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Compost from Sugarmill Pressmud and Distillery Spentwash for Sustainable Agriculture

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ABSTRACT

This paper describes the process for rapid composting of sugar mill pressmud and distillery spentwash by using microbial culture. These waste materials are processed to organic manure, a value added produce, which can be used to replenish soil nutrients. Replenishment of soil nutrients is essential since plants utilize them to generate a large amount of crop produce, year after year. Physico-chemical characteristics and the nutritive value of compost generated out of pressmud and distillery effluent have been found to support good plant growth. The product has gained wide utility as an ameliorating agent and as a soil conditioner to replenish soil nutrients for sustainable agriculture. Besides, composting is a suitable method for stabilization of organic wastes which avoids discharge of industrial wastes to land and water ecosystems that may cause pollution. Activated composting through microbial culture and appropriate conditions converts the organic matter of pressmud and spentwash into value added compost. The cumbersome bio-nondegradable portion of these wastes such as lignins, melanoidins and humic acid get converted to humus which is an essential component of soil and further enriches the soil for sustainable crop productivity.

Keywords: distillery compost, manure, organic fertilizer, soil conditioner

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INTRODUCTION

Crop harvesting removes nutrients from soil (Heckman *et al.* 2003). High yielding varieties and intensive cropping results in a greater rate of nutrient removal than traditional local varieties (Wanjari *et al.* 2006). The topsoil does not have an inexhaustive reserve of nutrients for agricultural activities. It is essential that the nutrients removed from the topsoil be replenished and the physico-chemical properties of the soil is maintained to restore the level of soil fertility for sustainable crop yield (Reeves 1997). Application of fertilizers can meet the inorganic requirements of plants to some extent but the physico-chemical characteristics of the soil are important to meet the sustained nutrient requirements of crops in intense cropping (De Datta *et al.* 1988; Dick 1992; Tester 1990; Dawe *et al.* 2000).

Recycling of organic manure is essential to replenish micronutrients, supplement macronutrients and to maintain soil health (Cassman 1999; Hati *et al.* 2007). High yielding varieties need increased fertilization through inorganic ferti-

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Invited Review

lizers. A high level of fertilization causes higher activity of microorganisms (Marinari *et al*. 2000; Timo *et al.* 2004), which consume the soil organic matter to meet their requirement of carbon or as source of energy. So, it is also essential to supplement the soil with organic manures to maintain the organic matter reserve. In addition, apart from being a source of plant nutrients, organic matter improves soil structure, helps to buffer the soil reaction, increase soil water holding capacity, and bring about essential and desirable biological activity that creates a healthy environment for enhancing crop yield (Tiessen *et al.* 1994; Reeves 1997; Editorial 2007; Hati *et al.* 2007). In general, the potential of organic wastes as manure as well as soil conditioner can be improved using three methods: a) Increasing the content of nutrients in a form available for the plant; b) enhancing the rate of mineralization in soil; c) developing an efficient method for composting.

In rural India most agricultural refuse and dung material generated from animal husbandry is utilized as fuel and for domestic cooking (Mishra *et al.* 1999). Therefore, waste material, including wastewater having high organic content and other inorganics viz. nitrogen, phosphorous, potash and some trace elements, has been successfully converted to value-added organic manure by adopting a scientifically designed composting process.

COMPOSTING OF WASTEWATER GENERATED FROM AN INTEGRATED INDIAN SUGAR-ALCOHOL INDUSTRY

Basic structure of Indian sugar-alcohol industry

India is the largest consumer of sugar in the world and the second largest producer next only to Brazil. The Indian sugar industry has about 571 sugar mills with an installed capacity of approximately 19 million tons (t) (Uppal 2004). The sugar industry is a major supplier of valuable by-products and waste materials like molasses, bagasse and pressmud. Distilleries may be considered as an allied industry of the sugar industry as they supply the basic raw material, molasses (or treacle, a thick syrup by-product from the processing of the sugarcane or sugar beet into sugar), for alcohol production. The majority of distilleries in India use molasses as basic raw material, though other feedstock's such as grain, malt and grapes are also employed. At present, there are about 319 distilleries in India with an installed capacity of 3.25 billion L of alcohol (Uppal 2004). Among the major end products of the distilleries, potable alcohol constitutes nearly half of the production (46%). The balance is industrial (40%), fuel grade "power" alcohol (10%) and alcohol for other applications (4%). Every 100 tons of sugarcane crushed on an average gives 10 t of sugar, 4.5 t of molasses, 33 t of bagasse and 2.5 t of pressmud. One t of molasses can produce around 225 L of alcohol. The sugar industry generates about 7.5 million t of molasses, 45 million t of bagasse, 5 million t of pressmud and 40 million m^3 of spentwash (Kumar 2003; Uppal 2004).

Sugar mills consume around 1,500-2,000 L of water and generate about 1,000 L of wastewater per t of cane crushed (Venkiteswaran 1987; Kumar 2003; Uppal 2004; http://envfor.nic.in:80/legis/water/water8.html). The effluent is mainly floor washing wastewater and condensate water, leakages from valves and glands of the pipeline, sugarcane juice, syrup and molasses in the effluent. The sugar mill effluent has a biological oxygen demand (BOD) of 1,000-1,500 mg/L (Kumar *et al.* 2003), but appears relatively clean initially; however after stagnating for about a week, it turns black and starts emitting a foul odour due to formation of H_2S.

Distilleries are one of the 17 most polluting industries listed by the Central Pollution Control Board (CPCB) (http://www.cpcb.nic.in) of India. For every L of alcohol produced, molasses-based distilleries generate 8-15 L of wastewater, characterized by high BOD (45-60,000 mg/L), high chemical oxygen demand (COD) (80-160,000 mg/L) and dark colour. Though wastewater is generated at various stages of alcohol production, wastewater from the fermenter sludge, spentwash and spent lees are the main contributors to pollution (Kaul and Nandy 1999; Nandy *et al.* 2002; Uppal 2004).

Wastewater treatment

In their effort to conform to discharge regulation, Indian distilleries employ various forms of primary, secondary and tertiary treatments. The typical treatment sequence is screening or equalization (controlling hydraulic velocity of wastewater flow rate preventing short term, high volumes of incoming flow, from forcing solids and organic material out of the treatment process and allowing adequate time for the physical, biological and chemical processes to take place) followed by biomethanation (anaerobic digestion with bio-gas recovery). The biomethanated (Nandy *et al.* 2002) effluent is occasionally subjected to a single or a two-stage aerobic treatment through activated sludge, trickling filters or even a second stage of anaerobic treatment in anaerobic lagoons. Ferti-irrigation and bio-composting with sugarcane pressmud are the most widely used options for effluent disposal. The conventional method of spentwash treatment through bio-methanation is not adequate and further secondary and tertiary treatments are needed to reduce the pollution potential to an acceptable limit (Kaul and Nandy 1999; Kumar 2003; Uppal 2004). Incineration completely destroys the utility of the spentwash and it is expensive. Evaporation of spentwash as well as membrane filtration (reverse osmosis) has also been recently employed as a treatment process by some distilleries in India (Goel *et al.* 2004; Sowmeyan *et al.* 2008). The above mentioned technologies have been tried for the treatment of spentwash; however none of these methods are found to be effective and economically viable to achieve the standards set by the CPCB and Pollution Control Boards at regional states of India. In this regard "Composting" technology is an alternative option for treatment. This technology not only prevents pollution but also produces valuable organic manure and a source of inorganic nutrients that may be applied to soil to enhance soil fertility. In practical terms, composting of wastewater promotes a new paradigm to reduce, reuse, recover and recycle wastes to conserve resources and reduce pollution.

COMPOST TECHNOLOGY

Composting emerges as the most widely applicable process for handling diverse wastes in recycling wastes (Haug 1980; Sharma *et al.* 1997; Masato *et al.* 2005). Organic wastes are composted in an appropriate manner depending on their physico-chemical nature (Anonymous 1980; Biddlestone and Gray 1985) to mitigate the environmental consequence of direct land application and meet the demand of organic manure for intensive agriculture (Fitzpatrick *et al.* 2005). A very wide variety of organic residues from sources of plant, animal and industrial wastes can be composted to generate a stable ecofriendly product (Haug 1993). Composting is a way of waste stabilization under special conditions of moisture and aeration (Lasaridi and Stentiford 1998, Mondini *et al.* 2003). It produces thermophilic temperatures, and eliminates the pathogens associated with accumulation of organic substrates and salts. Thermophilic temperatures are achieved using aqueous solutions with high substrate concentrations (Miller 1989) under special provision for aeration (Raviv 2005). Under aerobic conditions, the main products from composting of organic substrates are carbon dioxide, water and heat (Mari *et al.* 2003) and under anaerobic conditions metabolic products of the decompositions are methane, carbon dioxide and intermediates of low-molecular weight organic acids (Tuomela *et al.* 2000). Release of less heat energy per weight of organics decomposed indicates prevalence of anaerobic conditions and formation of numerous intermediates (Haug 1993). The nutrient content of compost is related to the quality of the original organic substrate (Mondini *et al.* 2003). Composting is particularly effective in converting wet materials, such as the spentwash, pressmud and other organic solid wastes produced from the sugar-distillery industries (Nandy *et al.* 2002; Strong *et al.* 2008), to a value added usable product that is readily disposed and has high agricultural use. The organic matter gets stabilized through decomposition, and the pathogenic organisms are destroyed, the exothermic heat generated during the reactions dry the wet substrate (Ranalli *et al.* 2001). All of these advantages of waste stabilization are obtained with minimal outside energy input; the major energy resource being the organics wastes as substrates. The external energy input associated with the aerotriller machine required for turning windrows is in the range of 50-75 HP.

