of the compost is required to be recycled for achieving desired solids content in the feed material. Accordingly, from March 2007 to May 2007 the Phase-IVA was conducted wherein exercises namely- handling and weighment of feed mix, formation of windrow; its drying and inoculation, spentwash spraying, turning and mixing of windrow, sampling and analysis of substrate as well as compost product, monitoring of pH, temperature and moisture in the windrows, weighment of the final compost product etc. were conducted in accordance with a routine that had already been established. A comprehensive mass balance analysis was made and observations were noted. The data was carefully collected and analyzed. Under the Phase-IVB, in addition to the compost recycle, experimentation with introduction of an amendment as the sugar cane trash was planned. The reasons for this were unique. The trash is nothing but a part of cane which is removed during harvesting of the crop and eventually burnt by the farmers. Being from the same crop, availability of trash (about 22% on wet weight basis) and nature of composition did not pose any problems in its use during the composting. The fully dried trash had very low bulk density and with a moisture content of about 15% to 20%, it could become a very good material from view point of both structural as well as energy amendment[8,9]. The cane trash was brought from fields through tractor trolleys, chopped in specially designed equipment which is used by farmers for shredding fodder i.e. the ‘kadba-kutti yantra’. As far as quantity of the cane trash was concerned; it was planned to take 20% of it in total solid feed mix going to the system. Under the experimentation in Phase-IVA, compost recycle was envisaged where the recycle mass replaced about 30% of the pressmud and now by introducing an amendment of 20%, there could be saving in 50% quantity of the pressmud, which otherwise would require as the total substrate. The feed mix : spentwash proportion was kept again as 1: 2.

After the end of Phase-IVB and Phase-VIB in September 2007 and September 2008 respectively, each time about 5.0 MT of compost product was taken to farm of the researcher, located at Gadmudshingi, Tal.: Karveer, Dist.: Kolhapur (MS). At the farm, two separate plots of areas 1 acre each were demarcated whereon sugarcane cultivation was done by using same cane seed material. However, on one plot (i.e the Regular Plot), sugarcane farming by using conventional fertilizers and farm yard manure (FYM) was done whereas on the other (i.e. the Experimental Plot), instead of FYM, spentwash compost formed through SABC was applied along with the routine fertilizers. Rest of practices towards farming were kept the same on both the plots. At the end of cane growing season, the crop was harvested from both the plots and weight of cane was recorded separately at the sugar factory’s weigh bridge which represented weigh per acre i.e. the cane yield. This was compared under the two cases and an inference was drawn.

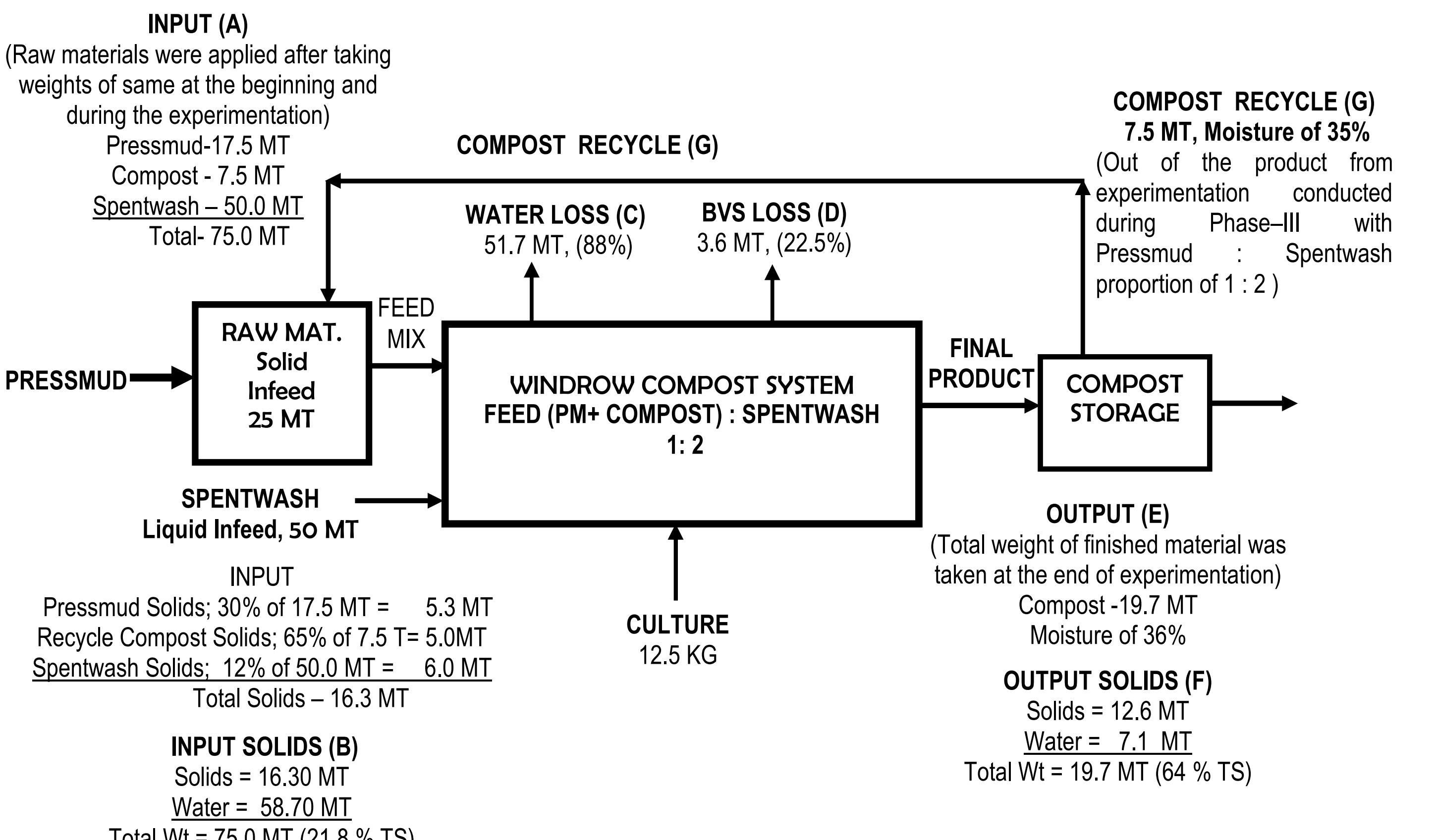
Evaluation of biodegradability was carried out for all the phases studied under experimentation. The same was determined based on ‘Total Mass Loss’ criteria (through an equation as Solids In = Solids Out + Volatile Solids Lost) wherein parameters of the feed mix (spentwash, pressmud, recycled compost) and compost product namely wet weights, fractional solid contents (from TS), volatile solid components as fraction of TS and percentage of TS were determined. Thereafter, from total solids into and out of the composting system, the degradability coefficient for the substrate (k_s) was worked out as a ratio of volatile solids (VS) lost from the process to VS input to the process.

Through the studies for spentwash composting, importance of feed conditioning was revealed. Designers and operators of composting systems usually have a limited number of areas to exercise control on the process out of which composition of the feed mixture is an important one. The proportions of feed components must be adjusted to satisfy the energy balance and avoid rate limitations caused by lack of moisture, lack of free airspace, sterile feed and low nutrient levels. The quantities of required feed components must be known to size the system and its metering, mixing, and conveying equipment. There are three aspects to feed conditioning namely physical or structural conditioning, chemical conditioning and thermodynamic or energy conditioning. Under present studies, only physical or structural conditioning was considered. In a composting system, the relationship between FAS and moisture content is of immense importance that must be considered to assure proper structural conditioning of the feed substrates.

The process flow diagram and mass balance for a single step windrow composting system under Phase-IVA have been presented in figure–1. Also, the details about proportioning and mass balance under Phase-IVA to Phase- VIA are given in table-1. Similar details in respect of two step composting process studied under Phase-VIB and Phase-VII are presented in figure-2 and table-2 respectively. The windrow composting matrix shown in figure-1 and figure-2 is a threefold system comprising of solids, water and gas. The total system volume (v_t) consists of two parts, the volume of solid matter (v_s) and the volume of voids (v_v). The volume of voids could be further distinguished into water volume (v_w) and gas volume (v_g). The terms namely porosity and FAS are commonly used in composting. Porosity, n, in a substrate undergoing composting is defined as the ratio of volume of voids to the total volume of the mass, thus porosity, $n = v_v / v_t$. Also the FAS, f, is defined as the ratio of gas volume to the total volume i.e. $f = v_g / v_t$. Further, the total volume of a composting mixture equals the sum of the volumes of water, solids, and gas contained in the mixture. Initially, the mass balance given in figure-1 (for Phase-IVA) was taken in to consideration for presenting terminology and nomenclature for determination of 'n' and 'f'. Subsequently, the 'n' and 'f' for rest of the phases were worked out. For determination of 'n' and 'f', parameters were evaluated for compost matrix substrate (i.e. pressmud, compost recycle, trash and spentwash) and for water component in the compost matrix which included unit bulk weight, fractional solid content (i.e. TS), specific gravity, volatile solid component of the material as fraction of TS. From laboratory analysis and subsequent mathematical calculations the porosity and FAS values were derived.

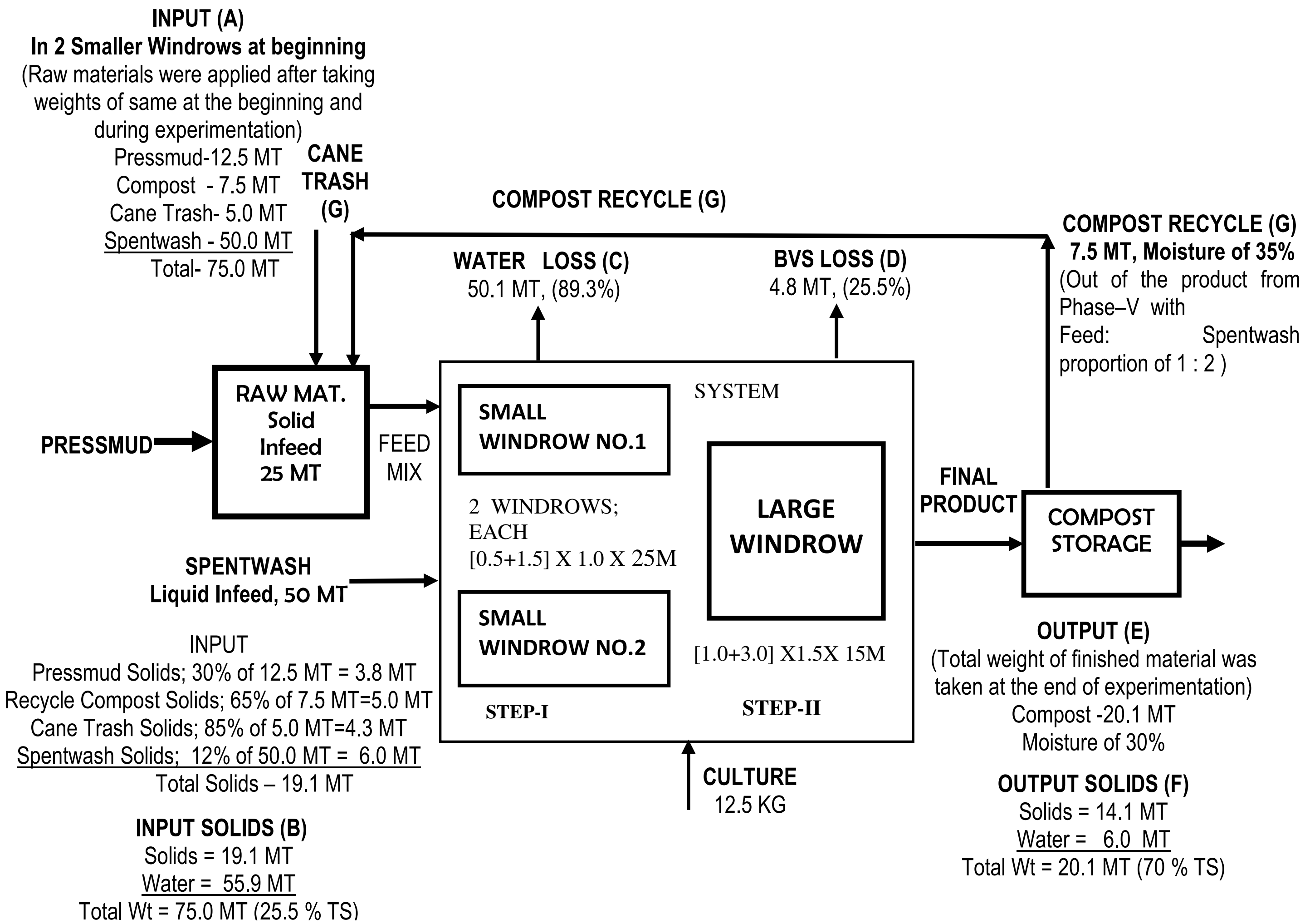
Results and Discussion

The results of studies conducted during the investigations under SABC are presented in this section.



