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Waste Reuse in Sugar Industries

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Abstract

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Pakistan being the 6th largest sugar producer has over 75 sugar mills with annual production capacity of about 2.4 million tons during 1996-97. The contribution of Sindh with 27 sugar mills is recorded over 50% of the total sugar production.

The majority of the mills in Pakistan use the Defecation-Remelt-Phosphitation (DRP; 24 mills), Defecation-Remelt-Carbonation (DRC; 21 mills) and Defecation-Remelt Carbonation and Sulphitation (DRCS; 11 mills) process. Seven of the 75 sugar mills in Pakistan also produce industrial alcohol from molasses, a by-product of sugar manufacturing process.

These sugar industries also produce fly ash, which have been found to contain unburned carbon and reach as far as four-kilo meter area with the wind direction, threatening the community health of people living around, besides posing other aesthetic problems. The untreated wastewater, in many cases, finds its way to open surface drains causing serious threat to livestock, flora and fauna.

One study showed that fly ash emitted from the chimneys contain particle size ranging from 38 um to 1000 um. About 50 per cent of each fly ash samples were above 300 um in size and were mostly unburned Carbon particles, which produced 85% weight loss on burning in air atmosphere at 1000^{0}C.
This fly ash (mostly carbon) was the main cause of many health and aesthetic problems in the sugar mill vicinity.

The environmental challenge for the local sugar mills is associated with liquid waste gaseous emission and solid waste.

This paper discusses various waste recycling technologies and practices in sugar industries of Pakistan. The application of EM technology and Biogas technology has proved very successful in reusing the sugar industry wastewater and mud, which otherwise were going waste.

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1. Introduction

1.1 The Sugar Industry in Pakistan

At the time of Pakistan's independence in 1947, there were only two sugar mills in the country with a total production of 7,932 tons during the season of 1947-48. Today, there are 75 sugar mills in the country, with a production of 2.4 million metric tons of sugar during 1996-97.
A number of chemicals including lime, sulphur, phosphoric acid, bleaching powder, poly-electrolyte, floatation aid, and decolorant, are used in sugar making process. The quantity of these chemicals varies from mill to mill due to different types of processes.

The environmental challenge for the local sugar mills is associated with liquid waste, gaseous emission and solid waste. Noise pollution though local in nature is also a great challenge. There are three major departments in sugar manufacturing: mill house, process house and boiler house. For the production of industrial alcohol, the distillery stage is added. Table – 1: Presents the main input of each stage and the important wastes and by-products that emerge from it.

Table 1: Wastes Produced During Sugar Production

Process Storage	Main Inputs	Wastes and By-products
Mill House	Sugarcane	ξ Wastewater containing suspended solids and oil content ξ Washing from floor cleaning containing sugar ξ Bagasse
Process House	Sugar Juice	ξ Filter cake ξ Washing of different components such as evaporator, juice heater, vacuum pan, clarifiers, etc., generate aggressive effluents with high BOD_5, COD and TDS concentrations
Boiler House	Bagasse and Furnace Oil	ξ Fly ash ξ Smoke ξ Flue gasses ξ Wastewater from scrubbers
Cooling Pond	Water and Chemicals	ξ Wastewater
Distillery	Molasses	ξ Wastewater (stillage) containing very high BOD_5, COD and suspended solids.

2. Waste Reuse & Management

2.1 Solid Waste

Two types of solid waste are produced during the manufacture of sugar. Bagasse is produced in the mill house in a quantity of about 30% of the crushed cane. The bagasse contains 50% moisture. Press mud or filter cake is produced in vacuum filters and press filters. The mud is produced in a range of 3-8% of the crushed cane, depending on the nature of sugar manufacturing process. The mud contains nearly three quarters of moisture. On dry basis mud contains about 70% organic matter and about 29% minerals.

Press mud is usually used by nearby farmers as manure, although in some cases its application as manure is preceded by biocomposting. Bagasse is used as fuel for boilers. It is estimated that 70% of the power requirements of sugar mills is fulfilled in this way. Bagasse is also used for chip board and paper manufacture.

Bagasse combustion also produces ash and fly ash. Flue gas contains 4500 mg/m3 of fly ash on average. This is a visual nuisance as well as a health concern. These problems are particularly high in boilers not equipped with scrubbing or cyclone systems. Bagasse ash can be used as cement supplement.

2.2 Wastewater

The wastewater analysis suggests a very high pollution level as compared to the limits stipulated in the NEQS on all important parameters. They are particularly severe in the case of wastewater from distilleries. For example, the national COD (Chemical Oxygen Demand) standard is 150 mg/I, whereas even the lowest observed level was over 1000 mg/I and the observed level for the distillery was higher than 100,000 mg/I. The situation is equally drastic for pH value, biological oxygen situation demand (BOD5) and total suspended solids (TSS).

