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# Achieving zero water use and zero discharge in the Chinese sugarcane industry

Kai Li[a,b], Fangxue Hang[a,b], Jidong Liu[a,b,*]

[a]*School of Light Industry and Food Engineering, Guangxi University, 100 Daxue Road, Nanning, Guangxi 530004 China; Tel. +86-771-3237329, Fax +86-771-3231590, email: gxlikai@126.com (K. Li), hangfx@163.com (F. Hang), liujd@gxu.edu.cn, liuan6126@126.com (J. Liu)*

[b]*Sugar Industry and Comprehensive Utilization Research Center of Ministry of Education,100 Daxue Road, Nanning, Guangxi 530004 China*

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ABSTRACT

Sugar making from cane is a water-consuming process, and the generation of organic compounds as liquid effluents is a major environmental problem in the sugarcane industry. The volume of freshwater required can be reduced significantly to zero by fully re-using the intrinsic water in sugarcane and by recycling wastewater generated during the sugar making process, such that no wastewater is discharged. In this study, a decontamination triage and hot-and-cold-stream separation was incorporated at the end of wastewater treatment at a typical Chinese sugar mill; the improved treatment design also ensured the closed recycle of wastewater. Water balance calculations indicated that the intrinsic moisture content of sugarcane could fully satisfy the loss of water in the sugar making process. These calculations were proved correct by the performance of the treatment system. The technology has achieved zero water consumption and zero $COD_{Cr}$ discharge since its implementation in the 2011–2012 milling campaign. The results demonstrate that the treatment modifications are feasible in full-scale implementation and can be used to significantly improve the environmental performance of the Chinese sugarcane industry.

*Keywords:* Sugarcane; Wastewater; Zero discharge; Reclaimed water

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## 1. Introduction

Cane sugar comprises more than 90% of plantation white sugar in China, and is mainly produced by the sulfitation process [1]. Since the 2011–2015 milling campaign, more than 1.05 million metric tons of sugar per year have been produced in China [2,3]. Sugar making is a water consuming process that generates and discharges a large quantity of wastewater; however, water consumption per ton of sugar produced varies widely around the world, from several to dozens of tons, with similar variation in the amount of wastewater generated [4]. China has a huge population of more than 1.35 billion, and the per capita distribution of water resources is only 2,200 $m^3$, which is one-third of the global average and ranks 121st in the world [5]. Thus, a reduced water demand in the sugar making industry would benefit every Chinese citizen.

As administrative and environment protection pressures have increased, more new water-saving production techniques have been developed in the sugarcane industry of China. As a result, the average fresh water consumption per ton of sugarcane produced was reduced from six tons during the 2005–2006 milling season to only 0.52 tons during the 2011–2012 season [6]. However, because more than 100 million metric tons of cane was crushed in each milling season in China, the water consumption at the average 2011–2013 rate was still a huge amount. Thus, further study to reduce water consumption in the sugar refining process is necessary.

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*Corresponding author.

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In the present study, we incorporated decontamination triage and hot-and-cold-stream separation in the end of wastewater treatment at a typical Chinese sugar mill, and ensured the closed recycle of wastewater. The technology was operated in the DuAn sugar mill (owned by Guangxi Yongxin Corp., with a grinding capacity of 4,000 metric ton/d, t/d) for 4 years from 2012. By fully employing the intrinsic water present in sugarcane, no fresh water was consumed and no wastewater was discharged during the sugar making process. We expect that this technique will help reduce water consumption and wastewater discharge in the Chinese sugar making industry.

## 2. Summary of sugarcane making process

The summarized procedure of sugar making with cane could be described in Fig. 1. Generally, sugarcane making process could be separated by four parts, they are cane juice extraction, clarification, evaporation and crystallization [7,8]. Cane was harvested and transported to the mill after remove of tips, leaves and roots, which were not suitable for crushing. Harvested cane juice after crushing contains lots of impurities, such as bagasse, pigments and colloidal suspensions [9].

Cane juice clarification is one of the most difficulty and high cost sections during sugar making [10]. To remove of the main impurities, several methods such as lime process [11,12], neutral sulfitation process [13], carbonatation process [9], phosphorus floatation [14], ion exchange process [15,16] and membrane separation process [17,18]. In China, the neutral sulfitation process was mostly used, due to its advantages of low cost and easy to control, and the strategy in the present paper was used in a neutral sulfitation process mill. The clarified cane juice was then heated in evaporators to reach a high supersaturation before the final process of crystallization.