Figure–1

Mass Balance under Phase-IVA; Feed (Pressmud + Compost) : Spentwash; 1 : 2.0 Single Step Composting Process



Figure–2
Mass Balance under Phase-VIB; Feed (Pressmud + Compost + Cane Trash) : Spentwash; 1 : 2.0 Two Step Composting Process

Table-1
Mass Balance under Phase-IVA to Phase-VIA (4 Phases), Single Step SABC Processes

Sr. No.	Description of Phase	A	B	C	D	E	F	G	TVS, Nitrogen, Carbon and C/N
		Substrate Input	**Input Solids**	**Water Loss**	**BVS Loss**	**Compost Output**	**Output Solids**	**Comp. Rec. and Amendment**	
01	**Phase-IVA** (Mar' 07–May 07) Feed Mix (70% PM + 30% COMP.) : SP, 1 : 2.0	FM-25MT SP- 50MT Total-75MT PM-17.5MT COMP-7.5MT	PM- 5.3 MT (30%) COMP-4.9MT (65%) TS of FM-10.2 MT (42%) TS of SP-	51.7MT, 88%	3.6 MT, 22.5%	19.7 MT, Moisture-36% Bulk Wt-315Kg/M^3	TS of 64% Total Solids-12.6MT, Total Water-7.1 MT	7.5 MT, Moisture 35% from product of Phase-III Experimentation with PM : SP proportion of 1 : 2.	**TVS-** PM-80% of TS, 4.2 MT, COMP Recycle-66% of TS,3.2 MT, SP-72% of TS,4.3 MT, Total System TVS - 11.7 MT i.e. 72.2% of Infeed TS, TVS of Final

		Bulk Wt- PM- $500Kg/M^3$ COMP- $320Kg/M^3$ FM- $430Kg/M^3$ SP-1100 Kg/M^3 **Moisture -** PM- 70% COMP- 35% FM-58% SP-88%	6MT (12%) Total system solids- 16.2MT, Total water- 58.8 MT i.e.21.8% of TS loading on the system.						Compost Product - 57% **Nitrogen -** PM- 1.5%, COMP- 1.97%,FM- 1.85%, SP-4.6%, Final Compost Product- 2.15% **Carbon -** PM- 48%, COMP- 38%,FM- 40%, SP-36%, Final Compost Product- 31.2% **C/N Ratio -** PM- 32, COMP- 19.3, FM-21.6, SP- 7.8, Compost Product- 14.51
02	**Phase-IVB** (Mar' 07 – May 07) Feed Mix (50%PM + 30%COMP+ 20% Cane Trash) : SP, 1 : 2.0	FM- 25MT SP- 50MT Total- 75MT PM- 12.5MT COMP- 7.5MT Trash-5 MT **Bulk Wt-** PM- $500Kg/M^3$ COMP- $300Kg/M^3$ Trash- $100Kg/M^3$ FM- $360Kg/M^3$ SP-1100 Kg/M^3 **Moisture -** PM- 70% COMP- 35% Trash- 15% FM- 48% SP-88%	PM- 3.75 MT (30%) COMP- 4.9MT (65%) Trash-4.25 MT (85%) TS of FM- 12.9 MT (52%) TS of SP- 6MT (12%) Total system solids- 18.9MT, Total water- 56.1MT i.e.25.2% of TS loading on the system.	50 MT, 89.1%	4.6 MT, 24.5%	20.4 MT, Moisture- 30% Bulk Wt- 280 Kg/M^3	TS of 70% Total Solids- 14.3 MT, Total Water- 6.1 MT	7.5 MT, Moisture 35% from product of Phase-III Experimentation with PM : SP proportion of 1 : 2. Amendment as Cane Trash-5.0 MT	**TVS-** PM-80% of TS, 3.0 MT,COMP Recycle-66% of TS,3.2 MT,Trash- 90% of TS,3.8 MT,SP-72% of TS,4.3 MT,Total System TVS - 14.3 MT i.e. 75% of TS in the Infeed TVS of Final Compost Product - 61.2% **Nitrogen -** PM- 1.5%, COMP-1.97% Trash-0.4%, FM- 1.6%,SP-4.6%, Final Compost Product- 1.95% **Carbon -** PM- 48%, COMP- 38%,Trash-52%, FM- 44%,SP- 36%, Final Compost Product- 34% **C/N Ratio -** PM- 32, COMP- 19.3,Trash- 130, FM- 27.5,SP- 7.8, Compost Product- 17.4
03	**Phase-V** (Dec' 07–	FM- 25MT	PM- 3.75 MT (30%)	45.2 MT,	4.3 MT,	25.5 MT, Moisture-	TS of 60%	7.5 MT, Moisture 26%	**TVS-** PM-80% of TS,

	Feb 08) Feed Mix (50%PM + 30%COMP+ 20% Cane Trash) : SP, 1 : 2.0	SP- 50MT Total- 75MT PM- 12.5MT COMP- 7.5MT Trash-5 MT **Bulk Wt-** PM- 500Kg/M^3 COMP- 270Kg/M^3 Trash- 100Kg/M^3 FM- 340Kg/M^3 SP-1100 Kg/M^3 **Moisture -** PM- 70% COMP- 26% Trash- 15% FM- 45% SP-88%	COMP- 5.6 MT (74%) Trash-4.25 MT (85%) TS of FM- 13.6 MT (53%) TS of SP- 6MT (12%) Total system solids-19.6 MT, Total water- 55.4 MT i.e.26.1% of TS loading on the system.	81.5%	22%	40% Bulk Wt- 330 Kg/M^3	Total Solids- 15.3 MT, Total Water- 10.2 MT	from product of Phase-IVB Experimentation with FM : SP proportion of 1 : 2. Amendment as Cane Trash-5.0 MT	3.0 MT,COMP Recycle-52% of TS, 2.9 MT,Trash- 90% of TS,3.8 MT,SP-72% of TS,4.3 MT,Total System TVS - 14.0 MT i.e. 71% of TS in the Infeed TVS of Final Compost Product – 54 % **Nitrogen -** PM- 1.5%, COMP- 1.8%,Trash- 0.35%, FM- 1.39%,SP-4.7%, Final Compost Product- 1.7% **Carbon -** PM- 48%, COMP- 30%,Trash-50%, FM- 37%,SP- 35%, Final Compost Product- 30% **C/N Ratio -** PM- 32, COMP- 16.6,Trash- 142.8, FM- 26.6,SP- 7.45, Final Compost Product- 17.6
04	**Phase-VIA** (Mar' 08– May 08) Feed Mix (50%PM + 30%COMP+ 20% Cane Trash) : SP, 1 : 2.5 [2.0+25%]	FM- 25MT SP- 62.5MT Total- 87.5MT PM- 12.5MT COMP- 7.5MT Trash-5 MT **Bulk Wt-** PM- 500Kg/M^3 COMP- 300Kg/M^3 Trash- 100Kg/M^3 FM-	PM- 3.75 MT (30%) COMP- 4.9 MT (65%) Trash-4.25 MT (85%) TS of FM- 12.9 MT (52%) TS of SP- 7.5 MT (12%) Total system solids- 20.4MT, Total water- 67.1 MT i.e.23.3% of	56.6 MT, 84.4%	4.7 MT, 23%	26.2 MT, Moisture- 40% Bulk Wt- 330 Kg/M^3	TS of 60% Total Solids- 15.7 MT, Total Water- 10.5 MT	7.5 MT, Moisture 35% from product of Phase-V Experimentation with FM : SP proportion of 1 : 2. Amendment as Cane Trash-5.0 MT	**TVS-** PM-80% of TS, 3.0 MT,COMP Recycle-51% of TS, 2.5 MT, Cane Trash- 90% of TS,3.8 MT, SP-72% of TS,5.4 MT, Total System TVS -14.7 MT i.e. 72% of TS in the Infeed,TVS of Final Compost Product –58 % **Nitrogen -** PM- 1.5%, COMP- 1.6%'Trash- 0.41%, FM- 1.32%,SP-4.8%, Final Compost Product- 2.5% **Carbon -**

		360Kg/M^3 SP-1100 Kg/M^3 **Moisture -** PM- 70% COMP- 35% Trash- 15% FM- 48.5% SP-88%	TS loading on the system.						PM- 48%, COMP- 28%,Trash-53%, FM- 35%,SP- 36%, Final Compost Product- 32% **C/N Ratio -** PM- 32, COMP- 17.5,Trash- 129.3, FM- 26.5,SP- 7.5, Final Compost Product- 12.8

Note: i. Pressmud, Recycled Compost and Cane Trash (Feed) Windrow Size : B= (0.5 + 1.5) / 2 M, D= 1.0 M, L= 50.0 M, ii. Windrow Volume = 50.00 M^3, iii. Wt of Feed in Windrow = 25,000 Kg. i.e.25 MT(Pressmud;12.5 MT + Rec. Compost; 7.5 MT+ Cane Trash; 5 MT), iv. SP- Spentwash, PM – Pressmud, COMP- Compost, FM- Feed Mix, v. In all the above phases, the microbial culture of 12.5 Kg was introduced to the solid feed mix windrow in second week before the spentwash spraying began. The proportion of culture was 0.5 Kg per MT of the solid substrate.

Table-2
Mass Balance under Phase-VIB & Phase-VII (2 Phases),Two Step SABC Processes

Sr. No.	**Description of Phase**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**TVS, Nitrogen, Carbon and C/N**
		Substrate Input	**Input Solids**	**Water Loss**	**BVS Loss**	**Compost Output**	**Output Solids**	**Compost Recycle**	
01	**Phase-VIB** (Mar' 09 – May 09) Feed Mix (50%PM+ 30%COMP + 20% Cane Trash) : SP, 1 : 2.0 Two Step Process	FM- 25MT SP- 50MT Total- 75MT PM- 12.5MT COMP- 7.5MT Trash-5 MT **Bulk Wt-** PM- 500Kg/M^3 COMP- 300Kg/M^3 Trash- 100Kg/M^3 FM- 360Kg/M^3 SP-1100 Kg/M^3 **Moisture**	PM- 3.8 MT (30%), COMP- 5MT (65%), Trash-4.3 MT (85%), TS of FM- 13.1 MT (53%), TS of SP- 6.0MT (12%) Total system solids- 19.1MT, Total water- 55.9MT i.e.25.5% of TS loading on	50.1 MT, 89.3%	4.8 MT, 25.5%	20.1 MT, Moisture- 30% Bulk Wt- 275Kg/M^3	TS of 70% Total Solids- 14.1 MT, Total Water- 6 MT	7.5 MT, Moisture 35% from product of Phase-V Experimentation with FM : SP proportion of 1 : 2. Amendment as Cane Trash-5.0 MT	**TVS-** PM-80% of TS, 3.0 MT COMP Recycle- 51% of TS,2.4 MT Trash- 93% of TS,3.8 MT SP-72% of TS,4.3 MT Total System TVS -13.5 MT i.e. 70.7% of TS in Infeed TVS of Final Compost Product - 49% **Nitrogen -** PM- 1.5%, COMP-1.6% Trash-0.41%, FM- 1.32% SP-4.8%, Final Compost Product- 1.85% **Carbon -** PM- 48%, COMP-28% Trash-53%, FM-