Factors governing composting

There are several factors, affecting composting (Haug 1993; Ranalli *et al.* 2001; Strong *et al.* 2008). These include segregation of refuse (composting matter/substrate) and grinding or shredding of the material, carbon-nitrogen relationship, blending or proportioning of the wastes, moisture content, placement of material for composting, temperature, aeration, organisms involved, utilization of microbial inocula, reaction of the substrates, climatic conditions, destruction of pathogenic organisms, fly control, reclamation of nitrogen and other volatile nutrients from the substrates, time period required for composting, monitoring the composting process for judging and completion, quality of the produced compost and other economic aspects of the composting (Haug 1980, 1993; Sowmeyan *et al.* 2008). Keeping these fundamentals in view, composting of the spentwash has been a well established process and practice in India (**Table 1**).

Biocompost production using sugar mill pressmud and distillery spentwash

Composting is the decomposition of organic matter by a mixed population of microorganisms in a moist, aerobic environment. The composting process involves an interaction between the organic waste, microorganisms, moisture and oxygen. Composting of spentwash is carried out usually using pressmud generated from sugar mills. This biological process is activated optimizing the different parameters and composting is facilitated using microbial cultures (Nandy *et al.* 2002; Sarangi *et al.* 2005; Strong *et al.* 2008). The composting process of pressmud using bio-methanated spentwash has two unique features distinguishing it from other composting processes. One is the use of microbial culture as catalyst, a specially developed mixed culture of bacteria, actinomycetes and fungi (Rajukkannu *et al.* 1996; Ravichandran 1998; Senthil 1999) selected for their ability to rapidly degrade spentwash. The other is, the convenient blending and mixing of the refuse comprising of pressmud and liquid spentwash using the aerotriller machine. Aerotrillers comprises of a tractor with a creeper gearbox and a separate machine to aerotrill the windows and may be fitted with pneumatic driving machines. The aerotriller agitates, aerates and shreds the composting mass. In the composting process, heaps of pressmud are prepared in windrows of 3.5 m base and 1.5 m height and are triangular in cross-section.

Windrows are sprayed with a measured quantity of spentwash. The pressmud acts as the solid matrix that absorbs the organic-rich liquid spentwash and the composting process is activated by the microbial cultures. The ratio of spentwash to pressmud in the composting mixture varies to a maximum of 2.5:1 and according to the availability of spentwash and pressmud. The microbial cultures are mixed with the substrates of spentwash or pressmud at 1 kg/t in 10% aqueous solution.

After the first spraying of spentwash, the windrows are inoculated with microbial culture which is a consortia of different species viz. *Mucor*, *Aspergillus*, *Humicola*, *Dactylamyces*, *Torula*, *Azotobacter*, *Pseudomonas*, *Aerobacter*, *Penicillium*, *Trichoderma* and *Chaetomium*. The aerotriller then moves over the windrows. Because of the aerotrilling operation, lumps of pressmud are shredded to uniform fine particles. This increases the surface area of the pressmud, also increasing spentwash absorption. The mixing also provides air for the proper growth of microorganisms and helps in dissipating the heat that is liberated due to the metabolic activities of the microorganisms. Due to mixing by the aerotriller, the gases evolved during metabolism are also vented. The aerotriller is also necessary for improving the substrate-microbe contact. The entire composting cycle takes 8 to 11 weeks depending on the ambient conditions (Kaul and Nandy 1999; Nandy *et al.* 2002; Sarangi *et al*. 2005). The composting refuse is aerotrilled thrice a week.

During the composting process, the pH, BOD, COD, temperature, moisture and the C/N ratio are monitored. Due to exothermic decomposition reactions, the temperature of the windrows rises to about 70°C and then stabilizes at about 55 to 60°C which is considered to be the optimum range for active decomposition. A gradual fall in the temperature indicates the end of the composting reaction. The moisture during composting is maintained at 50–60% (w/w) by periodic spraying of spentwash.

At the end, the compost is allowed to dry, to about 30–35% w/w moisture that becomes quite powdery, and is easily bagable. During composting there is a sharp decrease in the BOD, COD and C:N ratio. The pH also increases from 4.5 to about 7, and the initial colour and odour of spentwash is destroyed. At the end of composting, the BOD and COD are within the limits suitable for agricultural application and meet the standards stipulated by the pollution control authorities for land application.

The bio-composting process is aerobic and thermophillic. The windrow size is selected considering complex physiochemical and biological reactions. These windrows work as biodigesters and horizontal evaporators. The liquid part gets evaporated due to increased adsorption in the surface area of the pressmud and the solid part gets biodegraded along with the filler mud solids to form dark-coloured humus. The probability of leachate percolation and groundwater contamination is avoided as the spentwash is sprayed mechanically and in a controlled manner on the refuse windrows during aerotrilling. Under this condition the absorption capacity of windrows is maximum. Once the system is stabilized, spentwash application is stopped and compost is allowed to cure and age, until moisture content stabilizes to 30-35%. The resultant product is plain compost with synonyms viz., bioearth, biofertilizer and biocompost. The process of bio-composting utilizes the tremendous potential of spentwash for the benefit of both the distillery industry and the agricultural sector (Gaur 1979, 1985). Bio-compost serves as an economical and ecologically viable option not only to overcome pollution problems associated with spentwash but also to generate a valuable product for increasing crop productivity. Thus, the composting process is governed by the characteristics of pressmud, spentwash, microorganisms and the process thermodynamics is affected by environmental and physicochemical factors, etc. Details of each component are given below.

Pressmud

Pressmud is a soft, spongy, amorphous and dark brown to brownish white material, containing sugar, fiber, coagulated colloids including can-wax, aluminous inorganic salts and soil particles (Satisha *et al.* 2005, 2007). Its composition and properties vary, depending on the quality of cane crushed and the process being used for clarification. The raw sugar cane juice obtained during milling of sugarcane contains suspended and dissolved impurities. The suspended impurities include dispersed soil, bagasse particles, wax, fats, proteins, gums, pectin, tannins and coloring matter which remain in colloidal form in the juice. The dissolved impurities present in the juice are the reducing sugars and inorganic salts of N, K, and P etc., which are plant metabolites, inter-

Table 1 Factors affecting composting of distillery spentwash and pressmud.

Factors	Significance for composting, and methods adopted to attain optimum level	Optimum level
Segregation of refuse / grinding or shredding	- Helps availability of sufficient oxygen permitting arability. - Renders materials more uniform for decomposition - Heating more uniformly, withstands excessive drying at the surface of the pile, insulates the pile against heat loss - Makes the material more responsive to moisture control, moving and handling. - Resists moisture penetration from rain and better acceptability of the finished product. - The Aerotriller agitates, aerates and shreds the composting mass	Drying to 30% moisture
Blending or proportioning of wastes	- Enhance the composting process faster, accommodate more biodegradable wastes and value addition to the compost. - The C/N ratio, moisture content and harmless effect of the blending material to the microbial population. - Blending is not essential when the C/N ratio is between 30 and 40. - Materials too dry and wet to compost need blending with proper proportions.	Pressmud: spentwash = 1:2 (v/v)
Placement of material	- In open pile or windrows placed directly on a cemented area - The exact arrangement of windrows, piles depend on the local requirements relating to materials handling equipment, labor costs and climatic conditions - The most suitable height of pile is about 1.5-1.8 m and 0.9-1.22 m in width, about 2.44-3.66 m long for convenience of turning and heat insulation. The cross-section is usually trapezoidal, the top width is governed by the width of the base with the angle of repose of the material is about 30° from the vertical.	1.5-4.5 m wide × 0.5-1.5 m height
Carbon : Nitrogen ratio	- Under high carbon, the organisms die when the nitrogen is used up and decomposition decreases. Further, decomposition takes place when other organisms utilize the nitrogen stored in the dead organisms requiring more time to complete composting. - The initial C/N ratio 30 is most favorable for rapid composting and a C/N value of 26-35 is optimum	30-40
Moisture building	- When aeration is adequate decomposition proceeds at 30 to 100% moisture maximum moisture content can be up to 85%. - 30-50% moisture content favor increase in the initial temperature in comparison to moisture content of 73%. - In high moisture content substrates fibrous additives materials like saw dust, bagasse, pressmud, dried sludges are useful. - More frequent turning and aeration promotes moisture loss	40-60%
Temperature	- Indicate progress of exothermic biological reactions and aerobic fermentation process. - Essential for the destruction of pathogenic organisms and undesirable weeds. - 45-50°C is obtained in the first 24 h, 60-70°C after 2-5 days. - The organisms do not carry decomposition for extended period at temperature >70°C. - The final decline in temperature is more gradual than the original rise and indicates that the material has become well stabilized.	50-70°C
Aeration	Aeration is necessary for thermophilic aerobic composting to obtain rapid decomposition. Turning the material is the most common method of aeration. Mechanical Aerotrilleres machine are used for turning windrows. Aerotrillers is a modified from of tractor with a Creeper Gearbox and a separate machine with pneumatic driving machines. - When moisture >70% turning is recommended every day - When moisture 60-70%: 4 to 5 turnings at 2-day intervals - When moisture 40-60%: 3 to 4 turnings at 3-day intervals	Oxygen level is maintained at 10-15%.
Organisms involved	- Bacteria and fungi are the principal biological agents for composting. - Mesophillic bacterial dominate at the start of the composting process at 40-45°C. - Thermophilic actinomycetes and fungi grow at 45 and 60°C temperature range and decompose cellulose, lignin, and other more resistant materials. - Cellulose and lignin decomposition by actinomycetes and fungi occur near the end of the composting period by species of Micromonosperma, Streptomycetes and Actinomyces. - Actinomycetes undertake 80-90% of the composting activity.	Consortium of bacteria, actinomycetes and fung at 1 kg/tonne of pressmud
Use of microbial inoculum / activators	Composting processes have been activated using special inocula containing several pure strains of laboratory-cultured organisms, and other biological factors like; enzymes, hormones, preserved living organisms, activator factors and biocatalysts, etc. Useful only when the microbial populations are unable to develop sufficiently rapidly in the composting environment. - Individual microbial strains are prepared in pure culture and a consortium of the cultures is made to enhance their degradative ability greater than that of any single strain due to bioaugmentation and through a symbiotic catalytic effect	Contain several species of bacteria, actinomycetes and fungi.
Reaction thermodynamic s	- The pH between 5.0 and 7.0 is optimum for composting. - The pH rises during composting and stabilizes between 8.0 and 9.0 towards the end of the process. - Anaerobicity produces large amounts of organic acids. - Ash, carbonates, lime, or other alkaline substances help to maintain pH. - Initial pH values of 5.0 to 6.0 do not retard active decomposition, but the temperature increase more rapidly when the pH is in the range around 7.0 and above. - The energy released from the system is from the enthalpy changes as the sum of the enthalpy of products minus reactants as exothermic reactions. The organic molecules would always burn to form stable form such as CO_2 and H_2O, and the rate of the reaction is usually a function of temperature.	Temperature up to 70°C after 10 days
Climatic conditions	- Temperature, wind and rainfall, influence the composting operation. Strong winds lower the temperatures on the windward side of a compost stack. The coarseness of the materials affects the porosity and evaporation of the pile and the moisture content play important role in temperature lowering by winds. Increasing the size of the stack and wetting control the temperatures sufficiently. - Besides monsoon, rain usually does not seriously affect composting when stacks are built with a rounded top to run off water and the compost site is adequately drained to prevent water accumulation around the stacks and penetrate the pile. Compost stacks are made on concrete drainable surfaces.	Ambient temperature 25-30°C, concrete yard, proper drainage facility for leachate collection and analysis, operated under cover in monsoon

