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Original Research Paper

Water Conservation in Sugar Industry

Baban Gunjal and Aparna Gunjal*
Maharashtra State Agricultural Marketing Board, Pune, India
*Department of Environmental Sciences, University of Pune, Pune, India

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ABSTRACT

Sugarcane hot water balance shows that the water content of sugarcane itself is more than sufficient for internal processing. Surplus internal water is available for external use. By recycling, reuse and good house keeping, external consumption can be minimized. The polluted water is treated by anaerobic digestion-activated sludge process- pressure filtration and activated carbon. The treated water is recycled to reservoir to utilize for factory cleaning, washing, cooling water make-up, colony, gardening and irrigation. Alternatively, wastewater is made zero through bio-composting.

INTRODUCTION

The world population is growing rapidly and we must ensure the survival of communities throughout the world. By 2025, 2.7 billion people, 1/3 of the world's population, will be facing a severe water shortage, with the major scarcity in the southern hemisphere. Global food production will have to be doubled to achieve food security for all, but food shortages due to the lack of proper management of water resources pose a major challenge. Water tables all over the world are falling as world water demand has tripled over the last 50 years. When these aquifers are depleted, food production worldwide will fall.

As it is, water is scarce: From a per capita annual average of 5,177 cubic meter in 1951, freshwater availability in India dropped to 1,820 cubic meter in 2001. In fact, it is predicted that by 2025, per capita annual average of freshwater availability will be 1,340 cubic meter approximately. Already, the potential of most river basins is being exploited beyond 50% and several basins are considered to be water scarce. Over 80% of the domestic water supply in India is dependent on groundwater. However, groundwater is fast depleting. Water tables have fallen significantly in most areas and there is a significant pollution of groundwater from natural as well as man-made sources.

Water use in sugar industry: The sugar industry uses large quantity of water and also discharges huge amount of effluent into environment (Jensen & Schumann 2001). As per Water Prevention and Control of Pollution Cess Rules 1978, the water requirement for sugar industry is 2.0 m^3/ton of cane crushed and wastewater generation as 0.40 m^3/ton of cane crushed. Presently total number of sugar factories in India are 530 having crushing capacity of 16,04,462 ton/day. Considering these figures, water requirement and wastewater generation are 32,08,924 m^3/day and 6,41,784.80 m^3/day respectively. Central Pollution Control Board (CPCB) aims to bring down the quantity of effluent generated to as low as 0.10 m^3/ton of crane crushed. There are number of instances where the raw water requirement is as low as 0.10 to 0.20 m^3/ton of cane crushed.

Water content in sugarcane is about 0.70 m^3/ton of cane crushed, out of which about 0.50 to 0.60 m^3/ton of cane crushed is utilized in process and 0.10 to 0.20 m^3/ton of cane crushed will be excess water available in any sugar factory. This water can replace freshwater requirement and conserve natural resource.

Process of cane sugar manufacture: Most of the sugar factories in India follow double sulphitation process and produce plantation white sugar. The major unit operations are extraction of juice, clarification, evaporation, crystallization and centrifugation.

Extraction of juice: The sugarcane is passed through devices like knives for cutting the stalks into fine chips before being subjected to crushing in a milling tandem comprising 4 to 6 three roller mills. Fine preparation with its impact on final extraction, is receiving special attention and shredders and particularly the fibrizers are gaining popularity. The mills are of modern design, being equipped with turbine drive, special feeding devices, efficient compound imbibitions system, etc. In the best milling practice, more than 95% of the sugar in the cane goes into the juice, this percentage being called the sucrose extraction or more simply the extraction. A fibrous residue called bagasse; with a low sucrose content is produced about 25 to 30% of cane, which contains 45 to 55% moisture.

Clarification: The dark-green juice from the mills is acidic (pH 4.5) and turbid, called raw juice or mixed juice. The mixed juice after being heated to 65 to 75°C is treated with phosphoric acid, sulphur dioxide and milk of lime for removal of impurities in suspension in a continuously working apparatus. The treated juice on boiling is fed to continuous clarifier from which the clear juice is decanted while the settled impurities known as mud is sent to rotary drum vacuum filter for removal of unwanted stuff called filter cake is discarded or returned to the field as fertilizer. The clear juice goes to the evaporators without further treatment.