		- PM- 70% COMP- 35% Trash- 15% FM- 47% SP-88%	the system.						35% SP-36%, Final Compost Product- 27% **C/N Ratio -** PM- 32, COMP- 17.5 Trash- 129.3, FM- 26.5 SP- 7.5, Compost Product- 14.6
02	**Phase-VII** (Mar' 09 – May 09) Feed Mix (50%PM +30%COMP + 20% Cane Trash) : SP, 1 : 2.5 Two Step Process	FM- 25MT SP- 62.5MT Total- 75MT PM- 12.5MT COMP- 7.5MT Trash-5 MT **Bulk Wt-** PM- 500Kg/M^3 COMP- 245Kg/M^3 Trash- 100Kg/M^3 FM- 340Kg/M^3 SP-1100 Kg/M^3 **Moisture -** PM- 70% COMP- 25% Trash- 15% FM- 43% SP-88%	PM- 3.8 MT (30%) COMP- 5.6MT (75%) Trash-4.3 MT (85%) TS of FM- 13.7 MT (57%) TS of SP- 7.5 MT (12%) Total system solids- 21.2MT, Total water- 66.3MT i.e.24.2% of TS loading on the system.	55.6 MT, 83.8%	5.2 MT, 24.5%	26.7 MT, Moisture- 40% Bulk Wt- 332 Kg/M^3	TS of 60% Total Solids- 16.0 MT, Total Water- 10.7 MT	7.5 MT, Moisture 25% from product of Phase-VIB Experimentation with FM : SP proportion of 1 : 2. Amendment as Cane Trash-5.0 MT	**TVS-** PM-80% of TS, 3.0 MT COMP Recycle- 41% of TS,2.3 MT Cane Trash- 90% of TS,3.8 MT SP-72% of TS,5.4 MT Total System TVS -14.5 MT i.e. 68% of TS in the Infeed TVS of Final Compost Product - 50% **Nitrogen -** PM- 1.5%, COMP-1.5% Trash-0.36%, FM- 1.1% SP-4.8%, Final Compost Product- 1.95% **Carbon -** PM- 48%, COMP-22% Trash-54%, FM- 32% SP-36%, Final Compost Product- 28% **C/N Ratio -** PM- 32, COMP- 14.6 Trash- 150, FM- 29.1 SP- 7.5, Compost Product- 14.4

Note: i. Pressmud; Recycled Compost and Cane Trash (Feed) Windrows : Under STEP-I : Two Smaller Windrows, Each of (1.5 M Base and 0.5 M Top) X 1.0 M Ht X 25 M Length, Under STEP-II : One Large Windrow of (3.0 M Base and 1.0 M Top) X 1.5 M Ht X 15 M Length, ii. Windrow Volumes; Under Step-I, Total Volume of Two Windrows - 50.00 M^3, Under Step-II, Total Volume of Single Windrow - 45.00 M^3, iii. SP- Spentwash, PM – Pressmud, COMP- Compost, FM- Feed Mix, iv. In all the above phases, the microbial culture of 12.5 Kg was introduced to the solid feed mix windrow before the spentwash spraying began. The proportion of culture was 0.5 Kg per MT of the solid substrate.

Table–3
Results of Phase-IVB, Feed (Pressmud+ Compost + Trash) : Spentwash; 1 : 2.0, (March - May 2007), Single Step Process after Feed Conditioning

NO	Parameter	SP	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
01	pH	4.7	7.8	6.0	6.5	7.1	7.5	7.3	7.6	7.4	7.4	7.5
02	Temperature ^{0}C	32	35	65	66	67	65	61	55	51	46	41
03	Moisture % (combined feedmix)	88	48.4 - 31	76	77	78	68	57	50	44	35	30
04	Organic Matter %	71.8	75.9	----	----	----	----	67.6	----	----	----	58.6
05	Organic Carbon %	35	44.0	----	----	----	----	39.2	----	----	----	34.0
06	Nitrogen %	4.6	1.60	----	----	----	----	1.80	----	----	----	1.95
07	C / N Ratio	7.6	27.5	----	----	----	----	21.8	----	----	----	17.4
08	Phosphorus(P_2O_5) %	0.31	2.1	----	----	----	----	----	----	----	----	1.7
09	Potassium (K_2O) %	9.5	1.5	----	----	----	----	----	----	----	----	2.9
10	Calcium %	2.6	2.90	----	----	----	----	----	----	----	----	3.15
11	TVS %	72.5	77.0	----	----	----	----	70.6	----	----	----	61.2
12	Total Ash %	27.5	23.0	----	----	----	----	29.4	----	----	----	38.8
13	Sulphates %	4.7	1.80	----	----	----	----	------	----	----	----	3.90

Note: i. Pressmud, Recycled Compost and Cane Trash (Feed) Windrow Size : B= (0.5 + 1.5) / 2M, D= 1.0 M, L=50.0 M, ii. Windrow Volume = 50.00 M^3, iii. Wt of Feed in the Windrow =25,000 Kg. i.e.25.00 MT (Pressmud 12.5 MT+ Recycled Compost 7.5 MT + Cane Trash 5.0 MT), iv. Total spentwash sprayed in 1: 2.0 proportion, 50.0 MT (i.e. 100% Qty), v. '----' indicates not analyzed. vi. W1,W2,W3……..W10 - Week numbers in composting. vii. SP- Spentwash.

Table-4
Results of Phase-VIB, Feed (Pressmud + Compost + Trash) : Spentwash; 1 : 2.0, (March - May 2008), Two Step Process after Feed Conditioning

NO	Parameter	SP	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
			STEP-I; Two Smaller Windrows, Each of (1.5 M Base and 0.5 M Top) X 1.0 M Ht X25 M Length				**STEP-II; One Large Windrow, of (3.0 M Base and 1.0 M Top) X 1.5 M Ht X 15 M Length**					
01	**pH**	4.3	(Sat) 7.2	6.1	6.6	7.0	7.4	7.1	7.3	7.4	7.4	7.5
		4.6	(Sat) 7.0	5.9	7.0	7.1						
02	**Temperature ^{0}C**	32.0	36	64	66	66	70	73	67	52	45	40
		32.0	35.5	62	66	64						
03	**Moisture%** (feedmix)	88	48.5– 25	75	76	78	65	58	50	44	37	30
		88	48.5– 28	74	77	77						
04	**Organic Matter%,**	71.5	62.1	----	----	----	----	55.2	----	----	----	46.5
05	**Organic Carbon%**	34.5	35.0	----	----	----	----	32.0	----	----	----	27.0
06	**Nitrogen %**	4.8	1.32	----	----	----	----	1.70	----	----	----	1.85
07	**C / N Ratio**	7.5	26.5	----	----	----	----	18.8	----	----	----	14.6
08	**Phosphorus (P_2O_5) %**	0.3	1.3	----	----	----	----	----	----	----	----	1.0
09	**Potassium (K_2O) %**	9.3	1.80	----	----	----	----	----	----	----	----	3.28
10	**Calcium %**	2.8	3.10	----	----	----	----	----	----	----	----	3.12
11	**TVS %**	72	63.0	----	----	----	----	58.0	----	----	----	49.0
12	**Total Ash %**	28	37.0	----	----	----	----	42.0	----	----	----	51.0
13	**Sulphates %**	4.7	1.75	----	----	----	----	-----	----	----	----	3.55

Note: i**.** Two Windrows made out of Pressmud , Recycled Compost and Cane Trash (Feed) each having Size : B= (0.5 + 1.5)/2 M, D= 1 M, L=25 M, ii.Volume of Single Small Windrow = 25.00 M^3, iii. Wt of Feed in the Windrow = 12,500.00 Kg. i.e.12.50 MT, iv. For the Two Windrows, Total Feed Material was taken as – Pressmud; 12.5 MT+ Recycled Compost; 7.5MT+ Cane Trash; 5.0MT=25.0MT, v.Total spentwash sprayed in 1: 2.0 proportion = 50.0 MT (i.e. 100% Qty), vi.'----' indicates not analysed, vii.W1,W2,W3……..W10- Week numbers in composting, viii. SP- Spentwash.

From overall studies it was observed that the set up under Phase-VIB i.e. Two Step Process with feed to spentwash proportion of 1: 2.0 gave much satisfactory results as far as substrate degradability and quality of final product were concerned. The composting system under this phase revealed the best performance over rest of the phases in light of parameters namely – i. pH change of the substrate, ii. temperature rise in the composting mass, iii. attainment of the maximum temp. in the windrow, iv. moisture loss during the process, v. moisture content of the final product, vi. degradation of the organic matter, vii. loss of volatiles, viii. inorganic contents of the final compost mass, ix. C/N ratio of the product, and x. potassium content in the compost. Table-4 could be referred for various parameters analyzed during all the phases that were studied. Table-5 gives values of the degradability coefficient 'k_s' derived on the basis of concept mentioned above.

In table-6, information about porosity and FAS under various phases is presented.

Observations: In the beginning, five different substrates utilized during composting were analyzed which were spentwash (the only liquid substrate), pressmud, bagasse ash, cane trash and ready compost. The pressmud and ash were regular filler materials being used in the composting of spentwash at many distilleries. However, the cane trash and ready compost were studied from a view point of their role as probable amendments. The amendment is nothing but a material that could be introduced in other substrates for conditioning the feed mixture. There are two types of amendments. First, the structural amendment (also called as drying amendment) which is an organic / inorganic material just added in order to reduce the bulk weight as well as to increase air voids for allowing proper aeration in the compost mass. Second, the energy amendment (also referred as fuel amendment) is solely an organic material that is introduced to increase biodegradable organic contents of the composting substrate thereby improving energy content of the mixture. Various parameters of substrate materials which were tested during the experimentation included pH, moisture, temp., TS, TVS, organic matter and carbon, ash, N, P and K, calcium, sulphates and bulk weights.

The pressmud was looked up on as the first and foremost as well as major substrate in a composting system. Its organic and inorganic parts along with N, P and K contents in addition to the moisture received prime consideration. The ash although seemed to be a good filler material along with the pressmud due to its low moisture (9%), very less bulk weight (70 Kg/M^3) and reasonable N, P and K contents, its alkaline pH seemed to be a problem especially if its addition was done in an unplanned manner as per schedule of availability from a sugar factory. Shifting of the pH balance towards alkaline side in the feed mix was noted from studies conducted for its blending. The composting substrate becoming or remaining alkaline for longer time could have undesirable effects on the nitrogen content of the final products since at high pH the nitrogen is lost as ammonia gas from the windrow[10]. Properties of cane trash and ready compost presented in table-7 seemed suitable for their use as amendments with pressmud - individually or in a combined manner.

The materials being either generated directly from main cane crop (i.e. the trash) and indirectly after the crop's crushing (i.e. pressmud) as well as after processing of a by-product (i.e. the spentwash), their combination with main substrate (i.e. the pressmud) felt promising. Also, no any limitation was perceived on availability of cane trash and compost.

The lab scale studies conducted towards mixing and blending of different solid substrates so as to formulate solid feed mix for a composting system revealed a number of facts. The single substrate pressmud with initial moisture of 67% and bulk weight of 500 Kg/M^3 showed decrease in these parameters subsequent to blending with compost, ash and trash in various proportions. The improvement in moisture and bulk weight is very important from view point of handling of the materials as lesser loads (weights) are required to be transported and applied on yard. Further, for subsequent application of the spentwash with about 89% moisture, initial reduced moisture contents of the solid substrates is very much essential and desirable so that increased quantities of spentwash could be taken up by the feed mix. As the moisture content in feed mix went on decreasing, there was an improvement in FAS in substrate. This directly indicated that the gas / air volume in overall volume of voids (porosity) increased. This was an important observation of a situation required for maintaining aerobic atmosphere during composting, which is very much desirable. In laboratory, studies were also conducted for checking the potential of pressmud and feed mix towards initial spentwash holding where $1/5^{th}$ (i.e. 20%) of total quantity of spentwash to be consumed in accordance with pressmud / feed mix to spentwash proportion was utilized for blending. This was done under an assumption that the entire spentwash shall be sprayed within 5 weeks on a windrow during actual composting operation. Here important parameters of the substrates studied included pH, moisture, TS, porosity, FAS and bulk weights. With pressmud only, the moisture content of substrate went on increasing as the pressmud : spentwash proportion was increased from 1 : 1 to 1 : 3.5. Accordingly, the bulk weight increased in direct proportion whereas the FAS varied inversely. However, for pressmud plus compost, the reduction in initial moisture contents of feed mix had a specific advantage while taking up the spentwash load. This was reflected from reduced moisture of the blended materials along with reduction in bulk weight and increase in the FAS.