Table 1 (Cont.)

Factors	Significance for composting, and methods adopted to attain optimum level	Optimum level
Destruction of pathogens	- Aerobic thermophilic composting at high temperatures destroying pathogenic organisms. The magnitude and duration of the high temperatures are important. - Turnings ensure pathogen and parasite destruction and effective for controlling flies. - Fly-breeding is controlled by composting on a concrete surface on which the larvae cannot pupate.	Thermophillic composting at 70°C
Reclamation of nitrogen and other volatile nutrients	- Nitrogen loss as ammonia is affected by the C/N ratio, the pH, the moisture content, aeration, temperature, form of nitrogen compounds at the start of composting, and the adsorptive, or nitrogen-holding, capacity of the composting materials. - Nitrogen conservation decrease rapidly as the initial C/N ratio <30 or increase at 40-50. When carbon is in excess of the ideal C/N ratio, the organisms consume all nitrogen for decomposition of the carbonaceous materials and at low C/N ratio high quantities of ammonia and volatile forms of nitrogen is given off . - Large amounts of ash and amendments in the materials increases initial pH and lose more nitrogen as ammonia above pH 7.0. - Lime is added when the raw material has a high acidity pH <4.0. The pH increases to 5 on the resumption of biological action and nitrogen is conserved. - A moisture-content range of 50-70% is satisfactory for conserving nitrogen. The water serves as a solvent and diluents for the ammonia and reduces the vapour pressure and volatilization. - When other factors are favourable for nitrogen conservation, the losses due to mechanical turning is not high. - High temperatures increase volatilization and escape of ammonia. Temperatures >70°C retard bacterial activity and permit ammonia accumulation. - The cellulose and porous fibrous matter adsorb or hold moisture and volatile substances, and reduce nitrogen escape from the accumulated ammonia. - Loss of nitrogen, phosphorous and potash loss occurs by leaching in rainy weather and excess liquid wastes.	Temperature, pH, moisture and turning is regulated
Monitoring and completion time	- The compost is satisfactory when the C/N ratio is optimum and high temperatures is no long be maintained in spite of aerobic condition. - The time period required for satisfactory stabilization depends on: (a) the initial C/N ratio (b) the particle size (c) the maintenance of aerobic decomposition and (d) the moisture content. - Low C/N ratio materials are decomposed in the shortest time, while in higher C/N ratio materials where carbon is in the form of cellulose and lignin are attacked last by the changing biological population and take ore time for stabilization.	Not less than 12 weeks
Judging quality of compost	There are three groups of tests for judging the over-all operation and final product. - Tests of the sanitary quality of the operation and of the finished product - Tests of the fertilizing or agricultural value. The amount of nitrogen, phosphorous, potash, and other nutrients, nutrient conservation, the C/N ratio, and the compost value as shown by crop returns and soil analysis from time to time - Economic tests. The total cost of producing the compost is less than its value as fertilizer plus the cost of disposal by other means, such as incineration or land fill. Resource recovery from waste and an viable alternative for waste disposal	The process is monitored and product is evaluated before use
Economic aspects of composting	- When using composting as a method for waste disposal, the return from the compost need not pay the entire cost of composting. - Other methods of disposal, such as sanitary land fill, or incineration, which usually costs four to six times more than land fill and yield no return. - To be economically sound from only the viewpoint of costs, the income from the sale of the compost should be at least equal to the entire cost of processing, including overheads and interest, less the cost of disposal by whatever other method might be used	Economical and ecofriendly

Sources: Hauge 1980, Haug 1993, Kaul *et al*. 1999, Nandy *et al*. 2002, Kumar 2003, Sarangi *et al*. 2005

Table 2 Composition of typical pressmud from sugar factory.

Composition	%
Nitrogen	1.0-1.5
Phosphorus (P_2O_5)	1.4-4.0
Potassium (K_2O)	0.5-2.0
Calcium (CaO)	3.2-12.0
Magnesium (Mg)	1.0-2.0
Sulphur (S)	0.1-0.5
Organic Carbon	15.0-36.0
Iron (Fe)	0.08-0.3
Manganese (Mn)	0.01-0.3
Zinc (Zn)	0.14-0.04
Copper (Cu)	0.003-0.0245
C:N	16-36
pH	6.0-7.0
EC DS/m	3.0-3.3

Sources: Sarangi *et al*. 2005; Satisha *et al*. 2005, 2007

mediates and constituents. Two types of processes viz. sulphitation and carbonation are commonly used to clarify the cane juice to obtain crystal sugars from the juice. Sulphitation process is carried out with the help of lime and sulphur dioxide (SO_2), which forms $CaSO_3$ as a byproduct along with other impurities. Lime and CO_2 are used during the carbonation process to get a clear cane juice, which forms $CaCO_3$ as a by-product along with other impurities. The pressmud generated from the sugar industry contains a variety of essential elements with a carbon to nitrogen ratio 16:36 suitable for composting (reference). It is estimated that on an average each ton of pressmud contains about 10-15 kg N, 36 kg P, 14 kg K, and 23 kg S (Tandon 1992). The average composition of typical pressmud is given in **Table 2**.

Spentwash

Distillery spentwash is a caramelized, and cumbersome waste effluent of very high BOD (40,000–50,000 ppm) and COD (85,000–1,20,000 ppm) that contain complex inorganic and organic constituents (Pande *et al*. 1995; Rajukkannu *et al.* 1996). The treated effluent retains dark brown colour due to the presence of a natural polymer, known as "melanoidins", high total dissolved solids (TDS), sulphate, chloride and potash. In addition to this, formation of sulphide during the anaerobic digestion adds more darkness to the colour of the effluent. The physico-chemical characteristic

Table 3 Physico-chemical characteristics of treated distillery spentwash.

Parameter/composition	Raw spentwash	Primary treated	Treated
Color	Dark brown	Brown	Black
pH	4–4.5	5.0-6.0	7.0-7.5
Turbidity	High	High	High
Ec (dS/m)	<15	<10	<6
BOD (mg/L)	45000-60000	5000	2000
COD (mg/L)	80000-120000	42000	42000
Suspended solids (mg/L)	10000	1500	1500-2000
Total dissolved solids (mg/L)	100000	50000	20000-35000
Total Nitrogen (mg/L)	1000-2200	300-800	200-300
Phosphorus (mg/L)	400	200-300	70-100
Sulphate (mg/L)	2100-2300	1000-2000	500-900
Chloride (mg/L)	5800-7600	5000-6000	4000-1000
Sodium (mg/L)	400-500	300-400	300-400
Potassium (mg/L)	1100	10000-13000	5000-10000
Magnesium (mg/L)	1500-2000	1500-2000	500-700
Calcium (mg/L)	7500-8200	2000-3000	1000-2000
Zinc (mg/L)	3-4.5	4-5	5-6

Sources: Kaul and Nandy 1999; Sarangi *et al.* 2005

of typical untreated, primarily treated and treated distillery spentwash is presented in **Table 3**.

Alternative substrates for composting spentwash

Normally the spentwash is composted with the pressmud obtained from the sugar industries. But, most of the stand-alone distilleries find it difficult to obtain sufficient quantity of pressmud to use as substrate along with the spentwash. Therefore, alternative substrates like crop residues, sugar cane trash and coir pith are used instead of pressmud (Satisha and Devarajan 2007). Studies have indicated that crop residues like sunflower, maize stalks and sugarcane trash are ideal substrates (Kumar 2003). These substrates need to be finely chopped into pieces of ≤ 1 cm for early decomposition. Combinations of pressmud with sunflower stalks in 1: 1 proportion was found to be an ideal alterative substrate followed by pressmud with sugarcane trash. Application of spentwash to the substrates once in two days to a final 1: 3 ratio was ideal to decompose the substrates in four months to obtain a stable compost (Srinivasamurthy and Patil 2006). Wide ranges of alternative substrates have also been used for composting with spentwash (Satisha and Devarajan 2007) and pressmud (**Table 4**).

