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Water and Wastewater Management in a Sugar Process Production

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Since cane consists of about 70-75% water, cane sugar mill processes more water than sugar. All the water entering a mill must also leave it in one form or another. The sugar industry is a major water user and wastewater producer.

In this work are identify the structure of the main water and wastewater circuit in a sugar manufacturing process. It is analyzed using graphical techniques, and the structure of the main water and wastewater circuit can be optimized by the inspection of feasible options. By analyzing the combined effect of all the operations at given impurity contents in fresh water taken in and wastewater discharged, water pinch makes it possible to evaluate the water consumption at optimum utilization of circuit components. Both circuit structure, that is, set of connections between its components (considered as 'sources' and 'sinks'), and water flows in these connections were optimized.

1. Introduction

In theory there is a surplus of water produced in a sugar mill, which must inevitably find its way out of the mill in an effluent stream. Apart from water entering the mill in the cane, there may also be some additional water in the form of service or raw water added (Urbaniec et al., 2000). In most sugar-producing countries, water management in sugar factories is a hot issue as the industry is pressed to reduce its water consumption and the emission of pollutants. (Jensen and Schumann, 2001); (Klemeš, and Perry, 2007); (Klemeš et al., 2007) and (Lavarack, 2001). Water Pinch is a tool well known for studies of reducing water consumption in the industries of processes (Kim, 2009). The major objective of the Water Pinch study is to identify practical, technically feasible projects to reduce water intake to the process and wastewater effluent at the plant, so as to reduce annual operating costs (Kumana, 2000).

For any aqueous process operation it is possible to construct a composite profile of water demand (sinks) and wastewater effluents (sources). The profile is a scheme such a construction, which graphically depicts the water sources and sinks in a typical process, on purity versus flow axes. The point of contact between the curves is called the pinch,

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which is a feature of the system that limits the potential for water conservation. The area of overlap (shaded) shows the scope for water reuse.

2. Materials and Methods

The study was carried out in a sugar factory that processes 150 tons of cane per day. At first, the sugar manufacturing process data were collected, then the current base line of information on plant water use and wastewater generation was defined.

Water and wastewater flow rates in the main process units were quantified using actual measurements following an intensive water usage monitoring for key unit operations and wastewater generations in processes. Some flow rates were quantified on the basis of process mass balances or estimates. Water and wastewater samples were analyzed using analytical grade chemicals and adopting standard procedures for evaluation of different parameters (Alva-Argáez and Savulescu, 2009); (Alva-Argáez et al. 1998) and (Poplewski and Jezowski , 2009).

For accomplish the objective of minimized fresh water consumption and waste water disposal was used the water pinch methodology. This methodology can be broken down into six steps for obtained good results (Yoo et al., 2006):

1. Find flow data. Develop a simple flow sheet model of the water system, showing where water is used (including utility services), and where (waste) water is generated.
2. Develop a water balance accurate to within 10% of the metered amounts of the larger streams. Define the appropriate data for the Water Pinch analysis, i.e. determine water 'sources' and 'sinks'
3. Find contaminant data. Select key contaminants - e.g. COD, salts, suspended solids. In this paper was selected COD as a key contaminants.
4. Run water pinch analysis. Carry out the water pinch analysis to determine optimum matches between sources and sinks. Examine the sensitivity plots, relax constraints. Consider process modifications and regeneration options that may result in lower targets.
5. Review design. Examine the resulting network design. It is usually necessary at this point to evaluate the design and determine which additional contaminants should be considered, which matches should be forbidden, and which matches (if any) should be forced.

   Repeat steps 3-5 until a practical design has been evolved.

2.1 Factory water balance

In the sugar process, water requirements are the followings: imbibition, process water use, lime make up water, flocculants make up water, filter wash, pan house requirements and service water requirements. The use of external supplies should be kept to a minimum, because they inflate the quantity to be disposed of ultimately. It is possible for a mill to exist without an external supply, providing water circuits in the mill carefully managed.

A scheme showing the water flows in a sugar process production appear in Figure 1.