Table–5
Substrate Biodegradability in Phase-IVA to Phase-VII

No.	Phase	Series	Proportion	Duration	Deg. Coeff., K_m
01	Phase-I; Sum.	PM : SP	1 : 2.5	Mar - May 04	0.23
02	Phase-I; Win.	PM : SP	1 : 2.5	Dec 04 - Feb 05	0.18
03	Phase-II; Sum.	PM : SP	1 : 3.5	Mar - May 05	0.16
04	Phase-II; Win.	PM : SP	1 : 3.5	Dec 05 - Feb 06	0.13
05	Phase-III; Sum.	PM : SP	1 : 2.0	Mar - May 06	0.26
06	Phase-III; Win.	PM : SP	1 : 2.0	Dec 06 - Feb 07	0.22
07	Phase-IVA; Sum.	FM: SP	1 : 2.0	Mar - May 07	0.30
08	Phase-IVB; Sum.	FM: SP	1 : 2.0	Mar – May 07	0.33
09	Phase-V; Win	FM: SP	1 : 2.0	Dec 07– Feb 08	0.30
10	Phase-VIA; Sum.	FM: SP	1 : 2.5	Mar – May 08	0.31
11	Phase-VIB; Sum.	FM: SP	1 : 2.0	Mar – May 08	0.36
12	Phase-VII; Sum.	FM: SP	1 : 2.5	Mar – May09	0.36

Note: PM- Pressmud, FM-Feed Mix, SP- Spentwash, Sum.- Summer, Win.- Winter

Table–6
Porosity, FAS and Specific Gravity Values for Substrate Matrix during Phase-I to Phase-VII

Sr No.	Phase	Series	Proportion	Sp. Gr. of Mix Solids ‘G’	Porosity ‘n’	FAS ‘f’
01	Phase-I; Sum.	PM :SP	1 : 2.5	1.18	0.86	0.51
	Phase-I; Win.	PM :SP	1 : 2.5	1.16	0.87	0.50
02	Phase-II; Sum.	PM :SP	1 : 3.5	1.16	0.89	0.49
	Phase-II; Win.	PM :SP	1 : 3.5	1.16	0.90	0.47
03	Phase-III; Sum.	PM :SP	1 : 2.0	1.21	0.87	0.52
	Phase-III; Win.	PM :SP	1 : 2.0	1.19	0.87	0.51
04	Phase-IVA; Sum.	(PM +RC): SP	1 : 2.0	1.30	0.86	0.59
05	Phase-IVB; Sum.	(PM +RC+ CT) : SP	1 : 2.0	1.25	0.86	0.63
06	Phase-V; Win.	(PM +RC+ CT) : SP	1 : 2.0	1.27	0.88	0.58
07	Phase-VIA; Sum.	(PM +RC+ CT) : SP	1 : 2.5	1.27	0.88	0.57
08	Phase-VIB; Sum.	(PM + RC+ CT) : SP(Two Step Process)	1 : 2.0	1.29	0.86	0.63
09	Phase-VII; Sum.	PM + RC+ CT) : SP (Two Step Process)	1 : 2.5	1.35	0.88	0.61

Note: PM- Pressmud, RC-Recycle Compost, CT- Cane Trash, SP- Spentwash, Sum.- Summer, Win.- Winter

Table–7
Characteristics of Sugarcane Trash and Recycle Compost (%)

Sr. No.	Description	Cane Trash	Recycle Compost
01	Total Solids	87	45
02	Moisture Content	13	55
03	Sulphates as SO_4^{--}	0.47 (dry weight basis)	4.7
04	Total Volatile Solids	89.0 (dry weight basis)	72
05	Organic Matter	86.0 (dry weight basis)	68.9
06	Organic Carbon	50.0 (dry weight basis)	40
07	C/N Ratio	119	23.3
08	Potassium (K_2O)	0.1 (dry weight basis)	2.3
09	Total Ash	11.00 (dry weight basis)	28
10	Calcium (CaO)	0.03 (dry weight basis)	3.9
11	Phosphorus (P_2O_5)	0.12 (dry weight basis)	2.79
12	Nitrogen	0.42 (dry weight basis)	1.72
13	Bulk Weight	100 Kg/M^3	425 Kg/M^3

During the field studies, in recycling of the compost product for feed conditioning (Phase-IVA) and after introduction of amendment in the form of cane trash (Phase-IVB), distinct observations noted were: i. The moisture contents of pressmud, recycle compost and cane trash were 70%, 35% and 15% respectively. When a feed mix was prepared by blending all the three, the resultant mix showed moisture content of 48%. Thus, there was a remarkable improvement in the moisture content which was achieved at the beginning of experimentation without leaving the feed on yard for initial drying for one week. ii. Due to reduction in initial moisture content of feed mix in shortest possible time, the actual process of spentwash spraying can be started earlier thereby facilitating more output by consuming higher and higher quantities of spentwash in the given amount of time and on the given amount of compost yard area. This is possible as more number of composting cycles could be taken on the same area of compost yard in given time. In other words, the benefits of shortened time spans and reduced working areas could be simultaneously availed which would mean efficient process operations in minimum costs. iii. The overall solid content of the infeed (both solid and liquid substrates) to composting system was found to be 25.2%. As far as ingredients of individual solid feed mix were concerned, the pressmud had TS of 30%, recycled compost had TS of 65% and the trash had its value as 85%. After blending (at the start of Phase-IVB), the ultimate solid feed mix reflected TS content of 52% as against 42% where only compost recycle was adopted for feed conditioning (at the start of Phase-IVA). It was noted from earlier studies under Phase-I to Phase-III that the volatile losses increase with increase in solids loading in the feed to a composting system. The same observation was once again recorded after experimentation of Phase-IVB where loss of volatiles was found to be about 24.5%. This was more than the one observed during Phase-IVA (22.5%) and was the highest among all the previous findings. iv. In Phase-IVB further decrease in the bulk weights (densities), beyond those that were observed in Phase-IVA, were noted as far the solid feed and final compost product were concerned. The decrease in bulk weights of infeed and compost was a consequence of an increase in the solid content of the feed going in to the composting system. This again underlined the fact that there was an improvement in the interstices and air spaces in the body matrix of the feed as well as compost product when the respective components were compared with pressmud or compost made only from pressmud during previous phases. v. The improvement in bulk weight of feed mix is of utmost importance since it would mean that porosity of the substrate is more and in turn the same could absorb more moisture. In other words, the solid feed mix could take up more quantities of spentwash without leaching or excessive soaking. Thus, through a fixed amount of solid substrate material, more spentwash quantity could be utilized in given time and on the given area of yard. This is a very important finding from viewpoint of overall economics of the process. vi. In light of facts and figures noted during studies under Phase-IVB, the thought of going for an increased spentwash loading on composting system (conceived from observations of Phase-IVA) was confirmed and a planning was made accordingly. It was decided to carry out experiments on a windrow formed out of pressmud, recycled compost and cane trash by increasing the feed mix to spentwash proportion beyond 1:2 tried in Phase-IVA and Phase-IVB. Thus, during Phase-VIA feed mix to spentwash proportion was 1:2.5.

As stated earlier, studies were carried out towards effects of application of spentwash compost on sugarcane cultivation when the same was compared with application of farm yard manure (FYM) as well as other conventional fertilizers such as urea, DAP, SSP and potash. Certain observations were prominently noted after Phase-VIB compost utilization. The cane production through conventional fertilizers and FYM use at the Regular Plot, was about 50.7 MT / Acre. Whereas at the Experimental Plot, the cane production noted after harvesting was about 59.8 MT / Acre. Thus, there was an increase of 9.1 MT/Acre. i.e. by 18 %. Moreover, the individual cane from Experimental Plot had more length of about 20 to 25 cm than the regular cane. Also, noticeable difference was observed in vigor of the crop where the diameter of the cane stump was found to be more by about 15mm to 20 mm. Here while using the spentwash compost, there was a saving of about 30% in chemical fertilizers which is important in light of their cost and availability now-a-days. However, the overall water consumption in Experimental Plot was found to be more by about 40%. If the water quantity is inadequate, there are possibilities that the crop may wither leading to drying of the leaves with an adverse impact on overall yield. Thus, application of the 'Spentwash Compost' may not be feasible for crops in water scare areas as well as for the plants and crops which need lesser quantities of water during growth.

Hereunder, observations under Phase-VIB showing best performance towards BVS losses and degradability are presented where the solid feed mix comprised of pressmud (50%), compost recycle (30%) and cane trash (20%) and a two step composting process was adopted. Up to Phase-VIA, all the experimentation (under as many as seven different phases) was done with single step process only. Figure-2 may be referred for more details. TS loading on the composting system under experimental windrow was 25.5%. The spentwash consumed on Windrow No. 1 had a pH of 4.3 and that on the Windrow No.2 had 4.6 on an average basis. The pH of substrate in the both the windrows dropped after the start of spentwash spraying application in second week (W2). At the beginning of W5 both the windrows were combined and a larger windrow was formed. The pH of substrate in this windrow was 7.4 during W5 which remained in the neutral range till the end. The figure-3 represents above observations graphically.

At the beginning of experimentation, spentwash was having a temperature of 32^0C and the substrates in the Windrow No.1 and Windrow No.2 were at 36^0C and 35.5^0C respectively. After spentwash application, the temp. started rising up in both the windrows and reached up to maximum of 64^0C in Windrow No.1. Subsequent to the merging together of two windrows at the start of W5, the temperature recorded was 70^0C, 73^0C, 67^0C, 52^0C, 45^0C and 40^0C for W5, W6, W7, W8, W9 and W10 respectively. The peak of 73^0C was attained in W6. Figure-4 gives time-temp. graph.

The substrate moisture content of Windrow No.1 was initially 48.5% after blending of various ingredients of the feed mix. Thereafter, when left for drying, at the end of W1 the moisture content became 25%. Almost similar trend was noticed in case of Windrow No.2. Thereafter, in W2, the spentwash spraying started and moisture content in both the windrows increased. In W5, after combining of the two individual windrows, the moisture content was 65%. Thereafter, it was 58%, 50%, 44%, 37% and 30% during W6,W7,W8,W9 and W10 respectively. The spraying of spentwash on the combined single windrow was done through W5 and W6. At the end of W6, it was stopped and during W7 and W8 only windrow turning and mixing was carried out. Figure-5 could be referred for variations in the moisture content. The trend of variations, noted with respect to certain other relevant parameters during composting, was as shown in figure-6.

Further, it is quite interesting to record certain observations after comparison of the performances of composting systems under Phase-VIB, Phase-IVB and Phase-III; First Part. The reason to select theses three phases is that all of them were carried out during same period of years namely Phase-III from March 2006 to May 2006, Phase-IVB from March 2007 to May 2007 and Phase-VIB from March 2008 to May 2008. Moreover, the feed mix to spentwash proportion of **1:2** was the same under all the phases. Thus, the entire experiential set up and environmental conditions were identical under the three phases except two things. The feed conditioning was done by using amendments under Phase-IVB and Phase-VIB where the feed mix was a mixture of pressmud, recycled compost and cane trash (moisture of 47%-48% and bulk density of 360 Kg/M^3) whereas in Phase-III, feed to composting system was only the pressmud (moisture of 70% and bulk density of 500 Kg/M^3). Secondly, under Phase-VIB, a two step composting process was tried where as in rest of the two phases it was a single step process only. As a result of this, the performance of composting system during Phase-VIB was observed to be the best among all the three phases which is presented table-8.