Evaporation: The clarified juice contains about 85% water. About 75% of this water is evaporated in vacuum multiple effects consisting of a succeeding (generally four) of vacuum-boiling cells arranged in series so that each succeeding body has higher vacuum. The vapours from the final body go to condenser. The syrup leaves the last body continuously with about 60% solids and 40% water.

Crystallization: The syrup is again treated with sulphur dioxide before being sent to the pan station for crystallization of sugar. Crystallization takes place in single-effect vacuum pans, where the syrup is evaporated until saturated with sugar. At this point 'seed grain' is added to serve as a nucleus for the sugar crystals, and more syrup is added as water evaporates. The growth of the crystals continues until the pan is full. Given a skilled sugar boiler or adequate instrumentation, the original crystals can be grown without the formation of additional crystals, so that when the pan is just full, the crystals are all of desired size, and the crystals and syrup form a dense mass known as 'massecuite'. The 'strike' is then discharged through a foot valve into a crystallizer.

Centrifugation: The massecuite from crystallizer is drawn into revolving machines called centrifuges. The perforated lining retains the sugar crystals, which may be washed with water, if desired. The mother liquor 'molasses' passes through the lining because of the centrifugal force exerted and after the sugar is 'purged' it is cut down leaving the centrifuge ready for another charge of massecuite. Continuous centrifuges may purge low grades. The mother liquor separated from commercial sugar is again sent to pan for boiling and recrystallization. Three stage of recrystallization are adopted to ensure maximum recovery of sugar in crystal form. The final mother liquor referred to as final molasses is sent out of the factory as waste being unsuitable for recovery of sugar under commercial condition from economical point of view.

Table 1: Cold water consumption during process for the sugar unit (Average crushing capacity: 1620 TCD).

Sr. No.	Particulars	Before recycling	After recycling
A.	**Water which is recycled**		
	Mill turbines	614.00	614.00
	Mill bearings	308.00	308.00
	Power turbines	1583.20	1583.20
	Vertical crystallizer	268.60	268.60
	Sulphur burner	-	480.20
	Air compressor	-	100.50
	Hot liquor pump gland cooling	444.00	444.00
	Total	2773.80	3798.50
B.	**Warm water discharged into condenser cooling system**		
	Sulphur burner	480.00	-
	Air compressor	100.50	-
	Vacuum pumps	48.00	48.00
	Total	628.70	48.00
C.	**Water to waste - Hot liquor pumps for cooling**	444.00	-
	Total	444.00	-
D.	**Water required for cleaning and miscellaneous use**		
	Daily cleaning and washing	48.50	24.25
	Drinking water and laboratory use	5.30	5.30
	Total	53.80	29.55
E.	**Make-up water**		
	Boiler	6.78	6.78
	Spray pond	312.95	22.64
	Cooling water	23.81	32.69
	Total	343.24	64.11
	Total water required, cubic meter per day (B+C+D+E)	1470.04	139.66

Table 2: Effluent generation per day.

Sr. No.	Source	Before recycling (m^3/day)	After recycling (m^3/day)
1.	Cleaning and washing	54.50	24.25
2.	Hot liquor pumps for gland cooling	444.00	-
3.	Spray pond overflow	50.00	50.00
4.	Boiler blow-downs	19.87	19.87
5.	Gland leakages	23.81	32.69
	Total	592.18	126.81
	Effluent generation per ton cane (L/ton)	365.00	78.20

MATERIALS AND METHODS

Water meters were installed at each of the stations of M/s Rajgad SSK Sugar Factory, District Pune in order to know the water requirement and effluent generated from the stations (Sapkal et al. 1997). The V-notch was installed in the open streams at mill station, boiling house and at effluent treatment plant (ETP) to know the effluent generated.

RESULTS AND DISCUSSION

Minimizing water requirement: The water requirement was measured before recycling and modifications and after recycling for the sugar factory having an average daily cane crushing capacity of 1620 TCD (Table 1). The water requirement was brought down from 1470.04 cubic meter/day to 139.66 cubic meter/day. The effluent generation was reduced from 592.18 cubic meter/day to 126.81 cubic meter/day (Table 2).

Guidelines and Control Options for Conservation of Water

Rainwater harvesting: Rainwater is a precious water resource as it is freely available and water quality is good with minimum dissolved salts. In every monsoon season, from our buildings, roads and open areas, huge amount of good quality of rainwater is getting drained down to the gutters. Sugar factory complex has a large area and must provide adequate arrangement to filter and collect the rainwater from the factory premises and store it for utilization in the process. The total amount of collectable rainwater can be calculated considering total area available and average rainfall in the area as follows:

If the sugar factory complex has 20 hectares of land where 20,000 m^2 is the area of the main building, godowns and housing colony with proper rainwater harvesting system (runoff coefficient 0.9), impervious roads are 30,000 m^2 with side gutters (runoff coefficient 0.7), and open area is around 15 hectares (runoff coefficient 0.5) the water available will be as below.