The general practice is to use large unlined lagoons - built without proper engineering and environmental care - for wastewater storage. This can cause groundwater contamination and is particularly dangerous in areas where groundwater is used for drinking purposes. The stored water is then fed into the irrigation streams.

3. Waste treatment & Recycling Practices:

Various measures can be taken to address the environmental challenges faced by sugar mills and distilleries in Pakistan. The most immediate of these relate to waste reduction at source Table-2.

Table 2-: Waste Reduction at Source; In-house Improvement	
• **Flow measurement** (through flow meters) and monitoring at inlet and outlet of each consumer unit at the mill for better water management practices. • Use of **optimum imbibition rate** to save energy in terms of steam consumption and to reduce organic and hydraulic load from the process house. • **Dry cleaning** of mill floors with bagasse. • **Efficient operation of evaporators** will reduce waste disposal problems and enhance sugar recovery. Overloading of evaporators and vacuum pans, boiling at excessive rates, operating them at incorrect liquid levels, and variation of vacuum lead to a loss of sugar through condenser water. Improper design of these units – particularly the entrainment separator – may result in irregular boiling and splashing. • Recycling of cooling and condenser water. • The simple measure of **controlling spillover** of molasses can very significantly	• **Routine inspection of units** – particularly pumps, conveyors, pipes and other vessels. • **Reducing water used for floor sweeping and washing** by recovering water from various mill processes and reusing it for cleaning purposes. • **Detaining filter cloth washing** in a holding tank for a short time before being allowed to mix with other effluents from the mill will reduce the contamination in the wastewater stream. • Installation of **circular mist eliminators or demisters** constructed to stainless steel or monel in the multiple-effect evaporators can eliminate sugar entry in the condenser water. • **Bagasse management** is of paramount importance in establishing overall energy efficiency in the mill. Steam and power generation and reduction in fuel oil consumption are largely dependent on an adequate supply and efficient utilization of bagasse. Benefits will also result from ensuring that maximum moisture has been removed before bagasse is used in the boiler.

spillover of molasses can very significantly reduce the organic pollution content of the wastewater stream. • **Segregation of oil from other effluent** will allow for the recovery and reuse of lubricating oil and reduce soil contamination when wastewater is applied for irrigation. • Controlling the mixing of **filter mud** with wastewater can very significantly reduce the organic and inorganic pollution content of wastewater stream.	• As far as air emissions are concerned, the first step should be to set up a system of **regular monitoring of stack emissions with periodic boiler tune-ups.** This can considerably increase boiler efficiency and minimize emissions.

This has the potential to reduce the pollutant as well as the hydraulic load to a level where end-of-pipe technologies may then be able bring it down further to levels near, or below, the NEQS. Such measures are also likely to result in net savings from the mill in the long run. A strategy for wastewater management in presented in Box 1: Strategy for Waste Management

<u>Reduction</u> Improve filter press to prevent juice leakages. This will significantly reduce sugar content in the effluent. Reduce juice vapors from seeping into condenser cooling water by improving evaporator and pans. This will improve the functions of the condenser. Set up a pit for collecting juice-contaminated water to reduce sugar content in washing and cleaning water. Collected water can then be used as maceration of sugarcane milling process. Monitor and follow-up the quality and quantity of pollution sources to prevent additional polluting effluent.
<u>Recycling</u> Separate the clean warm water from the contaminated stream for reuse. After cooling down by cooling towers about 90% tail water can be recovered, the remaining 10% can be discharged and replaced by fresh water. After removal of grease and oil, cooled mill water can recycled for reuse.
<u>Regeneration</u> Precipitation and filtration of flue gas washing water will regenerate it into a colorless and transparent state. This regenerated clean water can be reused in the flue gas washing system
<u>Composting</u>: Composting of filter mud cake with additional moistening with stillage could be an attractive alternative solution to handle both the waste and to produce valuable by product (fertilizer). Various alternative can be applied: (1) windrow composting with natural aeration; (2) static pile composting with forced aeration; and (3) UASB-treatment of stillage and windrow or static pile composting with forced aeration.