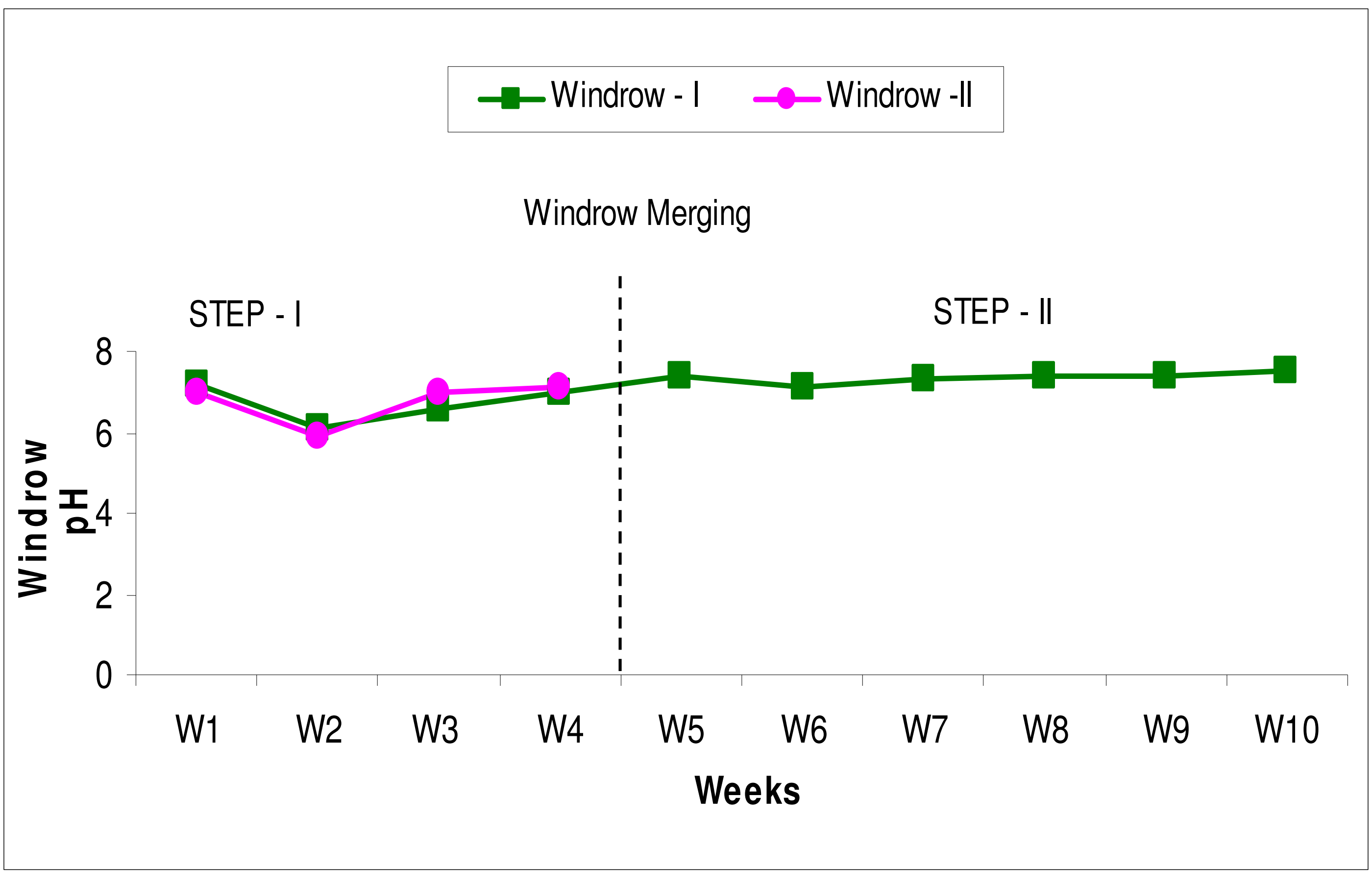


Figure-3
Relationship between substrate pH and time of composting

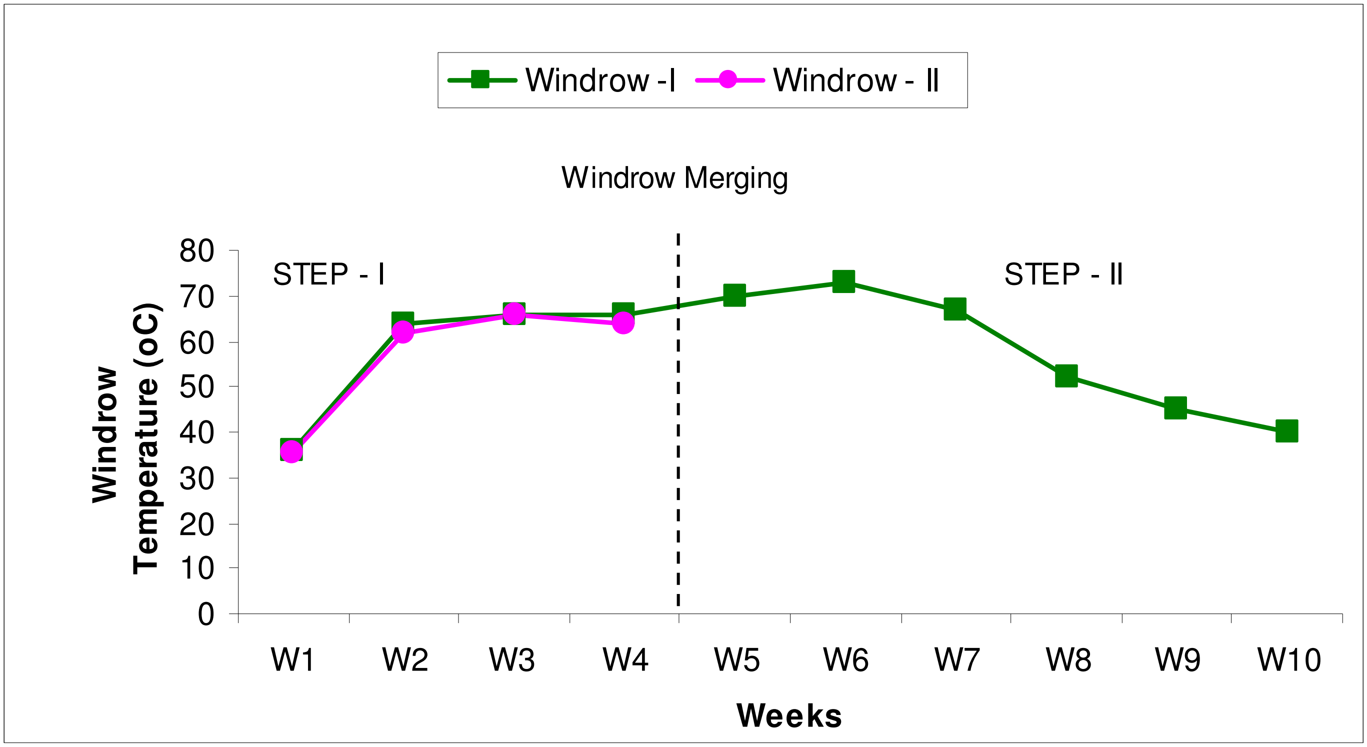


Figure-4
Relationship between substrate temperature and time of composting

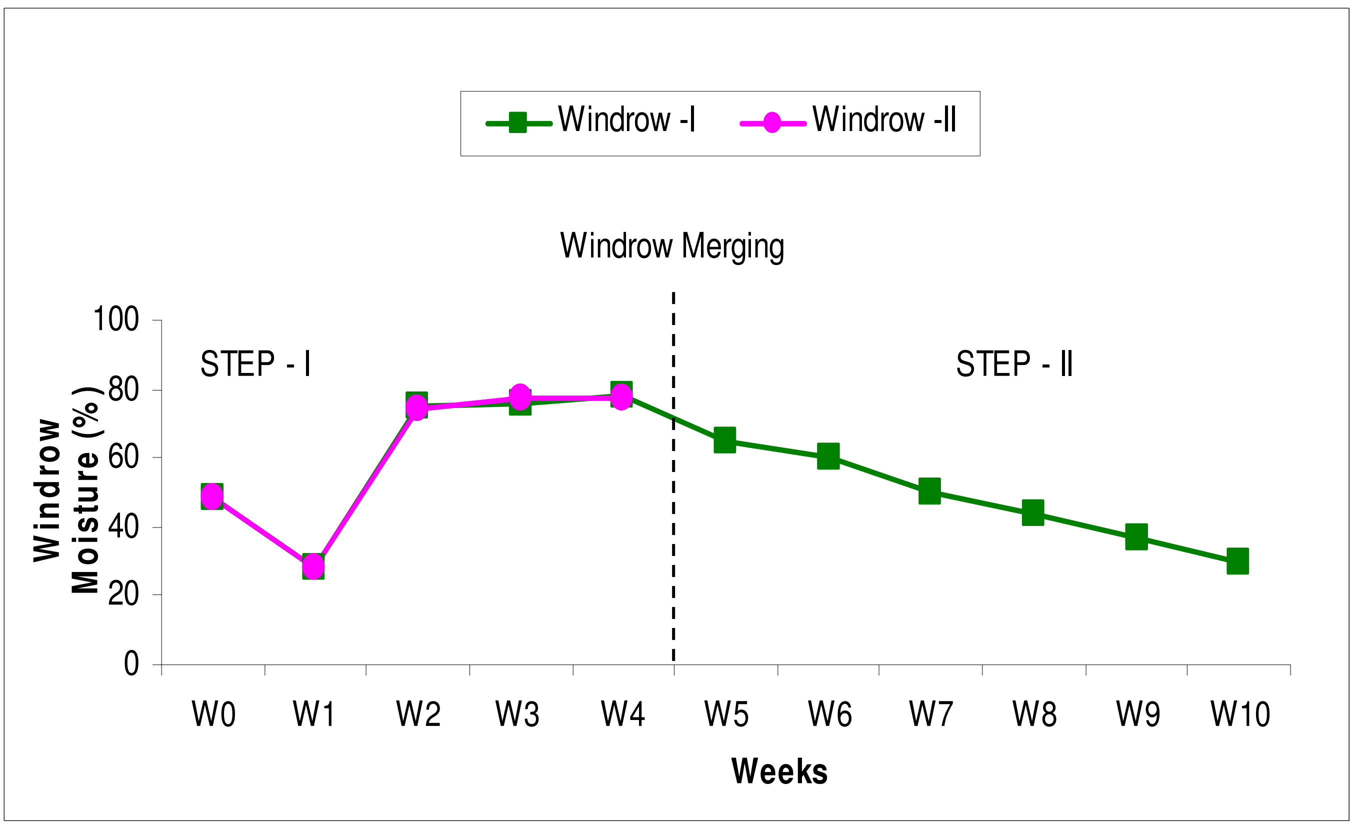
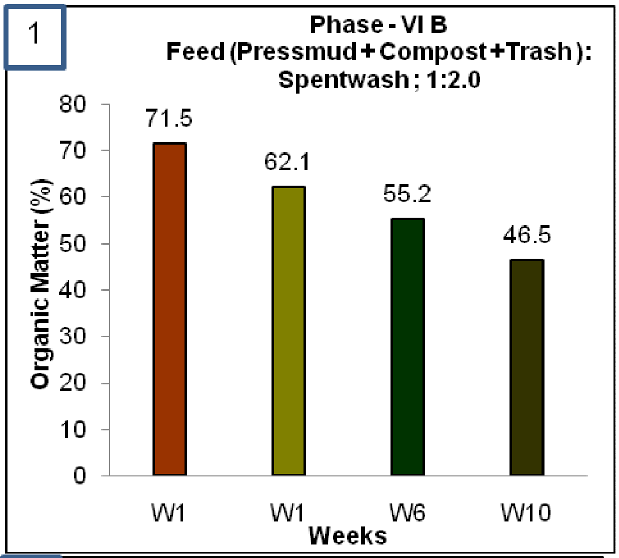
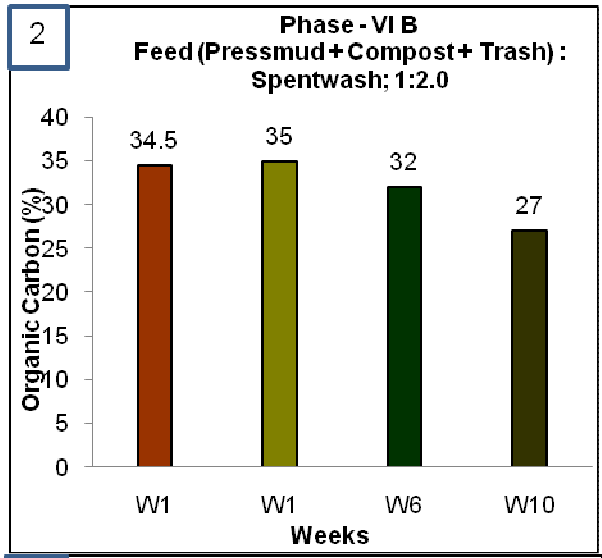
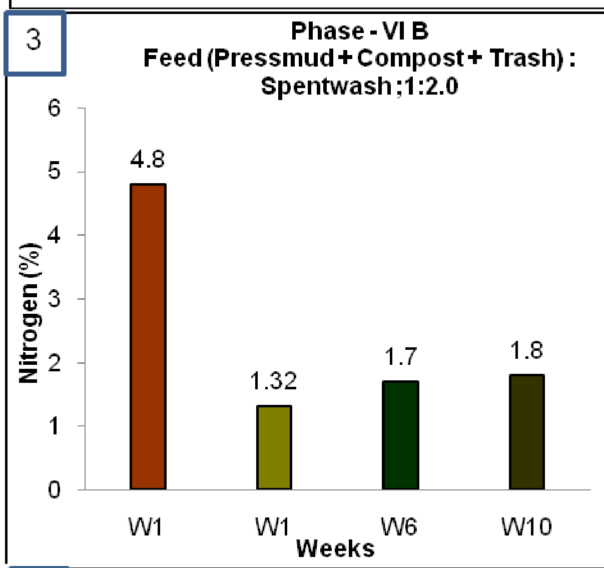
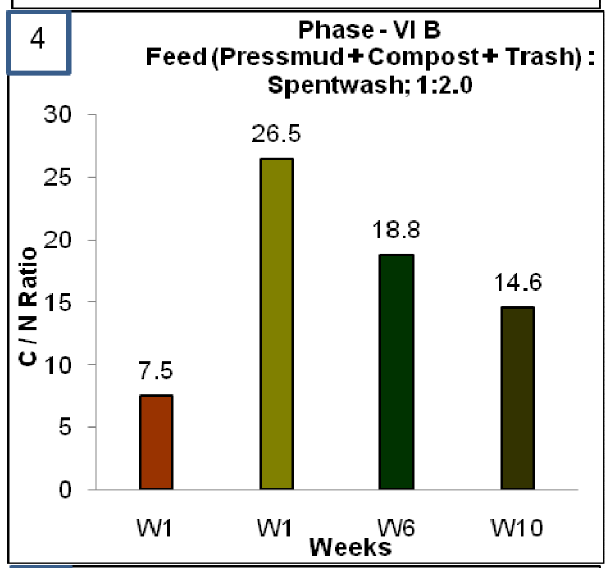