Assuming the rainfall in the area as 600 mm/year:

Rainwater from building- $20,000 \times 0.90 \times 600/1000 = 10,800\ m^3$

Rainwater from roads - $30,000 \times 0.70 \times 600/1000 = 12,600\ m^3$

Rainwater from area - $150,000 \times 0.50 \times 600/1000 = 45,000\ m^3$

Total $= 68400\ m^3$

This treated rainwater can be fed to the bore wells to improve the yields. Since this treated water has a very low total dissolved solids as well as very low hardness, processing cost of this water before making use in the process plant, for boiler feed water or cooling tower/spray pond make up applications gets reduced drastically.

Water available in cane: Sugarcane contains about 70% water. Based on mass and water balance for manufacturing process, surplus water is 23.23 MT per 100 MT cane (Fig. 1) (Sapkal & Gunjal 2004). This excess condensate having temperature 75-80°C can be used for melting, magma making, dilution of massecuite, cleaning of evaporator system, etc. In addition, the excess condensate may be cooled and used to replace freshwater.

Recycle/reuse: (i) Adopt water recirculation system, where mills are applying huge amount of water for mills bearing cooling (externally), (ii) the condenser water required per 100 MT cane crushed as shown in Fig. 2. It is advised to recycle vacuum filter condenser water through cooling tower/ spray pond, (iii) reuse cooling water from mills and turbines for sulphur burner, air compressor and vacuum pumps cooling, (iv) install cooling tower for cooling of water from sulphur burner and air compressor and reuse it for cooling of these units (Mijaylova et al. 2009), (v) the fulfilment of boiler feed water and generation of blow down water as 3MT per 100 MT cane crushed as shown in Fig. 3. It is advised to use boiler blow-down water for wet scrubber or after cooling for spray pond, (vi) use injection water for boiler ash quenching in emergency, brushing of juice heater, evaporators and general cleaning, (vii) reuse soda-boiling water as many times as possible and discard only once or twice during entire crushing season.

Reduce/Recover: (i) Construct common collection pit at mill side to collect juice leakages from pumps, juice overflow from tanks and sent to raw juice tank using separate pump, (ii) spill-over of juice or sugar bearing materials should be collected in collection pits and reprocessed with the help of pumps and steam ejectors and sent to weighed mixed juice tank, (iii) measures shall be taken to avoid entrainment of juice droplets into vapours going to condenser, (iv) oliver side washing should be collected by gravity and