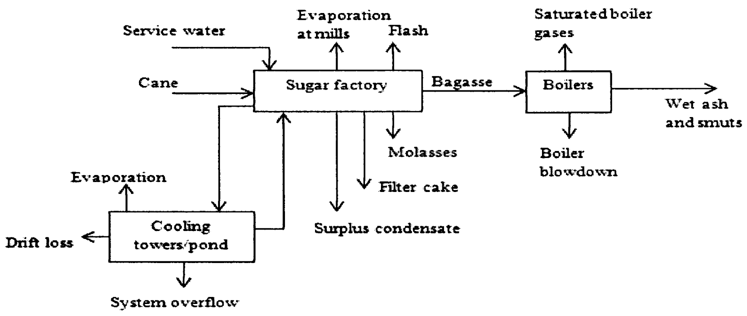

Figure 1: Streams containing water entereing and leavig a sugar mill.

In sugar process production water leaving the mill does so in the following ways (Rein, 2007) and (Purchase, 1995):

1. Together with the products of the mill: in molasses and in filter cake
2. In the form of vapor in: boiler gases, which may or may not be saturated, depending on whether a wet scrubber is used; vapor evaporated in cooling towers or spay pond; flash vapor from the heated juice flash tank; evaporation from diffuser or mills.
3. In liquid form as: surplus condensate; overflow from the cooling water circuit; boiler blow down; drift loss from the cooling towers or spray pond; effluent (wash down or spillage) from drains

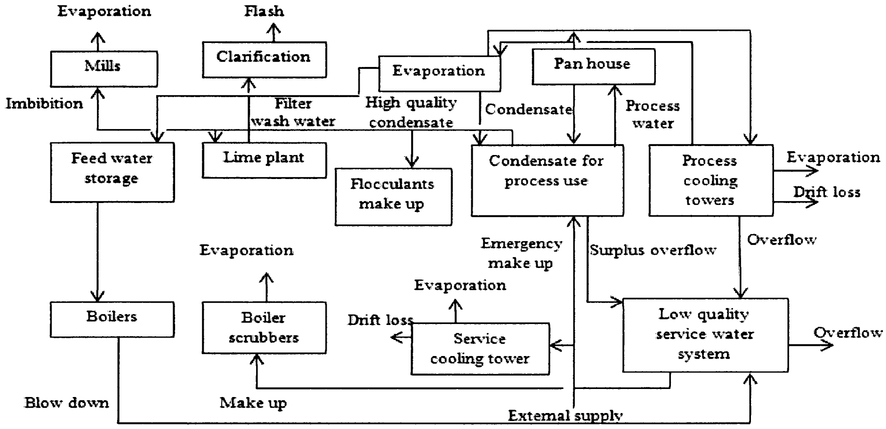

Figure 2: Major waterflow in a sugar mill

3. Results and analysis

From the process analysis were identify 13 source streams with opportunities to be recycled and 6 sinks. See Table 1 and Table 2.

Table 1: Results from water balances for sources

Source	Flow (kg/s)	Composition (mg sugar/kg water)
Condensate from heater 2	1.37	55
Condensate from heater 3	1.10	60
Condensate pre-evaporators	7.30	0
Condensate V1	3.30	23
Condensate V2	2.64	42
Condensate V3	6.50	48
Condensate V4	2.74	54
Condensate Pan 1	0.91	0
Condensate Pan 2	0.90	0
Condensate Pan 3	1.21	0
Condensate Pan 4	0.62	0
Condensate Pan 5	0.92	0
Condensate Pan 6	0.62	0
Total flow of sources	30.13	

Table 2: Results from water balances for sinks

Sinks	Flow (kg/s)	Composition (mg sugar/kg water)
Mills (Imbibition)	6.91	0-80
Boiler	12.53	0-10
Lime make up water	0.14	0-40
Filter wash	1.06	0-80
Centrifuges	0.29	0-80
First heater	1.29	0-40
Total water requirements	22.22	

The process has a requirement of water equal to 1990.47 m^3/day; from these 1036.96 m^3/day are fresh water. In other hand 2726.29 m^3/day of water are disposal as aqueous wastes with opportunities to be recycled.

Mathematical optimization was carried out using LINGO^{TM} software in order to achieve an optimal distribution of flows. The objective function was the minimization of fresh water consumption with constraints deals to levels of contaminants in the flows and mass balances constraints.

In Table 3 is showing the matrix of redistribution of streams to minimization of fresh water consumption.