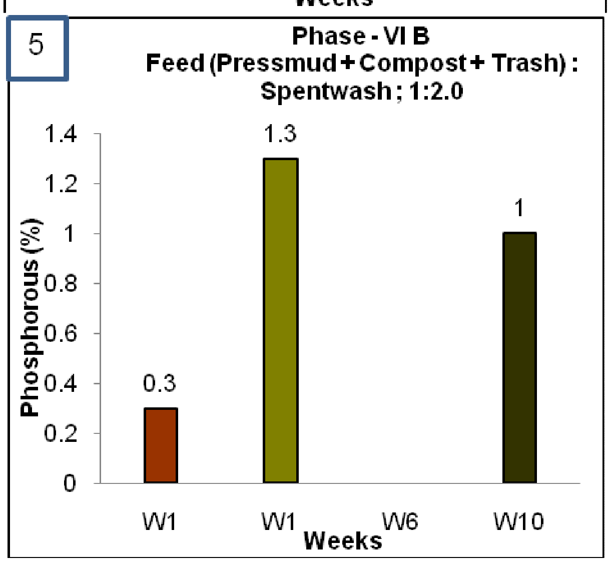
Figure-5
Relationship between substrate moisture and time of composting

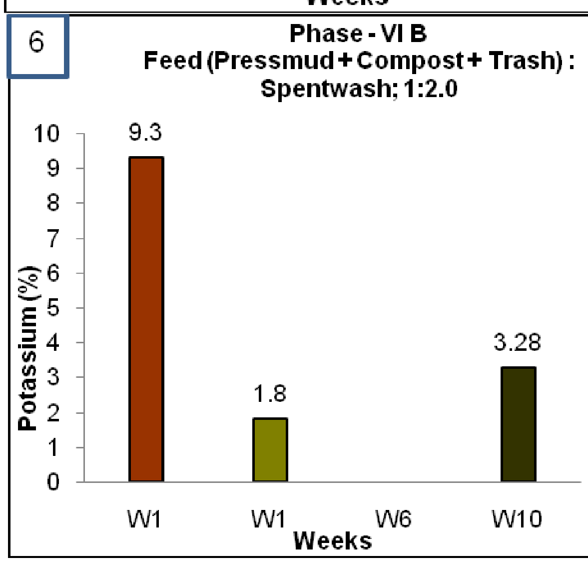

1
Phase - VI B
Feed (Pressmud+Compost+Trash): Spentwash; 1:2.0
Organic Matter (%)
80
70
60
50
40
30
20
10
0
71.5
62.1
55.2
46.5
W1
W1
W6
W10
Weeks


2
Phase - VI B
Feed (Pressmud+Compost+ Trash) : Spentwash; 1:2.0
Organic Carbon (%)
40
35
30
25
20
15
10
5
0
34.5
35
32
27
W1
W1
W6
W10
Weeks


3
Phase - VI B
Feed (Pressmud+Compost+ Trash) : Spentwash ;1:2.0
Nitrogen (%)
6
5
4
3
2
1
0
4.8
1.32
1.7
1.8
W1
W1
W6
W10
Weeks


4
Phase - VI B
Feed (Pressmud+Compost+ Trash) : Spentwash; 1:2.0
C / N Ratio
30
25
20
15
10
5
0
7.5
26.5
18.8
14.6
W1
W1
W6
W10
Weeks


5
Phase - VI B
Feed (Pressmud+Compost+ Trash) : Spentwash ; 1:2.0
Phosphorous (%)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.3
1.3
1
W1
W1
W6
W10
Weeks


6
Phase - VI B
Feed (Pressmud+Compost+ Trash) : Spentwash; 1:2.0
Potassium (%)
10
9
8
7
6
5
4
3
2
1
0
9.3
1.8
3.28
W1
W1
W6
W10
Weeks

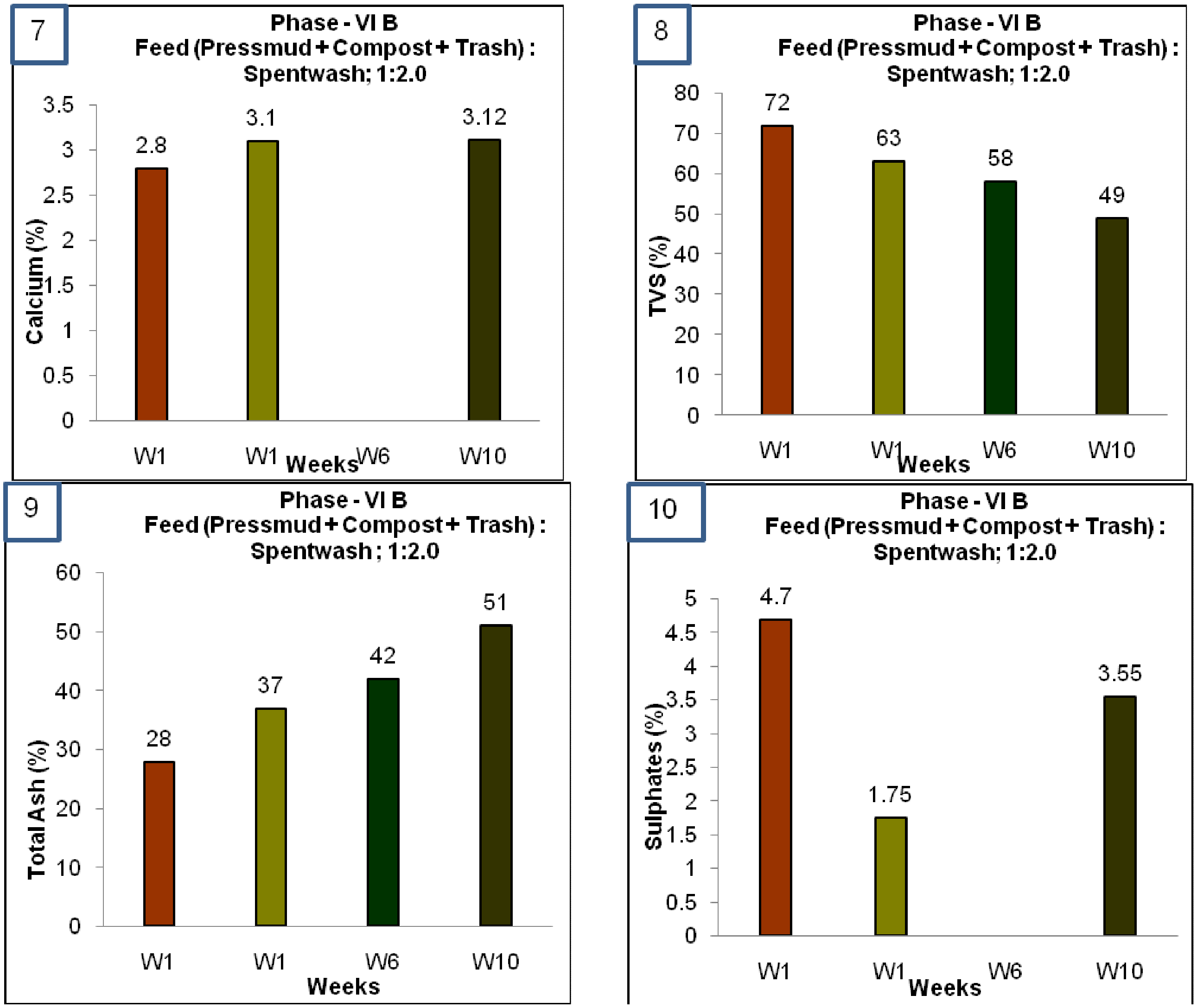


Figure-6
Trend for Variation of Parameters
Legends:- W1- Week No.1, W6- Week No.6, W10- Week No.10 Spentwash - Feed Mix - Substrate - Compost

Also, observations similar to the ones shown in table-8 were recorded when a comparison of the performances of composting systems under Phase-VII, Phase-VIA and Phase-I; First Part was made. These three phases again were carried out during same period of a year and under similar environmental and experimental conditions. The only difference here was with the feed mix to spentwash proportion which was **1:2.5** under all the phases. Here also the conditioning of the feed mix was done under Phase-VIA and Phase-VII. In Phase-I, the feed to composting system was only the pressmud (moisture of 70% and bulk density of 500 Kg/M^3). Secondly, under Phase-VII, a two step composting process was adopted where as in rest of the two phases it was a single step process only. As a result of improved porosity and FAS, due to the feed conditioning as well as under adoption of a two step process; the performance of composting system under Phase-VII was found to exceed the performance during rest of the two phases.

From the studies conducted so far and evaluation of individual performances of the composting systems under various phases, certain observations were recorded prominently. Overall better composting efficiencies were noted after the feed conditioning through compost recycle and introduction of amendment. Moreover, the two step composting process showed the best performance of all. Through the comparative studies made for different phases conducted under similar environmental conditions and experimental set ups, it was observed that just by altering the condition of feed and varying the operational procedure, better cost-economic results could be obtained for a given quality and quantity of spentwash on a given area of compost yard in a given amount of time period. This observation is of utmost importance from view point of harvesting commercial benefits through implementation of the study results on field at a distillery site.

Table-8
Performance of Composting under Phase-IVB, Phase-VIB and Phase-III

Sr. No.	Description	Phase-VIB	Phase-IVB	Phase-III (First Part)	Comments
01	Feed mix / infeed	PM (50%) + RC (30%) + CT (20%) and SP	PM (50%) + RC (30%) + CT(20%) and SP	PM (100%) and SP	All phases were conducted during the same time of a year.
02	Weight of infeed	Feed mix; 25 MT (PM; 12.5MT + RC; 7.5MT + CT;5MT) and SP; 50MT	Feed mix; 25 MT (PM;12.5MT + RC;7.5MT + CT; 5MT) and SP; 50MT	PM; 25 MT and SP; 50MT	Physical weights of the materials were taken before the same were put in to the composting system.
03	Feed mix to spentwash proportion	1 : 2.0	1 : 2.0	1 : 2.0	This was the same under all phases.
04	Gross solids loading on system	25.5%	25.2%	18.0%	
05	Bulk weight of solid infeed	360 Kg/M^3	360 Kg/M^3	500 Kg/M^3	Bulk density of spentwash, 1100 Kg/M^3.
06	TS of solid infeed	53%	52%	30%	
07	Moisture content of solid infeed	47%	48%	70%	
08	Weight of compost product	20.1 MT	20.4 MT	19.6 MT	Physical weights of the out feed materials were taken at the end of composting process.
09	Bulk weight of outfeed i.e. Compost	275 Kg/M^3	280 Kg/M^3	400 Kg/M^3	
10	TS content in the Compost	70%	70 %	55 %	
11	Moisture content in the Compost	30 %	30 %	45 %	
12	Loss of volatiles (BVS)	25.5 %	24.5 %	20 %	The highest BVS loss was observed under Phase-VIB.