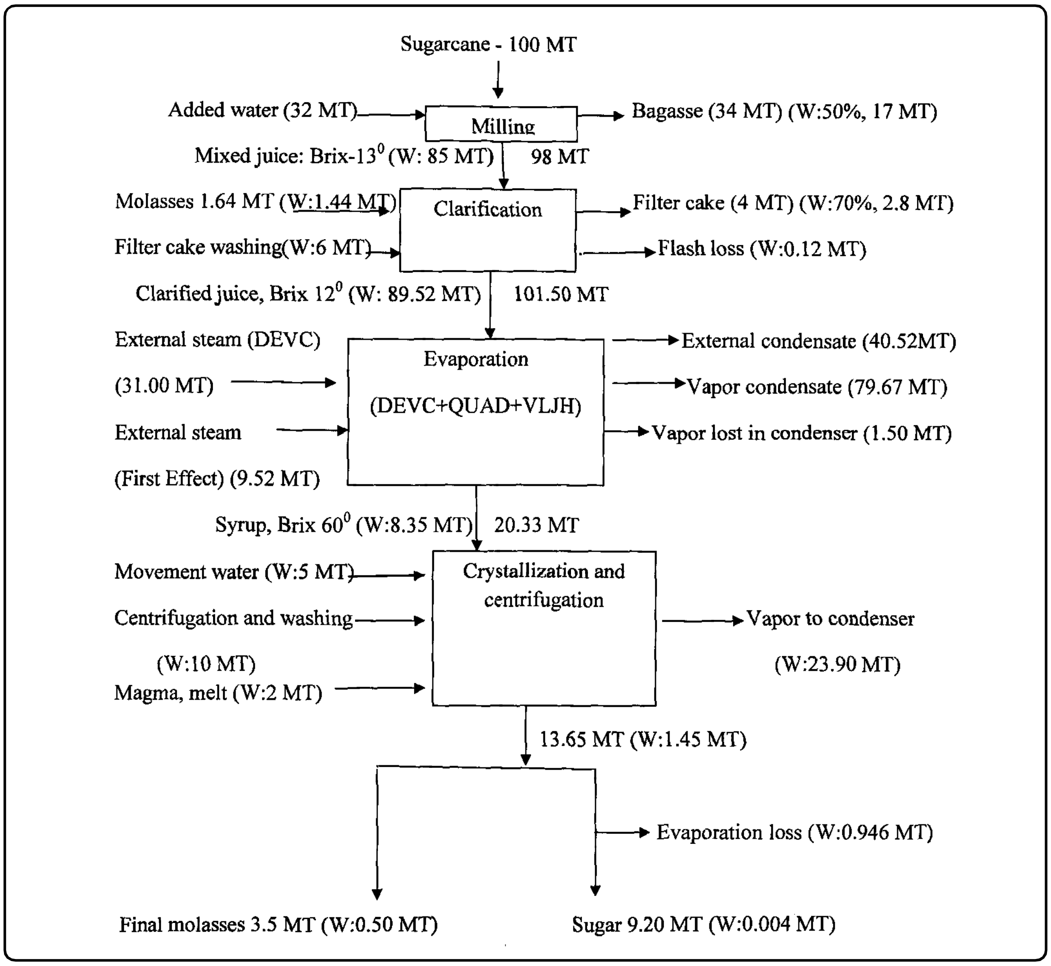

Fig. 1: Mass balance of internal water in the sulphitation process.

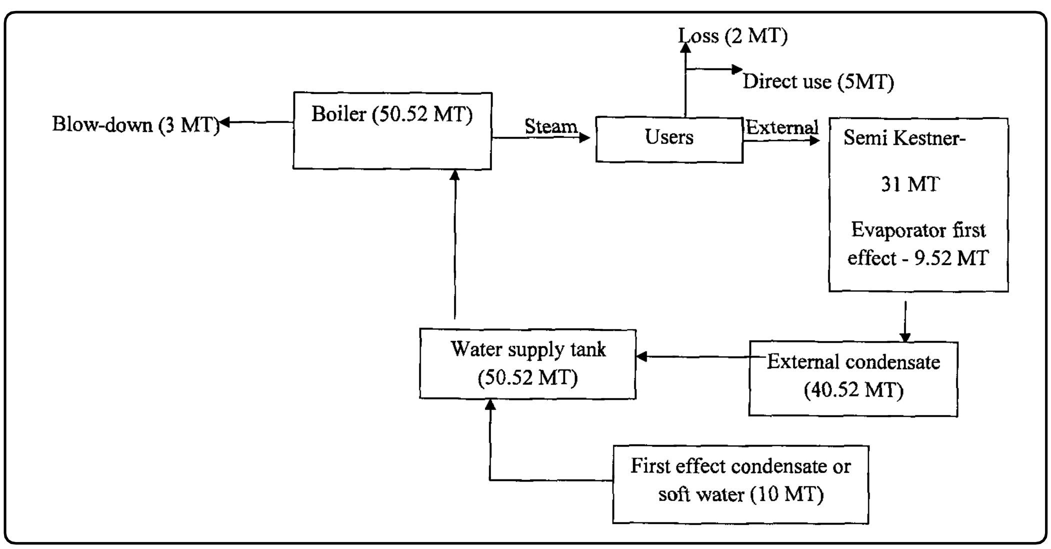

Fig. 2: Condenser water cooling system per 100 MT cane.