Microbial inoculum

The activating biocompost materials is a method of rapid bioconversion of the recalcitrant wastes from the distillery and sugar industries through the aerobic route, whereby heterotrophic microorganisms act on carbonaceous materials in the presence of inorganic material (Haug 1993; Insam *et al.* 2002; Bess 1999; http://www.bbclabs.com). It includes bacteria and fungi, which initiate and catalyse the process for active degradation of insoluble high molecular weight organics such as cellulose, chitin, proteins, waxes, paraffin, etc. The microbial populations are influenced by feed substrate, temperature, aeration, pH, moisture content and by the mechanical agitation applied to the substrates during composting (Laura and Idnani 1972; Riddech *et al.* 2002). Mesophillic bacterial types dominate at the start of the composting process followed by the activity of thermophilic types, as temperature increases above 40-45°C (http://www.epa.gov/waste/conserve/rrr/composting/index.htm). The different thermophilic bacteria play a major role in decomposing protein and other organic matter during the first few days (Haug 1980, 1993). They continue to predominate throughout the process in the interior of the piles, where temperatures are inhibitory to actinomycetes and fungi. When the temperature has reached 60-70°C, major changes in the nature of the compost stack take place, the stack shrinks drastically and the appearance of the material also undergoes rapid changes. Thermophilic fungi usually appear after 5–10 days, and actinomycetes predominate in the final stages during rapid composting. The thermophilic actinomycetes and fungi grow in the temperature range between about 45 and 60°C. Fungi and actinomycetes play an important role in the decomposition of cellulose, lignin, and other more resistant materials near the end of the composting period. Species of *Actinomycetes* genera, include *Micromonosperma*, *Streptomycetes* and *Actinomyces* that remain active during the composting process (Gaur *et al.* 1980). *Actinomycetes* undertake 80–90% of the composting activity. The fungal species prevalent in the refuse mass are in the order of genus *Mucor* > *Aspergillus* > *Humicola* > *Dactylamyces* > *Torula* > *Chaetomium*. High temperature, acidity and anaerobic conditions limit the fungal growth preventing the process of composting. When the necessary organisms for composting are present in the refuse, it is just needed to provide the environment favorable for their growth to carry on the process.

Specialized inoculum and activators

An exact knowledge of the microorganisms prevailing in the composting substrate helps to externally add those species into the refuse mass to improve the composting process. Developments in the composting process, have been accompanied by special inocula containing several pure strains of laboratory-cultured organisms, or other biological factors essential in the decomposition of organic matter and nitrogen fixation. Some of them include the use of enzymes, hormones, preserved living organisms, activated factors, biocatalysts, etc. These bioaugmentators are useful when the microbial populations are unable to develop sufficiently and/or rapidly in the composting environment. Some of the different groups of organisms in the mixed microbial population apparently remain inactive until the environment is satisfactory for their growth, and then emerge and perform their role in the succession of steps in the stabilization process. When any group of bacteria is capable of multiplying at a rate equal to that of its developing environment, any addition of similar organisms as an inoculum has no significant benefit.

The following observations are made on the use of spe-

Table 4 Physico-chemical properties of alternative substrates used for composting with pressmud and spentwash.

Parameters	Pressmud	Coirpith	Yeast sludge	Bagasse	Sugarcane trash	Water hyacinth
pH (1:10 w/v)	7.18	5.91	5.45	4.74	6.95	6.95
EC (dSm^{-1})	2.96	1.43	9.30	0.33	0.63	6.15
Organic carbon (%)	32.60	37.26	9.52	37.98	36.00	27.67
Nitrogen (%)	1.20	0.42	1.67	0.45	0.44	0.81
C:N ratio	27.17	88.71	5.70	84.40	81.82	34.16
Phosphorus (%)	1.15	0.02	0.78	0.06	0.17	0.07
Potassium (%)	0.62	0.54	4.48	0.14	0.46	1.43
Calcium (%)	4.14	0.46	7.66	0.70	0.24	1.76
Magnesium (%)	1.10	0.31	0.77	0.30	0.18	1.40
Total phenols (mg 100 g^{-1})	23.30	116.70	22.20	62.00	89.60	83.20

Source: Satisha *et al.* 2007

cial inoculums developed by several commercial companies to facilitate the composting processes (Haug 1980, 1993).

- The number of bacteria is rarely a limiting factor in composting when the environmental factors are appropriate. The indigenous bacteria, which are much better adapted than those cultured under laboratory conditions, multiply rapidly.
- Hormones are used to designate the growth factors and vitamins needed by the bacteria or other organisms.
- Biocatalysts and activated factors are materials, which are supposed to activate and accelerate decomposition and stabilization of organic materials. Such as, nitrogen and phosphorous usually materials lacking in the compost. They are added as a nutrient source for the microbes for carbon decomposition.

The microbial consortium is added as the initiation dose at the start of the compost cycle and as a maintenance dose at regular intervals of composting **(**Kaul and Nandy 1999; Sarangi *et al.* 2005). Bioaugmentation is the inoculation of individual strains that are isolated and selectively adapted to degrade specific compounds. The microbes enhance the biomass ability to degrade the recalcitrant substrates of pressmud-spentwash (Ravichandran 1998). A typical compost inoculum, contains several species of bacteria, actinomycetes and fungi. There is no dominant role to a species rather it is synergistic effect at different time period of the entire process. The performances of indigenous species are enhanced through microbial augmentation.

The efficiency of decomposition by the inoculum are judged and regulated by different attributes (Sarangi *et al.* 2005).

- No odour from the compost refuse;
- Evolution of good moisture and a smoke like appearance from the compost yard during a rainy day;
- No flies in the yard;
- Effluent consumption ratio to pressmud is more than 2;
- The finished product satisfying the leachate and other tests in minimum composting duration.

Activity schedule for composting pressmud with spentwash followed by Indian industries

The time schedule of different activities of biocomposting of spentwash using pressmud is as follows. 1st week: windrows formation with pressmud and natural drying of pressmud to bring down moisture content below 60%; 2nd week: seeding of pressmud with microbial inoculum, spentwash application and aerotilling; 3-9th week: spentwash application in the proper ration to maintain moisture content at 50–60%, trimming, aerotilling; 10-12th week: curing with water spray, trimming, aerotilling, drying to bring down moisture content below 30%; 13th week: removal of windrows and bagging for transportation to the enduser. Around 900 kg of compost is generated from the refuge of one ton of pressmud and 2.5 to 3 t of spentwash. Composting reaction is completed in about 10 weeks. Curing and maturation is carried out for another two weeks. The process steps adopted for rapid composting of pressmud with spentwash in windrows through solid-state aerobic decomposition are presented next (Nandy *et al.* 2002; Sarangi *et al.* 2005).

(1) The pressmud is stacked in windrows of 1.5 to 5.0 m in width, 0.5 to 1.5 m in height, lengths varying from 5 to 100 m depending on the area of the yard, and dried under open air to reduce moisture content to 30%.
(2) Windrows of pressmud are aerotilled and trimmed to break lumps and shredded to a nearly homogenous mass for uniform application.
(3) The windrows are inoculated with microbial consortia consisting of cellulolytic and lignin degrading species of *Mucor*, *Humicola*, *Dactylamyces*, *Torula*, *Chaetomium*, *Azotobacter*, *Pseudomonas*, *Aerobacter*, *Trichurus*, *Chaetomium*, *Aspergillus*, *Penicillium* and *Trichoderma* useful for decomposition of the recalcitrant substrates of spentwash, at 1 kg/t of pressmud in 10% aqueous solution.
(4) The spentwash is sprayed on the windrow at a ratio of 1:2.5-3 (v:v), and mixed uniformly with pressmud utilizing the aerotiller to build up moisture level of 50-60%.
(5) The specified quantity of spentwash is applied in two to three split doses within time duration of one week.
(6) The refuge mass is aerotilled for proper mixing, trimming and prevent anaerobic condition to buildup oxygenation to around 10-15%. Every windrow is turned by the aerotiller thrice a week.
(7) Population of inoculum is maintained for active degradation through proper dosing, if required, in case temperature of the windrow was not increased, additional small doses of inoculum were applied during aerotilling.
(8) The kinetics of reaction is monitored through recording of temperature of the mass. Temperature of the refuse mass reaches up to 70°C after 7 to 10 days time due to activity of thermophillic microbes, which also help to destruct the pathogens.
(9) Moisture content of the refuge is maintained to below 60% through aerotilling and shredding, avoid clump formation and build up of anerobic condition in the composting mass.
(10) The refuge mass is aerotilled after each spraying of spentwash, and afterwards, if the temperature of the mass drops or does not attains up to 70°C.
(11) Climatic conditions mainly temperature, humidity, wind velocity and rainfall in the compost yard is controlled not to impede the process.
(12) The C:N ratio of the compost produced from pressmud and distillery spentwash is monitored for each batch and maintained to 10. Otherwise the composting period is extended without addition of spentwash.
(13) Aerotilling is carried out intermittently for proper composting of the substrates.
(14) The final product is stabilized through curing or left over time for two to three weeks when no more active decomposition takes place and the refuge donot leach brown colour in aqueous solution.
(15) The total time period required for composting of one batch is up to 12 weeks.
(16) The entire activity is carried out on concrete yards with drainage system for collection of leachates.

Amongst the various possibilities for utilization of the distillery spentwash and sugar mill pres mud; biologically activated composting for conversion of the effluent to a value added resource is most meaningful that generates a useful product of profound agricultural use. The pressmud is a solid organic waste material available in large quantities in sugar factories and a good substrate for the solid-state fermentation as it contains about 40% organic matter (Xavier *et al.* 1994). The proximity of sugar units to many dis-

Table 5 Physico-chemical characteristics of biocompost produced from activated composting of pressmud with distillery spentwash.