Features of end of pipe treatment in Sugar industries are suggested in Box-2

Box 2: End-of-pipe treatment for Sugar Mills Wastewater

Combination of lagoons in sequence (anaerobic, facultative and maturation). Preliminary design and costing of this option for a mill generating 6,000 - 7,000 m3/day of wastewater containing 2,000 - 3,000 mg/I BOD5 suggests that to achieve 90% removal efficiency the lagoons system would require a total surface area of 120 hectares, a total volume of 1.5 million cubic meters, and a total retention time of 216 days. The exorbitant level of retention time, land requirement and high cost of lining make this option inadvisable for local sugar mills. However, unlined lagoons, though pose serious threat to groundwater quality, can also be taken into consideration after careful analysis of environmental condition around the mill. Combined treatment system comprising of a UASB Reactor and Activated Sludge System. When used alone, the activated sludge system has a high operational cost because of the energy required for aeration. Combining it with a UASB Reactor significantly reduces this cost. The UASB Reactor can remove about 80-90% BOD5; in addition, a by-product of the process is methane which can then be used as a source of energy for the boiler. After passing through the UASB Reactor, the effluent can further be treated through the Activated Sludge System for treatment of remaining BOD5. The combined system will achieve the same pollutant removal efficiency as the Activated Sludge System but at a lower cost. This combined system will bring the present BOD5 and suspended solids level near or below the NEQS. Preliminary cost calculations for such a combined system designed for sugar mills generating wastewater in a quantity of 3,500-6,500 m3/day, containing BOD5 in range of 1,000 - 5,000 mg/l and COD in range of 1,800 - 19,000 mg/l suggest that the total cost of the treatment plant would be in the range of rupees 20-90 millions. Such a system would require around 1,500-3,000 square meters of land and its annual operation and maintenance expenditure would be approximately 10% of its total cost. With in house improvement UASB reactor as single treatment system can be applied.

3.1 Effective Micro-organism (EM) Technology

The technology of effective micro-organism (EM) was developed by professor Dr. Teruo Higa in 1980 at the University of the Rhyukyus, Japan.

EM-Technology is an added dimension to nature/organic farming. It contains photosynthetic bacteria (Rhodopseudomonas spp.), lactic acid bacteria (Lactobacillus spp.), and yeast (Saccharomyces spp.). The photosynthetic bacteria is the pivot of EM activity. It supports the activities of other microbes as well as utilizes substance produced by other microbes.

3.1.1 Bio-Fertilizer

Eight years of experiments on EM-Technology on various crops have shown that it can convert all kinds of crop residues, Farmyard manure poultry manure, sugarcane filter cake (2m. tones from 76 sugar mills) and solid municipal wastes (billion tones) into high quality biofertilizer in 10 days using EM-Technology.

Nitrogen phosphorus, potassium sulphur, trace elements & one percent sugar in press mud is helpful for beneficial Microorganisms in EM solution. Press mud – Biokasht reduces water quantity in cane & increases sugar contents and cane weight & especially checks red rot, termite diseases in cane. Mud-Biokasht helps to improve saline and saline sodic soils by supplying EM-SFC bio-fertilizer in sugar cane.

Waste material of industries especially sugar industry press-mud has much importance for agriculture usage as it contents lots of nutrients. Recent analysis report of Sugar Filter Cake (SFC) or press-mud from various industries of Pakistan is shown below:

QUALITY AND CHEMICAL COMPOSITION OF PRESSMUD

Sugar Mills Location	Dry Press mud	pH	N_2 (%)	% $P_2 0_5$	K(%)	S(%)	Zn (mgg-1)	Cu (mgg-1)	Mu (mgg-1)	Fe (mgg-1)
Shakarganj Jhang	5441	5.33	1.77	2.29	0.70	5.40	143.0	60.0	276.0	5566
Gojra Samundry	4126	5.45	2.20	2.75	0.80	5.3	150.0	71.0	249.0	4750
Crescent Faisalabad	4041	5.71	2.20	2.75	0.60	6.30	220.0	64.0	298.0	5904
Fauji Sangla Hill	5237	5.96	2.30	2.98	0.80	6.30	220.0	64.0	330.0	5850
Hussain, Jaranwala	4050	5.57	2.00	2.98	0.80	6.30	150.0	58.0	270.0	5100
Average	4607	5.60	2.08	2.75	0.74	5.92	176.6	63.4	284.6	5435

3.1.2 MULCHING

New research has proved that mulching is necessary for orchards. It improves plant health and fruit quality. Mulching is an easy method. It must be done twice in a year in citrus, first time immediately after fruit harvest, second time in August rains and in mango only in Sept. in Sindh and October in Punjab.

3.1.2 .1 MULCHING PROCEDURE

1- Make a circle around the plant according to the canopy (for small plant circle should be 3 feet)

2- Dig the soil in circle up to six inches deep and fill it with EM-Biokasht (prepared from animal dung or poultry manure or Sugarcane Filter Cake (SFC) 100 – 200 kg per plant. Cover with straw and grasses pressing on it to protect it from air. If straw is not available, use the small soil to cover and with remaining soil make an edge of the circle, then irrigate from Fermenter. No doubt, you have made a house for your plant. It is called mulching. Now plant will take nutrients from it and effective microorganisms will also protect its roots from diseases.