Note: PM- Pressmud, RC-Recycle Compost, CT- Cane Trash, SP- Spentwash

Discussion: There is no any specific definition of composting that has been accepted universally. Composting is a process that involves biological decomposition and subsequent stabilization of organic substrates. During this, development of thermophilic temperatures occurs in the mass undergoing the process due to biologically produced heat. Eventually, a final product is obtained which is stable, free from pathogens and plant seeds, and same can be applied to farm lands harvesting distinct benefits. Thus, composting is nothing but a process of waste stabilization that requires special conditions of moisture and aeration to produce thermophilic temperatures. Composting is usually applied to solid or semisolid materials, making composting somewhat unique among the biological stabilization processes used in environmental and biochemical engineering[11]. Aerobic composting involves decomposition of organic substrates in presence of oxygen (air) resulting in to the end products that are mainly carbon dioxide, water and heat. Anaerobic composting, on the other hand, comprises of biological decomposition in the absence of oxygen that gives rise to the end products namely methane, carbon dioxide and numerous low molecular weight intermediates such as organic acids and alcohols[12,13]. Comparatively, anaerobic composting releases significantly less energy per unit weight of organic matter decomposed. Also, it has a higher odor potential because of the many intermediate metabolites that are generated. For these reasons almost all engineered compost systems are aerobic[11]. The substrate organics decomposition along with drying process during actual composting can lead to reduction of cost of subsequent handling while increasing the attractiveness of compost for reuse or disposal. Under present study, performance evaluation of composting systems using conventional feed materials as well as that after introduction of certain amendments was done in light of varying trends, towards the feed materials, being followed at various places with claims of the best results being achieved everywhere. Although, almost all of the spentwash treatment and disposal facility operators boast of the success in composting process, no any definite statistics is projected especially for the quantity of raw materials (pressmud, fresh bagasse, waste bagasse, bagassilo, boiler and fly ash, agro residue etc.) and their proportion, properties and composition of the materials, methods of operations as well as process efficiencies. Subsequent to evaluation of performance under each of the phases studied as well as after determining the same on a comparative basis, choices were made for certain composting systems. Accordingly, better and the best options were selected from a number of alternatives tried. Before the Phase-IV, studies were conducted under Phase-I, Phase-II and Phase-III where performances of composting systems for pressmud and spentwash proportions of 1: 2.5, 1:3.5 and 1:2.0 respectively were evaluated in light of overall functioning, substrate biodegradability and effects of solids loading on the system. It was observed that the losses (volatiles) went on increasing as the TS contents of infeed increased. So was the case with substrate biodegradability as shown below[10].

Table-9
Performance of Composting during Phase-I, Phase-II and Phase-III

Sr. No.	Phase Name	Pressmud : Spentwash Proportion	TS	BVS Losses
1	Phase-I	1 : 2.5	17%	18%
2	Phase-II	1 : 3.5	16%	12%
3	Phase-III	1 : 2.0	18%	20%

The overall performance of composting system during Phase-III with pressmud to spentwash proportion of 1:2.0 was found to be much satisfactory over rest of the two phases in light of – i. pH change of the substrate, ii. temperature rise in the composting mass, iii. attainment of the maximum temperature in the windrow, iv. moisture loss during the process, v. moisture content of the final product, vi. degradation of the organic matter, vii. loss of volatiles, viii. inorganic contents of the final compost mass, ix. C/N ratio of the product, and x. potassium content in the compost.

The TS variation in feed from Phase-I to Phase-II was by almost 7% with Phase-II having less TS whereas it varied by almost 6% in Phase-I and Phase-III with Phase-I having less TS. From the study of composting systems involving pressmud and spentwash proportions of 1:2.5, 1:3.5 and 1:2.0, it was noticed that when quantity of spentwash to be utilized in the composting was reduced, the resultant TS of the infeed was found to increase. Thus, for pressmud to spentwash proportion of 1:3.5 (Phase-II), the TS were 16%, for the proportion of 1:2.5 (Phase-I), the corresponding TS were 17.1% and ultimately when the proportion became 1:2.0 (Phase-III), the TS content was of 18%. In view this trend towards TS in a composting system, if one had to increase its content beyond 18%, then naturally the quantity of spentwash was required to be reduced further. Any increase in the TS content was possible only through subsequent reduction in the spentwash load on the system. This, if done, would have threatened the prime objective of spentwash consumption and disposal through SABC[10]. It was absolutely essential to utilize maximum quantity of spentwash by consuming minimum possible pressmud as the availability of latter was going to play an important role in the overall mass balance of composting process. Hence during subsequent studies, it was decided to increase the solids loading further and test the performance. Accordingly, the TS content in the feed to composting system subsequent to Phase-III was decided to be 22%. Thus for Phase-IVA, the TS content planned was 22% which was almost 25% more than those under Phase-III (18%TS).

Now-a-days, the composting facility operator is facing real problems due to pressmud availability and he is trying to put all the spentwash, at his disposal, on whatever pressmud available. This has, quite often, disturbed the proportion of pressmud and spentwash in the process leading to adverse effects on the overall efficiencies. Further, due to non-availability of adequate pressmud, the facility operator is forced to look for other options namely ash, waste bagasse, agro residues and waste biomass etc. which could go as filler materials in a composting system. These materials, although seem promising at a first glance, have led to more problems than benefits when employed during composting along with pressmud. The reason for this is that an importance has been given only to their look and feel without any consideration to a number of other important factors namely chemical properties, particle size distribution, moisture content, relative degradability along with other substrate ingredients etc. Abundant quantities and easy availability of the filler materials are the only criteria to go for their incorporation as a feed to a system. As such, many times these components lead to a totally heterogeneous substrate mass that has to form a solid matrix during composting with spentwash. In light of this, the TS increase was planned through feed conditioning during Phase-IVA. For the same, compost product of Phase-III was planned to be recycled and mixed with fresh pressmud. Accordingly, quantity of compost to be recycled for achieving the desired solids loading as well as feed conditioning was worked out.

Findings towards changes in bulk weights of the feed to a composting system as well as that of the compost product were noticeable when the TS contents of feed mix were varied. It was observed that the bulk weights of feed and compost product decreased with increase in TS to the compost system. This revealed that there was improvement in the interstices and air spaces in the body matrix of the feed as well as compost. For a feed, decrease in bulk weight meant that it could absorb more moisture i.e. could tackle more spentwash without leaching. For compost, decrease in bulk weight meant less water in the matrix. This is desirable during handling, transportation and land application of the product.

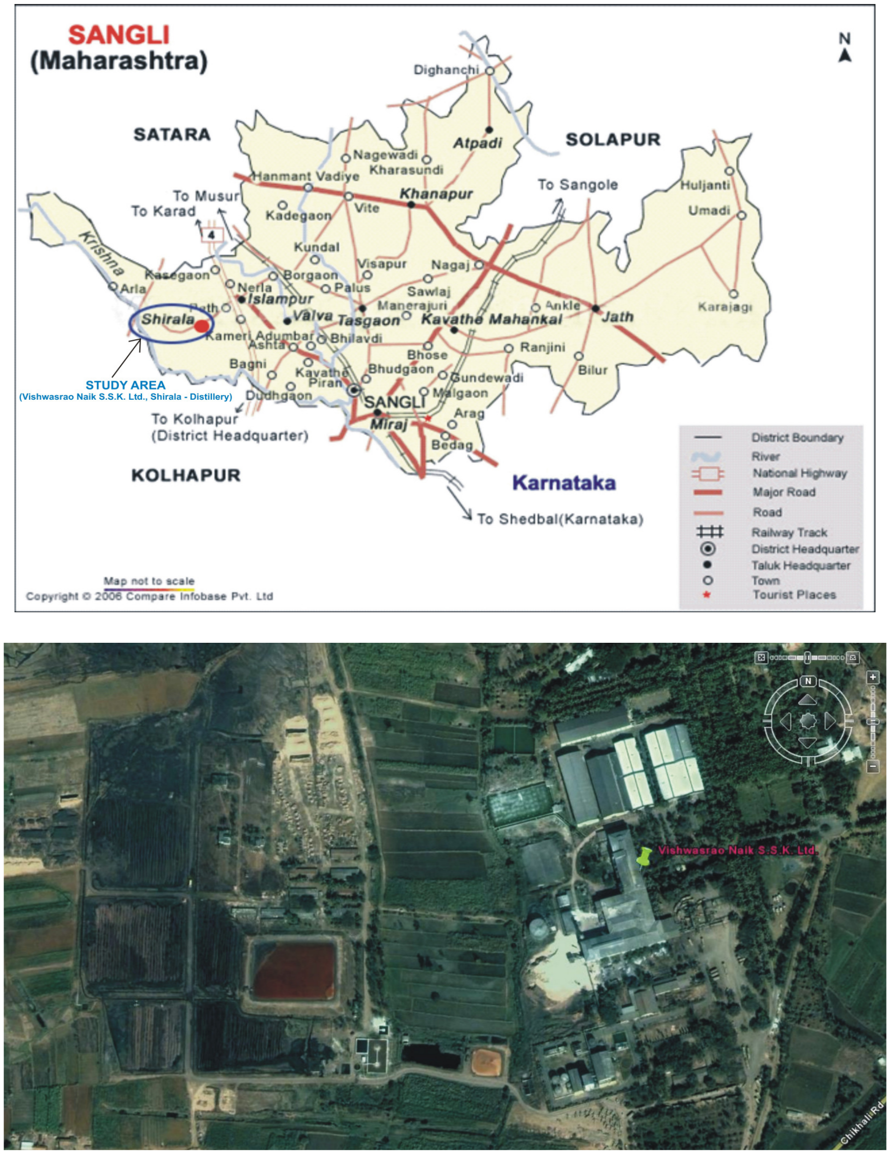
The observation that losses of volatiles were directly proportional to TS content recorded earlier in Phase-I, Phase-II and Phase-III was once again confirmed during subsequent studies. Further, overall performance of the composting system with feed conditioning done by compost recycle as well as that by the introduction of an amendment under Phase-IVB (feed : spentwash of 1 : 2) was the best as far as single step composting operation was concerned. However, during the Phase-VIB (feed : spentwash of 1 : 2), in two step process even better results than those under Phase-IVB were obtained.

The studies during Phase-VIA (feed : spentwash of 1 : 2.5) with increase in spentwash loading revealed that the performance of composting system under this phase was far better than that during Phase-I conducted with pressmud and spentwash in the proportion of 1:2.5. Here due to the feed conditioning, improved performance and better results were noted. This fact could be seen from a comparison of the degradability coefficients (k_s) under both the phases. Under Phase-I, its value was 0.23 (Table-10) whereas during Phase-VIA, the same was 0.31. Thus, it is revealed that the proportion of pressmud to spentwash of 1:2.5 that was rejected under Phase-I could be reasonably adopted only after conditioning of the feed. As a result more quantity of spentwash could be consumed while achieving performance at par with the lower proportions. Moreover, performance of the composting system under increased spentwash loading (feed : spentwash of 1:2.5) during Phase-VIA was better than that during Phase-V conducted during winter months for a proportion of 1:2.0. Thus, it could be possible to attain better degradation under increased spentwash utilization which is definitely the most desirable development. When the performance under Phase-VII (two step process with 1:2.5 proportion) and Phase-VIA (single step process with proportion of 1:2.5) are studied, it was noted that under Phase-VII better substrate degradation was observed (degradability coefficient; k_m of 0.35) than the Phase-VIA (degradability coefficient; k_m of 0.31) with respective BVS losses of 24.5% and 23%. It is important to note here that except the stages in composting operation, all other experimental and environmental conditions were the same under both the set ups.

Table-10
Composting Status at a Glance under Various Phases

Phase	Series	TS Loading in Feed	BVS	Degradability Coeff. 'K_s'	Unit Bulk Weight of Compost	Moisture Content of Compost	Porosity 'n'	Free Air Space 'f'
Phase- I, Mar- May 04	PM : SP; 1 : 2.5	17.1 %	18 %	0.23	405 Kg/M^3	50 %	0.86	0.51
Phase- II, Mar- May 05	PM: SP ; 1 : 3.5	16 %	12 %	0.16	430 Kg/M^3	60%	0.89	0.49
Phase-III, Mar-May 06	PM: SP; 1 : 2.0	18 %	20 %	0.26	340 Kg/M^3	45%	0.87	0.52
Phase-IVA, Mar- May 07	FM (PM + RC) : SP; 1 : 2.0	22 %	22.5 %	0.30	315 Kg/M^3	36%	0.86	0.59
Phase- IVB, Mar-May 07	FM (PM+RC+ CT) : SP; 1 : 2.0	25.2 %	24.5 %	0.33	280 Kg/M^3	30%	0.85	0.62
Phase-V, Dec 07-Feb 08	FM (PM+RC+ CT) : SP; 1 : 2.0	26.1 %	22 %	0.30	330 Kg/M^3	40%	0.88	0.58
Phase-VIA, Mar- May 08	FM (PM+RC+ CT) : SP; 1 : 2.5	23.3 %	23 %	0.31	330 Kg/M^3	40%	0.89	0.58
Phase-VIB, Mar- May 08	FM (PM+RC+ CT) : SP; 1 : 2.0 [Two Step]	25.5 %	25.5 %	0.36	275 Kg/M^3	30%	0.87	0.63
Phase-VII, Mar - May 09	FM (PM+RC+ CT) : SP; 1 : 2.5 [Two Step]	24.2 %	24.5 %	0.35	332 Kg/M^3	40 %	0.88	0.61

Note: i. PM- Pressmud, FM- Feed Mix, CR- Compost Recycle, CT- Cane Trash and SP- Spentwash, ii. Porosity is defined as the ratio of 'Voids Volume' to 'Total Volume'. FAS is defined as the ratio of 'Gas Volume' to 'Total Volume'. iii. In above table, Porosity is more or less the same but FAS has improved remarkably due to the Feed Conditioning. This means more voids were occupied by the air / gas for a given porosity in the material. And as more air means good aerobic conditions, better degradation resulted at higher FAS values under current experimentation.