Parameters	Value/concentration
pH	7-8
EC (dS/m)	1-1.4
Colour	Light brown
Ca (%)	4.3-5
Na (%)	0.5-0.7
K (%)	2.5-4.0
HCO_3 (%)	0.005-0.007
CO_3 (%)	0.001-0.002
Cl (%)	0.01-0.02
SO_4 (%)	0.1-0.2
Organic carbon (%)	15.98
Total nitrogen (%)	1.27
Available nitrogen (%)	0.11
Total phosphorus (%)	1.61
Total potassium (%)	1.42
Total ash content (%)	50.00

Source: Sarangi *et al.* 2005

tilleries helps the use of pressmud as the substrate for solid-state fermentation of the distillery spentwash, generate a value-based product utilizing both wastes, and prevent pollution and resources conservation through reuse of nutrients and water loss in the wastes, elimination of effluent discharge to surface water and conservation of surface water sources. The physico-chemical characteristics of the biocompost produced from the sugar-distillery industry is presented in **Table 5**.

Requirement for spentwash composting in a distillery industry – a case study

A distillery company attached with a sugarmill of 10,000 TCD (Tones Crushing per Day of sugarcane) has established biomethanation plant for treatment of spentwash and the treated spentwash was subjected for composting using pressmud and other wastes from sugarmill. The quantity of biomethanated spentwash was 750 m^3/day with a COD of 30,000–35,000 mg/L having BOD of 5000–6,000 mg/L. This biomethanated spentwash is pumped to biofertilizer manufacturing yards distribution feeder with a special class pipeline with uniform network in the compost yard. Through homogenizing machine the biomethanated spentwash is mechanically spread under controlled flow along with the aeration through aerotrilling of windrows of pressmud and other filler materials. The total material requirement includes pressmud (30% solid): 6600 t, boiler ash (100% solids): 412.5 t, rotten bagasse (80% solid): 1237.5 t, filler material (8250 t), ETP sludge (30% solid); 150 t and spentwash (15% solid): 22,500 t resulted in 30,060 metric t of finished biocompost per year. The total spentwash consumption per year in one hectare land works out to be 212 m^3/day. The biocompost produced in the process contains in %; N: 2-2.5; P: 1.6-1.8; K: 4-6; C:N ratio 8-11; moisture up to 30% and pH 7-8, which is comparable with the farm yard manure (FYM) (**Table 6**).

The crop nutritive value of biocompost derived from pressmud and distillery spentwash and the FYM compost are compared in **Table 6**. The N, P, K values of biocompost was much better than the FYM. Some of the inorganic components in the biocompost were higher than the FYM. These constituents act as good soil conditioner for marginal and low lands having poor soil health, and source of plant nutrient for intense agriculture.

The biocompost is rich in humus, which acts as the substrate to ligand the nutrients applied to the soil under intensive agriculture, and facilitates to make the nutrients available to the crop plant throughout the growth period. Increased crop yields have been reported through utilization of the biomanure (Ramdurai and Gerard 1994; Kaul and Nandy 1999; Kumar 2003). Biomanure produced from the composting process has numerous applications: (1) A source of material for maintaining and building soil humus, necessary for proper soil structure and moisture holding capacity. No quantity of chemical fertilizer can substitute for humus. Soils devoid of humus become infertile and demand more fertilizer at every crop cycle. Also, leaching or volatilization of the applied fertilizer takes place due to lack substrates that could bind it and retain in soil.

Table 6 Comparison of nutrient value of Farm Yard Manure and distillery biocompost.

Composition	FYM	Distillery biocompost
Nitrogen (%)	0.3-0.5	2.0-2.5
Phosphorus (P_2O_5) (%)	0.5-0.9	1.6-1.8
Potassium (K_2O) (%)	0.4-0.6	4.05-6.0
Calcium (CaO) (%)	0.5-1.1	4.3-5.0
Magnesium (Mg) (%)	0.2-0.4	0.3-1.0
Sulphur (S) (%)	0.1	0.5-0.10
Organic carbon (%)	8-12	20.0-28.00
Iron (Fe) (%)	0.129	0.4-0.6
Manganese (Mn) (%)	0.032	0.014-0.019
Zinc (%)	0.047	0.02-0.25
Cupper (Cu) (%)	0.006	0.01-0.15
C:N	10-22	8-11
pH	6.5-7.5	7-8
EC (dS/m)	-	1-1.4

Sources: Kumar 2003, Sarangi *et al.* 2005

Limitations and problems associated with composting of spentwash

More fibrous and bulky composting material like the pressmud absorbs water of the spentwash and can retain high amount of moisture from the liquid effluent. High moisture level eliminate inter particle spaces within the composting mass; reduces the rates of oxygen transfer and reaction temperature and the rate of biological activity (Gaur *et al.* 1980; Haug 1980; Gaur *et al.* 1985; Pathak 1995). The principal factors, optimum levels and steps, adopted for rapid composting of the pressmud and spentwash have been discussed earlier. It is essential to adhere to the prescribed levels of the different factors for effective composting and proper quality of the biocompost.

- Due to high moisture content the composting of the refuse mass lack porosity, and tend to compact and prevalence of anaerobic conditions.
- Proper composting does not take place through manual or just mechanical shoveling. Adequate aeration is essential through extensive mechanized aerotilling arrangement in a large volume of the refuse.
- Improper application of the effluent lead to high moisture content of the refuge mass and decrease the composting temperature.
- Proper C:N ratio of the refuge is essential to meet the nitrogen requirement of the decomposers for efficient operation of the composting process, and prevent nitrogen loss during the process due to high temperature.
- The final product is stabilized through curing when no more active decomposition takes place, and the compost do not leach brown color in aqueous solution.
- The long time period required for composting depends upon the initial C:N ratio, particle size, aerobic condition, and moisture content.
- The rapid buildup of heat is dependent on the microbial population in the substrate and availability of oxygen in the refuge mass, which require thorough aerotilling at regular intervals. Rapid drop in temperature during the initial period indicates reduced microbial activity.
- The moisture content of the pressmud is maintained in the range of 40-60% by addition of concentrated spentwash. The level is adhered to strictly at the initial stages of the biocomposting process, when the microbial activity is at its highest. Development of anaerobic conditions results in offensive odours and also leaching out of essential nutrients and intermediate products of decomposition.

A need exists to minimize the VOC emissions from composting of distillery spentwash in order to facilitate composting in a more acceptable and aesthetic manner.

Advantages of composting of pressmud and spentwash

Pressmud is used as; (i) a source of plant nutrients, (ii) an ameliorant for acidic and saline-sodic soils, (iii) as a medium for germination and growth of seedlings and (iv) as a carrier for microbial inoculants and applied as such to fields for raising crops (Deodhar 1991; Rajukkannu *et al.* 1996). Its direct use on land for raising crops may impart adverse affect on the soil and crop due to high content of wax (8-15%) and carbon, which can alter the physico-chemical properties of the soil, affect crop productivity and possible termites infestation in soils. It is necessary to convert the pressmud to a more stable and safe product through composting. Likewise, the distillery effluent contains high BOD, COD, charred organic complexes, and other inorganic compounds inhibit microbial activity for further degradation. It is however, a potential source of plant nutrients, which could be recycled to a valuable product through biocomposting with pressmud and other substrates (Gaur 1979, 1985). The advantages of spentwash composting using pressmud are highlighted below.

- Recycle and reuse of pressmud and spentwash in the process for producing biocompost
- Helps in achieving the target of zero discharge
- Provide organic manure to the nearby farmers in rural areas at lower cost
- Non degraded organic and inorganic matter of the spentwash gets stabilized in the soil
- Minimization or odours problem and VOCs generated from spentwash
- Minimum land requirement as compared to conventional treatment processes.

SIGNIFICANCE OF USE OF SPENTWASH AND SPENTWASH BASED COMPOST FOR SUSTAINABLE AGRICULTURE

Composting of sugar mill pressmud along with partially treated or completely treated distillery spentwash; activated through proper procedure along with microbial culture, produce valuable compost for sustainable agriculture. The spentwash based compost is beneficial to soil and crop and also provide benefit of utilization of waste as a resource and proper management of environment (Anonymous 1980; Tandon 1995). In some parts of India, where water availability is poor but distillery spentwash is in plenty, the farmers directly utilize spentwash in suitable quantities mixed with water for the irrigation of soil and crops. In most of the cases, the distillery industry prepares the spentwash based compost and the same is sold to the farmer for agricultural use.

Spentwash and spentwash-based compost can be used for sustainable agriculture. Their use not only improves soil quality and enhances soil nutrients but also results in increase in crop productivity. The various advantages of use of spentwash and spentwash based compost in agriculture is outlined below:

Improve soil quality and nutrients

The compost produced from the distillery spentwash and pressmud with and without amendments is known in different names viz. bio-compost/compost/bioearth/biomanure. The beneficial effects of distillery spentwash (partially treated after methane production through anaerobic digestion methanation) on the physico-chemical properties of soil after application are widely reported. Studies on using raw spentwash on soil indicated a beneficial effect on fallow dry lands and ameliorative effect on reclamation of alkaline sodic soils (Sindhu *et al*. 2007).

Studies were conducted by Nasir and Qureshi (1999) to assess the long-term effect of biocompost prepared from filter cake (dewatered activated sludge produced from effluent treatment plant) and stillage (liquid effluent after distillation of ethanol) of distillery on soil and sugarcane health. The biocompost was used alone and/or in combination with inorganic fertilizers and its residual effect was studied on first and second ratoon crop. Soil was analyzed before planting and after each harvest. After three years, available K increased from 138 to 195 mg/kg, while electrical conductivity of soil extract (ECe) was reduced from 1.95 to 1.50 dS/m and P and organic manure were sustained in the treatments where biocompost was applied. Residual effect of biocompost was quite pronounced in the first ratoon. It could be concluded that 25 t/ha biocompost could save all K and half N and P with a significant increase in yield over fertilizer treatments. It was suggested that bio-composting from filter cake and stillage is the best way to exploit the environment polluting effluent and to improve the soil and plant health.

The high concentration of calcium (2050–7000 mg/L) in spentwash had great potential in reclaiming sodic soils similar to that of gypsum effect. Conjoint application of spentwash and organic amendments (farm yard manure, green leaf manure and bio-compost) was found to be suitable under dry land conditions (Sindhu *et al.* 2007).