If you have no Fermenter, spray 20 liters extended EM-Bioaab or through drip method in the watercourse along with every irrigation.

3.1.2.2 BENEFITS OF MULCHING

Mulching keeps proper moisture is soil and provides nutrition to the roots by converting organic matter into CO_2, amino acids and poly-saccharide to solve the problems of fruit drop and water stress. Besides this, plant becomes safe from root diseases and beneficial microorganisms do not allow pathogens to survive. Farmers are advised not to cultivate grain crops like wheat and maize in orchards. After mulching if there is enough space, one cane grow vegetable like onion, chilies, aniseed, garlic, pepper, mint, clonge etc. and can get extra production with inter cropping. If there is no crop in orchards in May and June, do not leave it empty cultivate Janter. At the time of cultivation and half bag of triple super phosphate (TSP) or one bag of single superhosphate (SSP) to develop big nodules. In this way nitrogen fixing bacteria (Rhizobium) fixes more nitrogen. Rotavate Janter after 45 – 60 days of cultivation and provide 60 liters extended EM-Bioaab along with irrigation. One acre Janter (as green manure) provides 36 kg nitrogen (1-1/2 bags of Urea). Most of farmers sow Barseem in garden which causes fruit dropping due to excessive requirement of water but Fermenter water has capacity to keep proper moisture for longer period. Farmer can cultivate fodder/Barseem in orchards because it needs less water and do not cause fruit-drop if EM is used continuously.

3.2. BIOGAS GENERATION

Molasses based alcohol distillery produces a spent wash, which is considered to be one of the worst industrial effluents in the world. This industrial activity is termed to be highly detrimental to human habitation and seriously affects the environment, if the effluent is discharged into the environment without treatment.

Three biogas plants are in operation in Pakistan while the Habib Sugar Mills (HSM) Nawabshah is the leader in this field and has specialized in treating highly organic industrial wastewater, coming as a waste, to produce valuable BIOGAS - a renewable non-conventional energy resource, which is a by-product of the treatment process.

The anaerobic wastewater treatment plant is not only effective in environmental protection but also pays for itself over a short period of time through steam / power generation.
These Biogas plants offer higher Hydraulic Retention Time (HRT) to ensure optimum BOD/COD degradation and maximum biogas generation. It is estimated that the biogas generated from a 30,000 LPD distillery biogas plant can produce about 3 to 4 tons/hr of steam or about 1 MW of captive electric power.
Besides the primary treatment, secondary treatment process is designed to ensure less energy consumption and optimum reductions in the pollution loads of the effluent thereby meeting the discharge limits.
The system works at 100% rated capacity. Hence payback is assured within a very short period of time of about 1-2 months. It does not require any shut down and can operate continuously for several years. No major replacement is involved and power requirement is nominal which is required only for two pumps and four agitators.

3.2.1 Bio-Methanization Process

The effluent water, which is above 60 C at the outlet, is cooled in a tank and passed into rectangular digester. Two digesters of identical dimensions to hold about 2.5 million liters of effluent are built with R.C. base and sidewalls and stainless steel top with water seal leak-proof cover. The digester is specially designed to provide fixed polythene films for boosted anaerobic microbial activity.

3.2.2 Anaerobic Digestion

The effluent at about 35 C is acted upon by anaerobic bacteria, utilizing the organic substances in the medium, the retention time being 5 to 8 days. The anaerobic process helps in converting the organic matter into biogas and reducing the BOD to about 3000 to 4000. The biogas contains about 60% methane, 1-2% hydrogen sulphide and 35% carbon dioxide. At 90% efficiency about 10,000-m3/day biogas is obtained which is taken to the distillery as fuel substitute for the boiler.

DATA OF THE BIOGAS PLANT

i.	Molasses Consumed	169	tons/day.
ii.	Alcohol Produced	43750	liters/day.
iii.	Spent Wash Produced (Waste from Distillery)	672	m^3
iv.	Biogas Produced	529	m^3
v.	COD (in)	70286	mg/liter
vi.	COD (out)	32256	mg./liter
vii.	% of COD Removed	72	%
viii.	pH.(in) of Spent Wash	4.70	
ix.	pH.(out) of Biogas plant wastewater	7.66	

4. Composting Plant at Shakarganj Mill

A composting plant for the disposal of filter cakes and the liquid waste from the distillery is under construction at Shakarganj Mills. At present the composting plant will operate at 25 percent capacity, that is 100 tons / day. After evaluating the performance of the pilot plant the full scale composting plant will be constructed.

Shakarganj Mills has installed an oil skimmer and improved the efficiency of the cyclones for trapping ash. These two add-ins will improve the treatment efficiency of existing lagoons. A comprehensive management and monitoring system has been developed to monitor the efficiency of de-misters and water flow rates.

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