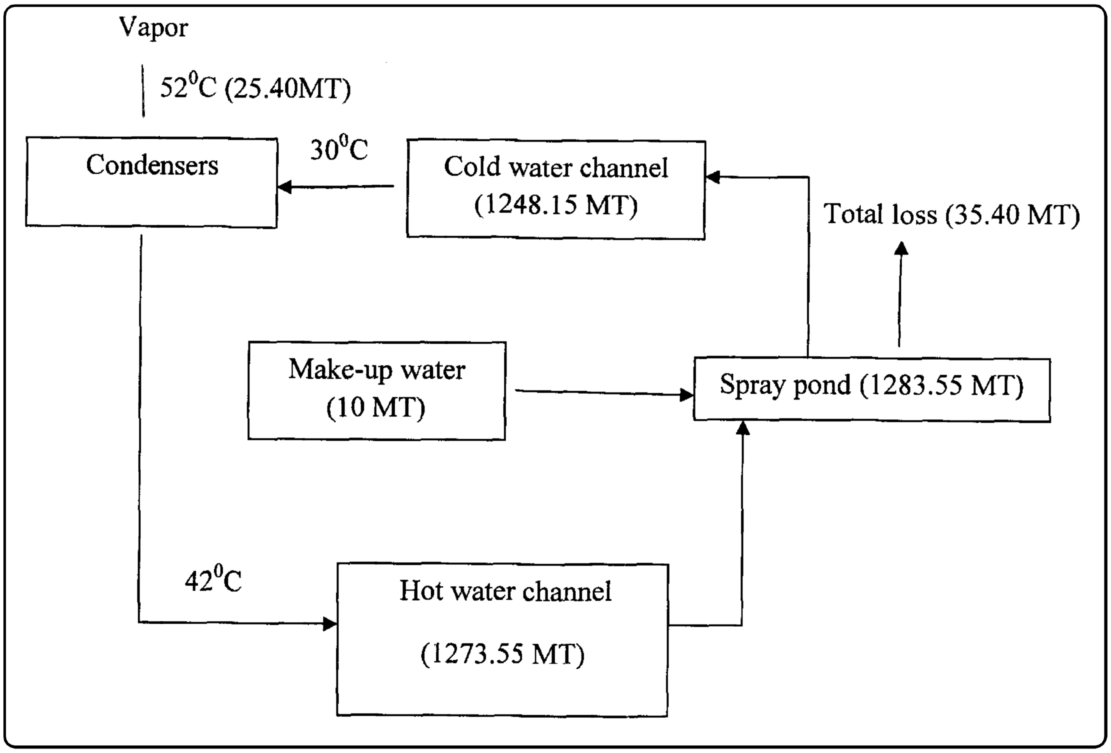

Fig. 3: Boiler water system per 100 MT cane.

returned to filtrate tank, (v) juice and maceration water receiving tank overflows shall be arrested using auto control valves, (vi) install auto level control system at service water pump to check the over-flow from the overhead tank, (vii) water leakages and cooling water used for pumps should be minimized by installing mechanical seals and proper maintenance of pumps, (viii) follow dry cleaning of mills side floor and wash with hot water once a day, (ix) install juice heater for raw juice heating with excess condensate and send the excess condensate for further cooling tower or wet scrubber and use cooled excess condensate for spray pond water make-up, (x) restrict the use of the water hoses that are used to wash floor or in non-essential cleaning operations, equip all water hoses with spray guns, (xi) collect steam from steam traps installed on various exhaust lines at a place and after condensation use it for boiler, (xii) use vapours from clarifier through direct contact heater for clear juice heating from 95-99^{0}C, (xiii) pan body washing with double evaporation vapour cell (DEVC) second effect vapour is possible. Steam saving up to 0.73% cane can be achieved, (xiv) avoid use of raw water for process, (xv) install holding tank for storage of highly polluted water during mills cleaning to avoid shock loading to ETP, (xvi) install ETP system such as anaerobic digester/trickling filter + aerobic (Hampannar & Shivayogimath 2010) followed by pressure filtration and carbon filter and recover treated water for utilization.

Record keeping: (i) Keep daily record of water with separate water meters/flow meter for water used for industry, domestic and agriculture, (ii) maintain the cooling water quality with addition of make-up water from excess condensate and blow-down if necessary. Daily monitoring shall be carried out for TDS, chlorides, sulphates, conductivity and pH, (iii) keep daily record of effluent (untreated and treated) for flow rate and its quality.

Establishment of environmental management cell: Establish environmental management cell, headed by Managing Director and Team members consisting of Head of Departments, Chemists and Engineers in the factory.

CONCLUSION

The main conclusions are that factory shall implement rainwater harvesting program and excess condensate after cooling can be recycled. The monitoring of water quality of spray pond has to be done by the factory. The wastewater generation less than 100 L/ton of cane can be achievable. For recovery of wastewater, treated water from existing ETP can be sent to tertiary system consisting of polishing tank followed by pressure filtration, activated carbon system and disinfection by chlorination.

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