Large amounts of soluble salts were leached from calcareous and high pH sodic soils amended with spentwash. Leaching of high amounts of sodium from high pH sodic soils resulted in ameliorating soil quality. The results of the study indicated that, in general, the substrates amended with distillery composts showed improved physical and physico-chemical properties, absence of phytotoxicity and good nutrient content, especially with respect N, P and K. However, these substrates also showed pH and electrical conductivity values higher than pure peat (Bustamante *et al.* 2008).

The effect of amendments on composting of sugar industry pressmud was studied by Satisha and Devarajan (2007). Rock phosphate and micronutrients viz., $ZnSO_4$ and $FeSO_4$ were used as inorganic additives. The organic additives used with pressmud were yeast sludge, bagasse, coir pith, water hyacinth and sugarcane trash. Addition of additives showed potential in improving the C/N ratios, increase in cation exchange capacity (CEC) and increase in the germination index value of *Raphanus sativus* crop.

A US patent has been granted for a novel product for agricultural use, which is obtained from distillery spentwash and sludge (Novalpotro 2006). The product which is in the form of granules or pellets comprises of at least 4% (w/w) of vinasses and/or sludge and an organic or inorganic solid support. It has potential application in agriculture for improving soil quality and nutrients.

The short-term carbon and nitrogen mineralization in soil amended with winery and distillery organic wastes was assessed (Bustamante *et al.* 2007). The influence of the organic wastes derived from the winery and distillery industry i.e. grape stalk (GS), grape marc (GM), wine lees (WL) and exhausted grape marc (EG) and different soil type viz. clayey-loam (S1), loam (S2) and sandy textured (S3) was used to assess the carbon and nitrogen mineralization. The C mineralization reaction rate fitted a first-order kinetic model for all amended soils. An initial increase was observed in specific respiration (qCO_2) at the beginning of the experiment. Afterwards, the evolution in the qCO_2 was to tend towards the values of the control soil due to the pattern of the soil to recover its initial equilibrium status. The addition of these materials in the soil produced a slight increase of the inorganic nitrogen content, except in the case of GS and EG in most of the studied soils. The use of GS as amendment produced an inhibition in the N mineralization in all three types of soils studied. Organic matter mineralization was influenced by soil type, sandy soil favoring more N and C mineralization processes than the clayey-loam and loam soils. It was concluded that addition of these wastes to the soils did not modify the pH values due to the calcareous character of the soils used, however, soil salinity increased in most of the amended soils. This was found to be a major concern regarding the use of the studied dose of winery and distillery wastes (96 t/ha, dry weight). The organic C mineralization was influenced by the soil characteristics and residue type, increasing this mineralization when the clay content was lower in the soil and higher in the presence of soluble compounds in the residues. The residue type had a major effect on the N mineralization than the soil characteristics, with the observation that the polyphenol and the initial N and soluble compound contents, as well as the C:N ratio of the residue were the most important influencing factors on the N soil dynamics. A low N mineralization of these materials and low N immobilization was observed in the soils amended with GS. Although these wastes did not show a high N fertilizing capacity, their use to protect the soil and conserve the organic carbon could be possible due to the C mineralization as the qCO_2 evolution followed the same pattern similar to other wastes usually used as soil amendment. Soils fertilized with traditional inorganic fertilizers were used for comparison. Fertilization with the wastewater caused a decrease of soil pH to a depth of 100 cm, increase in electrical conductivity because of the large concentration of K in the wastewater and also increased the organic matter content throughout the profile. Vinasse application yielded the intercalation of some compounds in the clay mineral. The formation of organo-mineral complexes produced little change in the particle size distribution, but an increase in the poorly crystalline Fe oxyhydroxides in the upper horizon probably due to dissolution and reprecipitation of these oxides by the acid pH of the wastewater was observed. The amendment material increased the mobility of metals because of the formation of water-soluble complexes with organic ligands. The results showed that long-term wastewater irrigation could be of agricultural interest due mainly to its organic matter concentration, but micronutrient concentrations in the upper horizons were negatively affected because complexing of metals favored their transport throughout the soil profile, which may eventually lead to deterioration of groundwater quality and micronutrient deficiency.

Increase crop productivity

The prospect of agricultural use of distillery spentwash in India and other countries has been widely reported (Tester 1990; Kaul and Nandy 1999; Nandy *et al.* 2002; Baskar *et al.* 2003; Mahimairaja and Bolan 2004; Sarangi *et al.* 2005; Rosabal *et al.* 2007; Sindhu *et al.* 2007; Strong 2008). Many of these authors have concluded that application of spentwash and spentwash based compost increases crop productivity. For example, in all biocompost treatments applied to ratoon sugarcane crop, it was observed that there was an increase in P and K in leaf tissues with significant increase in cane yield than with the application of fertilizer alone. In the 2^{nd} ratoon 25 t/ha biocompost incorporated with 75-50-0 NPK kg/ha increased cane yield by 36.11%, over fertilizer alone.

Mahimairaja and Bolan (2004) assessed the effect of spentwash at rates equivalent to single application of 0, 25, 50, 125, 250 and 500 m^3/ha with and without organic amendments viz., farm yard manure (12.5 t/ha), green leaf manure ('dhaincha' (*Sesbania bispinosa*), 6.25 t/ha) and bio-compost (3 t/ha) on selected soil properties (EC, pH, N, P, K, organic carbon, and exchangeable sodium percentage, ESP), and productivity of selected dryland crops like ragi, groundnut, gingelly, sorghum, rice and green gram. Their studies have shown that, use of spentwash at lower doses (125 m^3/ha) remarkably improves germination, growth and yield of dryland crops. Although at higher doses (>250 m^3/ha) spentwash application was found to be detrimental to crop growth and soil fertility. The acidic spentwash (pH 3.94 to 4.30), loaded with organic and inorganic salts, high EC (30-45 dS/m), nitrogen content 1660 to 4200 mg/L, P 225 to 3038 mg/L and K 9600 to 17475 mg/L with appreciable amounts of Ca, Mg, SO_4 and Cl was effectively used as a source of plant nutrients and as soil amendment (Sindhu *et al.* 2007). The presence of appreciable amounts of plant growth promoters viz., gibberellic acid and indole-3acetic acid have also been detected which enhances the nutriient value of spentwash. This study revealed that, its use at lower doses (125 m^3/ha) remarkably improved germination, growth and yield of dryland crops though at higher doses (> 250 m^3/ha) spentwash application is found detrimental to crop growth and soil fertility Mahimairaja and Bolan (2004).

Sindhu *et al.* (2007) reported that the use of spentwash for seed hardening at a concentration of 10 and 20% (v/v) markedly improved the germination of ragi, groundnut, gingelly, sorghum and green gram by 16, 30, 28, 27, and 28%, respectively as compared to the control. Seed treatment with spentwash also improved root length (420%), plant height (500%), biomass production (161%) and vigour index (315%). Increase in N (11-13%), P (17-20%) and a K (16-27%) content of crops was also observed over the control due to spentwash treatment. This effect was more pronounced in green gram than other crops. The seed hardening with spentwash at higher rate (20%) was found more effective than the lower rate (10%) and other chemical treatments in improving the growth parameters. Data from pot experiment demonstrated that the spentwash >50 m^3/ha was found detrimental for the germination and establishment of green gram in vertisol, whereas, in alfisol even at a rate of 25 m^3/ha, the spentwash was found to inhibit the germination and growth of green gram (Sindhu *et al.* 2007) whereas, in vertisol, the germination, growth, nutrients contents and yield of green gram were significantly improved with spentwash application at 25 m^3/ha. Differential crops response to spentwash application was also evident. For example, in a field experiment with rice (*Oryza sativa*) grown on sodic soil Saliha (2005) observed that the application of spentwash at a rate of 125 m^3/ha followed by four leaching resulted significantly higher grain yield than at 250 and 500 m^3/ha.

The use of composts from distillery wastes as alternative growing media ingredients, for transplant production instead of peat, was studied by Bustamante *et al.* (2008). Two composts were prepared with exhausted grape marc and cattle manure (C1), and with exhausted grape marc and poultry manure (C2). Nine substrates were compared: limed white peat (control); compost C1; compost C2; and six mixtures containing 25, 50 and 75% by volume of each compost with the corresponding peat as diluent. These media did not induce any reduction in the germination rate compared to pure peat, except for 100% of C1 and C2 in chard, and 100% of C2 in coriander. Therefore, it was concluded that the composting of distillery wastes can be suitable for recycling and reducing the environmental impact of these residues (Bustamante *et al.* 2008). The germination and the effects on the transplant morphological and nutritional aspects of the different mixtures peat/compost showed adequate physical, physico-chemical and chemical properties compared to peat alone for their use as growing media in horticulture, with these two composts suitable ingredients for the partial substitution of peat, in quantities of 25–50% by volume, without causing any loss in the yield. Moreover, and due to their physical and, especially, physico-chemical characteristics (pH and salinity), the composts produced was considered as valuable partial peat substitutes for seedling production, especially at the rates of 25 and 50% of distillery compost, which showed beneficial effects on the growth of lettuce, broccoli, chard and coriander transplants when compared to peat.

A study showed that continuous application of organic fertilizers could show little effect on crop growth due to the slow-release characteristics of organically bound N. Further, N immobilization can occur, leading to an enrichment of the soil N pool (Gutser *et al.* 2005). They studied the short-term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. The efficiency of N derived from organic fertilizers was examined with different soils and fertilizers. Short-term N release from organic fertilizers, measured as mineral-fertilizer equivalents (MFE), varies greatly in composts. The most important indicators used for predicting the short-term availability of N are total and NH_4–N contents, C: N ratio and stability of the organic substances. Composting reduces mineral-N content and increases the stability of the organic matter, whereas anaerobic fermentation increases NH_4–N content as well as the stability of organic matter, but decreases the C: N ratio, resulting in a high content of directly available N in the product. Slowly releasing N are considered for long-term effects of organic fertilizers and enable optimization of fertilizer use. It was found that the overall N-use efficiency was adequate after long-term application of organic fertilizers to a MFE in the range of 40–70%.