Table 3: Matrix of redistribution of streams to minimization of fresh water consumption

Flow (kg/s)	Mills	Boiler	Lime Make up water	Filter	Centrifuges	First heater
Fresh water	0.00	0.00	0.00	0.00	0.00	0.00
Cond. heater2	0.00	0.00	0.00	0.00	0.00	0.00
Cond. heater3	0.00	0.00	0.05	0.00	0.00	0.00
Cond. pre-evaporators	0.00	7.29	0.00	0.00	0.00	0.00
Condensate V1	1.87	0.68	0.07	0.00	0.28	0.41
Condensate V2	1.87	0.00	0.00	0.00	0.00	0.00
Condensate V3	1.87	0.00	0.00	1.06	0.00	0.88
Condensate V4	0.38	1.87	0.00	0.00	0.00	0.00
Cond. Pan 1	0.91	0.00	0.00	0.00	0.00	0.00
Cond. Pan 2	0.00	0.90	0.00	0.00	0.00	0.00
Cond. Pan 3	0.00	1.21	0.00	0.00	0.00	0.00
Cond. Pan 4	0.00	0.00	0.00	0.00	0.00	0.00
Cond. Pan 5	0.00	0.00	0.00	0.00	0.00	0.00
Cond. Pan 6	0.01	0.59	0.01	0.00	0.00	0.00
Total consumption	6.91	12.53	0.14	1.06	0.29	1.29

Table 4: Consumption and availability of water after optimization

Quality of water	Consumption, m^3/day	Availability, m^3/day	Subtotal, m^3/day
Good	271.7	394	122.3
Contaminated	481.4	452.4	-29
			93.3

Conclusions

Water pinch analysis provides us with a systematic framework for accomplishing our process objectives optimally. The identification of source and sinks in the sugar process permitted to demonstrate a surplus of water in this process. While the target for fresh water requirement was 1990.47m^3/day, the requirement was successfully lowered achieving a reduction of approximately 85%. A decrease in net effluent outflow from the process is also observed. The solution strategies proposed are not arbitrary or based on experience but are derived from a rigorous non-linear optimization program formulated with the appropriate constraints. The methodology is flexible and can handle large processes.

References

Alva-Argáez A. and Savulescu L., 2009, Process integration for sustainable development water reuse project selection – a retrofit path to water and energy savings. Chemical Engineering Transactions, 18, 403-408.

Alva-Argáez A., Kokossis A. and Smith R., 1998, An integrated design approach for wastewater minimization: theory and applications, Proceedings IChemE Research Event, Apr 7–8.

Jensen C. and Schumann G., 2001, Implementing a zero effluent philosophy at a cane sugar factory. Proc. Int. Soc. Sugar Cane Technol. 24, 74-79.

Kim J.K., 2009, Process integration and conceptual design with process simulators. Chemical Engineering Transactions, 18, 833-838.

Klemeš J. and Perry S. J., 2007, Process optimization to minimize energy use and Process optimization to minimize water use and wastage, in Waldron K (ed.),Waste Management and Co-product Recovery in Food Processing, 59–89, 90– 115.

Klemeš J, Smith R, and Kim J., 2007, Handbook of water and energy management in food processing. Woodhead Publishing Limited, Cambridge, England.

Kumana J., 2000, Water Pinch success story at Solutia's Krummrich plant. Proceedings from the Twenty-second National Industrial Energy Technology Conference, Houston, TX, April 5-6.

Lavarack B., 2001, Reducing process steam usage? What will happen to the water balance? Proc. Aust. Sugar Cane Technol. 23, 410-415.

Poplewski G. and Jezowski J., 2009, Optimisation based approach for designing flexible water usage network. Chemical Engineering Transactions, 18, 409-414.

Purchase B., 1995, Disposal of liquid effluents from cane sugar factories. Proc. Int. Sugar Cane Technol. 22, 49-54.

Rein P., 2007, Cane sugar engineering. Berlin, Germany.

Urbaniec K., Zalewski P. and Klemeš J., 2000, Applications of process integration methods to retrofit design for Polish sugar factories, Sugar Industry/Zuckerindustrie, 125, 439–443.

Yoo K., Lee T., Jung H. and Hang Ch., 2006, Water Reuse Network Design in Process Industries: State of the art. Monograph (Eco-Industrial Park Workshop)