Map of the Research Work Study Area

The porosity (n) and FAS (f) in a composting matrix were found to improve after conditioning of the feed with compost recycle. The 'n' and 'f' were further improved with an introduction of amendment in the form of cane trash. However, once the feed mix ingredients (pressmud, compost recycle and cane trash) were proportioned and blended to achieve bulk weights in the range of 340 Kg/M^3 (Phase-V) to 360 Kg/M^3 (Phase-VIA and Phase-VIB), there was a little improvement in the 'n' and 'f' values of substrates during subsequent composting. This meant that for particular feed mix conditioning through combination of the individual ingredients, the 'n' and FAS in substrate achieved an optimum limit. This fact could be verified from the analysis of substrate during Phase-VIA that was under increased spentwash loading (feed mix: spentwash of 1:2.5). Here the porosity and FAS ('n' of 0.89 and 'f' of 0.58) were almost the same as that during Phase-V ('n' of 0.88 and 'f' of 0.58) conducted with feed mix to spentwash proportion of 1:2.0 i.e. under lower spentwash loading. It is important to note here that the feed mix to Phase-VIA (pressmud, compost recycle and cane trash) was exactly the same (proportioning by weight) as that under Phase-V. This was the reason for improved performance during Phase-VIA even under increased spentwash loading (which was not the case during previous studies under Phase-I to Phase-III). Here, greater moisture contents could be easily tackled due to better porosity and FAS in the substrate matrix. If amendments with low bulk weights, such as cane trash, are blended with the substrate having high moisture levels, it could be possible to achieve adequate degree of FAS at even higher moisture contents. Thus, the composting process could be carried out without the substrate becoming too wet to cause soaking and subsequent leaching problems. From the observations and discussions so far, it has become quite clear that porosity and FAS are the two important parameters, in addition to the degradability coefficient, which underline performance of a composting system and are important tools that are often used to determine process efficiencies.

From the details about TS loadings and BVS losses in Table-10 it could be observed that although there was an increase in the losses of BVS with TS, the trend of increase was somewhat peculiar. There, following points were noted – i. When the TS of infeed was increased from 16% (i.e. the lowest value met in Phase-II) to 25.5% (i.e. the highest value met in Phase-VIB), the BVS losses increased from 12% to 25.5%. Thus, there was an increase by about 112.5%. ii. Similarly, when the losses are compared for systems under same spentwash loading, it could be seen that they were 20% during Phase-III (press mud : spentwash of 1:2.0; TS of 18%) and 25.5% in Phase-VIB (feed : spentwash of 1:2.0; TS of 25.5%). Here, the 4.8 MT of volatiles lost (weight basis) during composting under Phase-VIB were almost 1.75 times more than those lost under Phase-III; which were 2.7 MT. iii. This BVS loss trend was found to be accelerated when the TS increase from 16% (Phase-II) to 17.1% (Phase-I) as well as to 18% (Phase-III) occurred during initial part of the studies where the losses increased by about 50% and 67% respectively. However, thereafter, as the TS were increased to 21.8% (Phase-IVA), 25.2% (Phase-IVB) and 25.5% (Phase-VIB), the corresponding losses were 22.5%, 24.5% and 25.5% respectively. Here, the increase in BVS loss occurred by 87.5%, 104% and 112% over that noted for the lowest TS loading of 16% (i.e. the 12% BVS loss). This means as the infeed TS of composting system increased and approached a value of 25% or so, the losses went on increasing gradually and eventually became somewhat stable around a figure of 25%. This revealed that the BVS losses reached an optimum value for particular combination of solid infeed materials namely pressmud, compost recycle and cane trash as well as liquid substrate spentwash. Beyond the BVS loss of 25.5%, no further appreciable increase could be possible for the adopted combination of solid and liquid raw materials in the composting system. Any increase could have been possible only if the infeed TS were further improved through some other combinations of solid substrates i.e. pressmud, compost recycle and trash. However, there was no random increase possible in the quantum of compost recycle and trash matter due to certain limitations felt towards their availability and viability of the overall composting procedure and its economics. iv. Reaching a particular stable value for BVS losses (Phase-IVB and Phase-VIB) meant that the optimum biodegradability had reached for a particular TS content in a composting system which in turn was achieved through certain feasible combination of the solid and liquid infeed materials. The TS increase could be further possible through use of some alternative amendments that could go perfectly well with other ingredients of the composting system. Here again considerations of particle size distribution, relative degradability of the amendments, their organic contents (i.e. structural as well as energy amendment), ease of availability and cost would play an important role. v. The increase of BVS losses in a direct proportion to the system TS occurred at a greater pace in initial stages of the experimentation as stated above. Thereafter, the losses followed a trend of reduction as noted after Phase-IVA experimentation. Eventually, there was an attainment of stability towards the losses as noted after Phase-IVB and Phase-VIB. The variations in rate of losses are attributable to nothing but kinetics of degradation reactions that took place in substrate matrix under composting. An explanation towards the change in trend of BVS losses could be given only after evaluation of ‘First Order Reaction Rate Constant’ through respirometer studies under elaborate laboratory experimentation on different individual substrates and their combinations in composting[11,14].

The particle size distribution of the amendment was an important factor that needed to be taken in to account before going for its introduction to a windrow substrate matrix. During the experimentation under Phase-IVA, recycling of the final compost product was adopted for feed conditioning. The composting process was carried out with the feed mix comprising of pressmud and compost recycle. Here, the compost that was used did not pose any problems of particle size when blended with the pressmud to form a solid feed mix. This was due to a fact that the compost was, in fact, formed out of pressmud only during the Phase-III and the same was of homogenous nature which when added to pressmud during Phase-IVA blended perfectly with it. However, while dealing with an amendment the case was different. Although the trash belonged to cane crop, it was essential to convert it in to smaller and uniformly sized material to go in the pressmud and recycled compost matrix without any trouble. Thus, the particle size distribution of trash was an important consideration from view point of structural conditioning of the infeed to a system. If the amendment is too fine, it may not provide the expected increase in free air space even though the mixture solids content is acceptable. Too small or fine particles of the amendment material tend to produce a muddy consistency in the mix. As a result, the saturated condition can produce anaerobic environment in the compost mass due to lack of free air space. Under present studies with cane trash, the ultimate particle size that was formed was about 5 mm to 8 mm. The particle size distribution is also important to energy conditioning. Generally, the biodegradability of amendments is favoured by small particle size. Too many fines may be undesirable from a structural standpoint, but very attractive for energy conditioning. The demands for structural and energy conditioning should both be considered while adopting specifications towards an amendment[11].

Conclusion

From the discussions and reviews taken so far towards the actual onsite composting operations performed with spentwash and pressmud, cane trash as well as recycled compost, it could be seen that the SABC process could produce good quality organic manure in abundant quantities. Moreover, the SABC process when looked up on as a waste treatment and disposal method provides many advantages over the various distillery effluent treatment and disposal means tried so far. The SABC process, with various ingredients used therein is an eco friendly, less energy intensive and cost economic treatment methodology envisaged for spentwash treatment and disposal. Further, being a good quality manure generation process, the SABC could receive well social acceptance not only among the entrepreneurs, but also from the farmers utilizing the ultimate end product. The actual composting operations under SABC are carried out on plain surface above ground under totally aerobic conditions. In fact, the thermophilic temperatures generated during the process offer dual benefits namely providing heat necessary for faster evaporation of moisture in the spentwash as well as a means for destroying pathogens and larvae as well as eggs of flies in the substrate matrix. Under SABC, the end products of degradation of the organic matter happen to be CO_2 and water vapours. Apart from faster reaction rates under aerobic conditions in SABC, the end products also provide a distinct merit in the sense that no gases like CH_4, H_2S etc. are produced. Neither the blackish effluents, as encountered in lagoons, remain as leftovers which are further needed to be handled and disposed off. These effluents and the obnoxious gases are, in fact, the end products of anaerobic degradation reactions which are totally avoided in the SABC. The spentwash is an extremely difficult effluent to handle as it poses some unique problems due to its acidic nature, high organic contents and liquid state. Under the SABC, it gets totally converted into a solid compost product which is easier to handle, transport and apply in farms. The SABC virtually utilizes raw materials that either directly or indirectly come from the sugar cane crop. The pressmud, cane trash, spentwash and compost used for recycle are nothing but the materials that are directly or indirectly derived from sugarcane crop before, during and after its processing. The pressmud retains some organics from cane and some reach the molasses. An effluent, i.e. the spentwash, is produced after alcohol recovery from the molasses. It should be logical, therefore, to apply pressmud and distillery effluent to the soil in order to recycle the much needed organics provided a due consideration is given to the other troublesome contents of spentwash.

From the information and comments presented in above paragraphs, it could be concluded that the optimized SABC process, under current studies, utilized for treatment and disposal of spentwash is a boon in turning wastes in to resources by closing the cycles locally, visibly and elegantly.

References

1. Pande H.P.,Sinha B.K. and Singh G.B., Use of Distillery Waste as Fertilizer in Sugarcane Agro-industrial Alternatives (ed.) Solomon S., Oxford-IBH Publishing Co. Pvt. Ltd., New Delhi, 401-413 **(1995)**
2. Rajukkannu K., Manickam S.T., Marimuthu R., Mohamed H. and Shanmugam R., Use of Distillery and Sugar Industry Wastes in Agriculture, Proceedings of the National Symposium, 28th - 29th October, 1996, Kothari Sugars And Chemicals Limited, Tiruchirapalli, Tamil Nadu **(1996)**
3. Suryawanshi P.C., Jain K.A., Bhardwaj S., Chaudhari A.B. and Yeole T.Y., Solid and Liquid Wastes: Avenues of Collection and Disposal, *International Research Journal of Environmental Sciences*, **2(3)**, 74-77 **(2013)**
4. Ladwani Kiran D., Ladwani Krishna D., Manik Vivek S. and Ramteke Dilip S., Impact of Industrial Effluent Discharge on Physico-Chemical Characteristics of Agricultural Soil, *International Research Journal of Environmental Sciences,* **1(3)**, 32-36 **(2012)**
5. Washington State University; Puyallup Research Centre, USA, Department of Crops and Soils, Organic Farming Systems and Nutrient Management **(2001)**
6. Washington Organic Recycling Council; USA, Compost Facility Operator Training and Seminar **(2002)**
7. Standard Methods for the Examination of Water and Wastewater, Prepared and Published Jointly by American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), 21st Edition, APHA, Washington, DC 20001-3710. ISBN 0-87553-047-8, ISSN 55-1979 **(2005)**
8. Robertson F., Sugarcane Trash Management: Consequences for Soil Carbon and Nitrogen, The Final Report to the CRC for Sustainable Sugar Production of the Project – Nutrient Cycling in Relation to Trash Management, A CRC Sugar Technical Publication, CRC for Sustainable Sugar Production, Townsville : 39, ISBN – 1876679271 **(2003)**
9. Woytiuk K., Sugarcane Trash Processing for Heat and Power Production, Master's Thesis, Continuation Courses in Sustainable Energy Systems, Department of Applied Physics and Mechanical Engineering, Division of Energy Engineering, Lulea University of Technology **(2006)**
10. Ghugare S.P. and Samant J.S., Performance Evaluation of Effluent Management in Molasses based Distillery through Bio-composting Process, *Environmental Pollution Control Journal*, **16(5)**, 16-36 **(2013)**
11. Haug R.T., The Practical Handbook of Compost Engineering, Lewis Publishers, CRC Press Inc., Boca Raton, Florida, ISBN 0-87371-373-7 **(1993)**
12. Gotaas H.B., Composting, Sanitary Disposal and Reclamation of Organic Wastes. World Health Organization, Geneva, Switzerland **(1956)**
13. Poincelot R.P., The Biochemistry and Methodology of Composting, Conn. Agr. Exp. Sta. Bull. No. **727 (1972)**
14. M.S. Rahman and M.A. Islam, Application of Multichannel Respirometer to Asses the Biokinetic Parameters of Industrial Wastewater, *International Research Journal of Environmental Sciences*, **2(6)**, 71-75 **(2013)**