A study was conducted by Rosabal *et al.* (2007) on long-term use of raw vinasse in agriculture as substitutes for chemical fertilizers. The effects of vinasse application for 40 years on physicochemical and mineralogical properties of Ultisol type of soils (of Cuba) were investigated.

Studies were carried out to assess the role of biocom-

Table 7 Soil properties as affected by bio-compost application after the harvest of crops.

Treatments	Ragi UAS, Bangalore				Maize – Uas, Dharwad			
	pH	EC (dS/m)	OC (%)	K_2O (kg/ha)	pH	EC (dS/m)	OC (%)	K_2O (kg/ha)
1 P FYM	6.14	0.26	0.85	211	7.04	0.24	1.32	286
1.5 P FYM	6.13	0.27	0.90	225	7.12	0.26	1.40	334
1 P Bio-compost	6.28	0.28	0.95	234	7.13	0.30	1.36	336
1.5 P Bio-compost	6.48	0.28	1.08	263	6.90	0.30	1.47	372
1 P SSP	6.32	0.26	0.93	220	6.92	0.19	1.28	284

Source: Srinivasamurthy *et al.* 2006

post on crop yield and soil properties by the Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Bangalore and Department of Environmental Sciences, University of Agricultural Sciences, Dharwad, India, (Srinivasamurthy and Patil 2006). The recommended dose of phosphate fertilizer was supplied through the distillery biocompost or applied as single super phosphate or as FYM. The results indicated that distillery biocompost was better than the FYM. No significant changes in the pH and EC was observed after harvest to ragi and maize crops in red and black soil (**Table 7**). While, there was a significant increase in the organic carbon and available K content of soils after biocompost application.

Enhance microbial activity

In a study, the impact of the application of distillery waste compost on the actual and potential C mineralisation activities, size (biomass and cell number) and genetic structure of total soil bacterial community was assessed (Saison *et al.* 2004). 90 g of soil and compost mixtures were incubated in microcosms under constant conditions (28°C, 80% of water holding capacity) for one year. Five treatments were studied viz. (1) control soil, (2) soil + low level of compost (0.5% mass basis) (3) soil + high level of compost (5%) (4) sterilized soil + high level of compost, and (5) soil + high level of sterilized compost. Actual and potential carbon mineralization increased significantly along with the quantity of compost added to the soil, and this effect persisted even after one year. The sterilization of the soil resulted in a decrease in C-mineralization (actual and potential) whereas the sterilization of compost did not significantly alter these activities. The cell number of heterotrophic bacteria (measured 4 and 180 days after the beginning of the experiment), and the microbial biomass was also stimulated after the application of compost, but the stimulation of bacterial biomass after compost application did not persist even though the activities remained at a high level.

Application of spentwash and spentwash based compost to crop

The benefits of crop yield due to application of distillery biocompost with reference to different crops are reported. Most of the studies are conducted with the sugarcane crop which is widely cultivated in the proximity of distillery industries due to easy availability of biocompost. The biocompost prepared from activated composting of pressmud and spentwash is routinely used to maintain the soil fertility of sugarcane and paddy crops, which are the two principal cash crops in south India. The partially treated and treated spentwash is also applied on fallow lands enriching the fallow land and rendering it suitable for raising a oilseed or pulse crop. Further, the anerobically treated spentwash after methane production is diluted with irrigation water and used for a standing sugarcane and paddy crop, known as ferti-irrigation. Application of 5 t/ha of biocompost recorded the highest sugarcane yield followed by 1.5 and 1 t in the sugarcane crop. Application of 0.61 t/ha of biocompost recorded the highest gain yield on rice followed by 1.23 and 2.47 t/ha (Ramdurai *et al.* 1996). Similar observations of increase in yield were also made in case of rice. A field study to asses the effect of bio-compost on yield and quality of sugarcane variety at Tmail Nadu state of India indicated that the soil applied with bio-compost registered significantly higher available P, K and Ca than (FYM) alone. The sugarcane crop yield was highest (150 t/ha) in comparison to the FYM (128 t/ha). Further the quality of the sugarcane juice was not affected by the biocompost (Devarajan *et al.* 1996).

A field experiment was carried out by Rajannan *et al.* (1996) to assess economy in the use of K fertilizer by the application of biocompost amended with different levels of P and K. An eight percentage increase in cane yield (158 t/ha) was recorded by compost application at 2 t/ha. The pH of the soil did not change with application with different level of biocompost up to 2 t/ha and EC (electrical conductivity) of the soil ranged from 0.16 to 0.41 dS/m. The available P and K content in the soil was increased and fertilizer application of P and K was reduced by 25%. Addition of compost at all concentrations enhanced population of soil bacteria, and actinomycetes which was significantly higher (29.18×10^5/g) than control at 2 t compost/ha.

Baskar *et al.* (2003) assessed the effect of distillery effluent, with high biological oxygen demand (BOD), chemical oxygen demand (COD) and electrical conductivity (EC) having large quantities of soluble organic matter and plant nutrients on crop productivity. These problems were overcome either by the application of distillery effluent after proper dilution (1:10 to 1:50) with irrigation water or by pre-plant application (40 to 60 days before planting) to give sufficient time for the natural oxidation of organic matter. Application of distillery spentwash/effluent significantly increased the EC, organic carbon, and available N, P, K, Ca, Mg and micronutrient status of the soil. Distillery effluent application significantly increased the yield of crops viz., sorghum, wheat, maize, sugarcane, cotton, groundnut, sunflower, soyabean, sugarbeet, potatoes and other vegetables, forage crops and tree crops, but had adverse effect on legumes and no effect on rice. The distillery effluent was successfully used for composting of pressmud, pressmud along with sugarcane trash and coir waste, pressmud plus bagasse ash and city garbage. Thus, it was concluded that utilization of distillery effluents in agriculture saves costs on fertilizers. The acidic (pH=3.5-4.0) untreated distillery spentwash could be effectively used for the reclamation of non-saline sodic soil. Application of biocompost in alkaline soil of Tamilnadu state of India at a dose of 5 t/ha was carried out (Nagappan *et al.* 1996). Biometric observations like germination percentage, tiller count, shoot count and ten cane weights, cane yield and quality of cane juice were more over the control. Application of fortified pressmud increased cane yield to 136 t/ha which was 26.8% more over control (106 t/ha). Similarly, the brix, pol and purity of the cane juice were increased by 11.35, 10.82 and 3.89%, respectively over control.

Kumar (2003) also compiled details on the effect of spentwash based compost on different soils and crops. Some of the salient observations are presented below. Effect of bio-compost produced from composting of pressmud and spentwash on potatoes was conducted at two locations in the research centre of University of California. A blend of 556 kg of bio-compost and 334 kg of commercial fertilizer/ha of crop showed higher yield and better potato quality in comparison to a dose of 1359 kg/ha of N:P:K (19:19:0) fertilizer alone. In another study the effect of biocompost was studied on grape and peach plantation. A dose of 5 t biocompost/ha was applied for five years. The results indicated 10% increase in grape yield and 25% increase in peach yield. The benefit of compost on soil indicated that organic matter content of top soil doubled from 0.5 to 1.0% before and after compost applications respectively. There was also increase in the nitrogen, phosphorous and potassium content of the soil.

The effect of biocompost amended with powdered rock phosphate (that give a N:P:K value of 4:13:3) was investigated on rice, corn, sugar cane and coffee in the Phillipines. There was an increase in yield of all crops. The yield of rice increased by 19.6% with a 28.5% decrease in the cost of fertilizer. The yield of sugarcane was increased by 42.9% and lowered fertilizer cost by 25%. Similarly in case of coffee the yield was increased by 20% and the fertilizer cost was reduced by 25.25%.

The performance of bio-compost in comparison to the FYM on sugar cane was extensively studied in black clay soil of India. Biocompost application at the rate of 10.7% with the recommended chemical fertilizer dose increased yield by about 20% in comparison to use of chemical fertilizer alone. Whereas, a blend of the recommended dose of chemical fertilizer with farm yard manure had 18% higher yield. Other cane quality parameters like brix, polarity, purity and recovery also increased when the sugar cane was grown with biocompost. The above results indicated that.

- Application bio-compost in conjunction with chemical fertilizers increased the yield of all tried crops. The increase in yield was about 20 to 40% as compared with chemical fertilizer alone.
- The application of bio-compost to soil improved the physio-chemical properties of soil due to its high humus content.
- The efficiency of applied chemical fertilizer improved when it was applied in combination with bio-compost. These together reflect in an increase in yield and a saving in the use of costly chemical fertilizers.
- The need for chemical fertilizers decreased due to bio-compost application.
- Application of a compost prepared from pressmud and diluted spentwash at 10 t/ha have 118.2 t/ha cane yield as compared to 95.1 t/ha in the control. It also raised the soil organic carbon content to 0.89% as compared to 0.68% in control in the medium black soil.
- Increases crop yields by 15–20% over a period of three years (Senthil 1999).

Kumar (2003) has reported the doses of biocompost, prepared from pressmud utilizing bio-methanated spentwash recommended for different crops. A dose of 2.5-5.0 t biocompost/ha of crop were applied in trenches for sugarcane crop just before plantation. In case of rice, wheat and potato 2.5–5.0, 5.0–6.25, 6.5–7.5 t biocompost/ha of crop is applied during field preparation. In the case of vegetable crops 2–2.5 t of biocompost is applied near the roots of the plantation. In horticulture plants, growing in soil pots, about 100 gm of biocompost is applied per plant. Different doses of biocompost were applied to soil to assess its effect in the yield of sugarcane and rice crops. In the case of control crop a yield of 92.41 t/ha was recorded, and sugarcane yield was 102.05, 109.95 and 112.67 t/ha with 1.23, 2.471 and 3.706 t/ha of biocompost, respectively. The sugar cane yield was maximum i.e. 113.66 t/ha with 5.0 t/ha of biocompost. Similarly in the case of rice, the control crop had a yield of 2.39 t of grain/ha of crop, whereas the crops treated with 0.61, 1.23 and 2.471 t biocompost/ha of crop had a yield of 2.619, 2.569 and 2.520 t of grain/ha. The results indicate that 0.61 t biocompost/ha of land enhanced maximum yield of rice crop.

The response of 'Raj 3765' wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and 'Ganga Safed 2' maize (*Zea mays* L.) to biocompost prepared from distillery effluent and pressmud was assessed (Tripathi *et al.* 2007). Chemical composition of biocompost was pH 7.7, EC 12.56 dS/m, organic C 36.33%, N 1.90%, P 1.85%, K 1.48 %, Zn 255.2 ppm, Mn 347.8 ppm, Cu 91.1 ppm and Fe 58.57 ppm. Incorporation of biocompost alone or in combination with N and P fertilizers improved the growth and yield of maize and wheat. The grain yield of wheat recorded highest when biocompost was applied at 5 t/ha with 50% N and P fertilizers. The cob yield of maize was highest when biocompost was applied at 5 t/ha with 50% N and P fertilizers which was at par with the treatment 2.5 t/ha biocompost with 75% N and P. Use of biocompost at 5 t/ha with 50% N and P improved the physical and chemical status particularly N and K content of the soil.

The effect of amendments on composting of sugar industry pressmud on the germination index value of a sensitive crop *Raphanus sativus* was studied by Satisha and Devarajan (2007). The compost samples collected at the 60th, 90th, 105th and 120th day of composting were used for the germination test of *Raphanus sativus*. The germination percentage of radish in compost samples collected on the 60th day of composting was found to be low, with values ranging between 63.70 and 70.15%. The germination rate of 80% was obtained in all the enriched composts on the 90th day itself, and the subsequent increase in germination percentage of radish indicated that the composts were free from phytotoxic substances.

The effect of dried distillery sludge cakes amendments with garden soil (10, 20, 40, 60, 80 and 100%) on seed germination and growth parameters of *Phaseolus mungo* L. was studied by Chandra *et al.* (2008). Germination percentage and index values decreased with rise in sludge concentration. Soil amended with 10% (w/w) sludge showed favorable growth while >10% was inhibitory for plant growth. Soil amended with 10% (w/w) distillery sludge induced the growth in root length, shoot length, number of leaves, biomass, photosynthetic pigment, protein and starch while 20% (w/w) sludge amended soil had variable effects on the root, shoot, leaves and nodules of *P. mungo* L. The heavy metals content were also increased in different parts of *P. mungo* grown on increasing concentration of sludge amended garden soil with time. Zn and Cu accumulation was maximum comared to other heavy metals. Based on these studies, sludge having concentrations <10% (w/w) was most probably suitable as a fertilizer.

The influence of growing doses of distillery vinasses on vegetative growth, leaf mineral levels, grape yield and quality was assessed in a four year period (Tano *et al.* 2005). Doses of vinasses were computed to apply 0 (test), 50, 100, 150 kg N/ha. Vinasses doses were factorially combined with three levels of urea (0, 50 and 100 kg N/ha). In plots without vinasses supply, ureic nitrogen reduced the number of blind buds and increased the potential and actual bud fertility. The application of vinasses nitrogen had a similar result, even if ureic and vinasses nitrogen had no additive effects. The most profitable grape yield was obtained by application of 50 kg/ha of nitrogen either in urea or in the form of vinasses. Highest vinasses supply improved the ripening levels of grapes increasing sugars and reducing acidity of juice. Results clearly show the possibility to use vinasses for proper vineyard fertilization. The annual supply of 50 kg/ha of nitrogen by vinasses, corresponding to 2.5–3.0 t/ha of organic matter, with a possible addition of mineral nitrogen was optimum according to the annual vineyard crop load.

The effect of incorporation of biocompost on lowland rice with four treatments viz. M1-control, M2-FYM at the rate of 12 t/ha, M3-Green Leaf Manure at the rate of 6.25 t/ha, M4-Biocompost at the rate of 3 t/ha was investigated (Saliha *et al.* 2005) using two rice varieties Co43 and IR50. Application of biocompost recorded the highest values of available N (230 kg/ha), available P (27.35 kg/ha) and available K (335 kg/ha) in soil. Biocompost application also recorded maximum population of bacteria (21.75×10^5), actinomycetes (4.46×10^4) and fungi (3.62×10^4) per g of oven dried soil. Application of biocompost recorded the highest number of panicles i.e. 307/m^2, maximum filled grain (145/panicle) and maximum 1000 grain weight (24 g). Application of biocompost recorded maximum crop yield of 5.31 t/ha. The grain yield was enhanced by 30% over that of the control. Application of biocomost at the rate of 3 t/ha registered higher yield and improved the soil physical and biological properties.

CONCLUSIONS AND PERSPECTIVES

There is a need to improve the efficiency and kinetics of composting process by developing insights in to the heat and mass transfer aspects. The major constraint in pressmud and spentwash is the activation of composting process due to high liquid containing effluents. Efficient stabilization of the different types of spentwash viz, raw, partially treated and treated through biomethanation followed by composting is another challenge since their organic load and physico-chemical characteristics differs widely. Further, in some cases the spentwash is concentrated in process to reduce its volume to accommodate in the storage facility. This further increases the total dissolve solids of the effleuent that affects the physicochemical properties of the refuse and hinders microbial growth during composting. Depending of the process of generation the physicochemical characteristics and inorganic content of the spentwash vary widely. These inorganics change their face from one form to the other and cannot be taken away during composting. Therefore, continuous agricultural application of biocompost produced from spentwash need periodic monitoring of physicochemical characteristics of the soil to alleviate its unforeseen deterioration. Further, the problems and prospects of agriculture use of distillery spentwash and biocompost also needs to be critically assessed, particularly with respect to ground water contamination.

There are at least thirteen elements which are absolutely essential for the growth, development and maturation of crop plants. These are N, P, K, S, Ca, Mg, B, Cl, Cu, Fe, Mn, Mo and Zn. The harvested crop and plant biomass takes away the nutrients with it that are absorbed from the field. The nutrients that are removed from the soil by crops and other natural process is need to be put back into the soil, else the nutrient reserve of the soil and its capacity to nourish plants, gets depleted. To produce one t of grain, a cereal crop for example, absorbs about 60-75 kg of these inorganic elements. Their individual amount varies from 20-25 kg N, to a couple of grams of Mo (Tandon 1992).

It is understood that no single source of plant nutrients; be it fertilizer, organic manure, crop residues or bio-fertilizer, can provide the total nutrient needs of modern agriculture for sustainable crop production (Cassman 1999; Dawe *et al.* 2000; Hati *et al.* 2007). It is being increasingly recognized that sustainable agriculture should ideally be based on integrated nutrient supply systems (Editorial 2007; Strong *et al.* 2008). It aims to make use of organic manures, crop residues, recyclable materials, bio-fertilizes along with chemical fertilizes, in an integrated manner. Plants depend upon organic as well as mineral matter to support their growth to give high level of productivity. The organic input has a profound and vital role to play in improving soil physical properties such as, its tilth, and water holding capacity, growth of essential microflora and providing the favorable environment for root growth (Tiessen *et al.* 1994; Marinari *et al.* 2000). The fertility of a productive soil depends on organic matter content of the soil. Nutrient supply systems derived from industrial organic solid and liquid wastes have great relevance and prospects when the techno-economic aspects of the produce are practically feasible.

Recycling of organic wastes in agriculture brings in the much-needed organic and mineral matter to the soils and leads to an improvement in overall soil productivity, of which soil fertility is a key component. Extensive research work has been carried out on treatment of distillery spentwash in many part of the world. It is learnt that spentwash is a valuable resource which is essentially a plant extract derived from the sugarcane (in case of molasses) besides microbial residues. It is rich in organic matter like N, P, K, Ca, S contain micronutrients such as iron, Zn, Cu, Mn, Bo and Mo. The distillery spentwash does not contain any toxic heavy metals and hazardous constituents.

The findings from the above cited different investigations also indicate that application of highly acidic raw spentwash could be deleterious to soil in long term due to build up salinity in soil. It is highly effective in improving the physico-chemical properties and nutritional status of drylands and sandy soils. One time application diluted with irrigation water is beneficial to crop plants in arable agricultural land. Whereas, the biocompost produced from the aerobic decomposition of the pressmud and spentwash (partially treated or raw), is superior as an organic manure and soil amendment to increase the nutritive value of an intensively cultivated soil. The organic carbon and resistant portion present in the biocompost give rise to lignins and humic acids and get converted to humus in the soil. Both types of wastes; pressmud and distillery spentwash, when disposed in the environment as such; create severe pollution in the land and aquatic ecosystems. But using the process of activated composting, they could be turned into a valuable resource, very much essential for sustainable agriculture. There are several advantages that result out of its application and reuse in soil.

Organic farming was being practiced for thousand of years before the beginning of the "Green Revolution". Agriculture based on the chemical fertilizers has now realized that the benefits from chemical fertilizes were for short term, continuous use of chemical fertilizers without organic amendments has reduced yield per ha considerably. It has resulted in degradation of soils and formation of saline soils in many places. The concept of organic farming has been renewed in the present time. More and more farmers are turning towards organic farming all over the world. In fact, in developed countries, the agricultural produce obtained exclusively through organic farming attracts premium price in the market. In India, farmers desiring to capture export market are also practicing organic farming through application of biocompost.

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