## 3. Evaluation of zero fresh water demand and zero wastewater discharge

Before the grinding process of the mill began, 2,000 m$^3$ of fresh water was supplied for both boilers and the part of the production process that preceded the crushing of canes. During the grinding season, no supplementary fresh water was needed during the sugar making process, due to the fact that water in the cane accounted for approximately 70% of its weight and could be fully used; furthermore, appropriately treated water from the biochemical treatment system was recycled and no fresh water was consumed, realizing a zero water demand [19]. In addition, the 2,000 m$^3$ of fresh water was actually a residual from the previous sugar making campaign, because more water was obtained using the new technique than was needed for the sugar production and some of this water could be reserved for use at the start of the next campaign. Except for the moisture in products and by-products and the emissions of vapor from heat exchanges, no wastewater was discharged to the environment in the new process, realizing a so-called zero wastewater discharge.

### 3.1. Wastewater process by classification and decontamination triage

The drainage system of the mill was divided into three parts: the sewage pipelines, the clean water pipelines and the rainwater pipelines. Water from sewage pipelines included high proportions of wastewater, floor cleaning water, lime slaking residue water and the wastewater from the milling house after grease separation. The water from the sewage pipelines was collected and sent to the biochemical treatment system. The clean water pipelines were specially designed to fully utilize the intrinsic water from cane, including the boilers, evaporation and pan boiling jet condensers, cooling of equipment and water-film dust collectors and other processes. The rainwater pipelines were designed for rain water drainage. In gen-

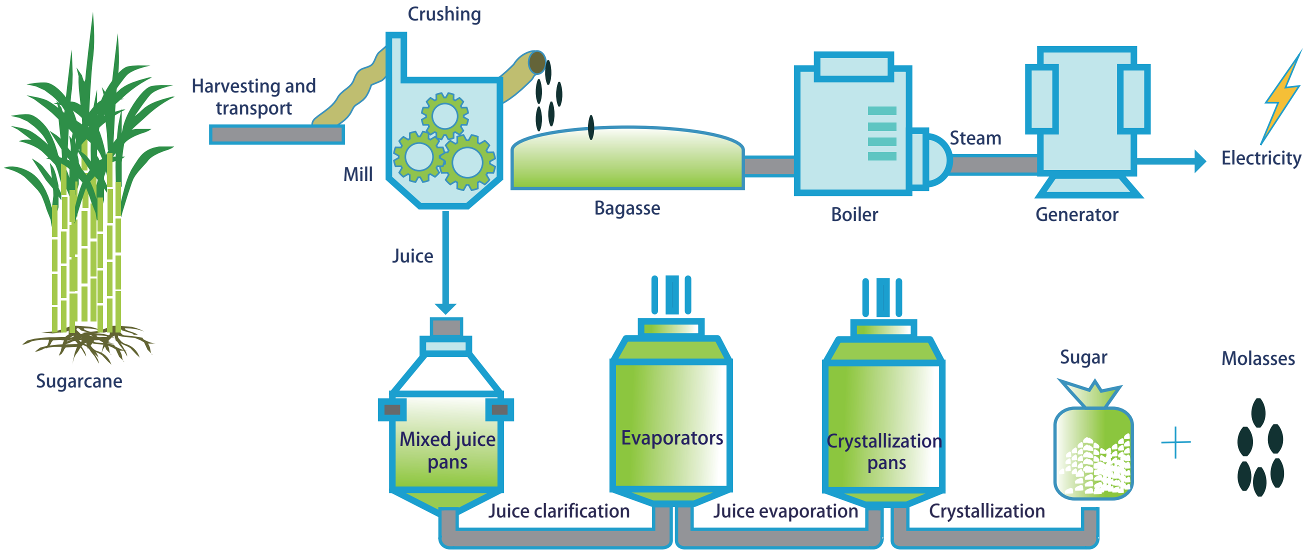

Fig. 1. Summary of sugarcane making process.

eral, the decontamination triage was proved by industrial measurement to be a feasible way to achieve a zero discharge of wastewater.

### *3.1.1. Collecting of water from condensates*

To collect water embodied in steam, an evaporation hot water tank, a pan boiling hot water tank and a cold water tank were equipped in the pan floor of the boiler,to segregate condensates collected from heaters, evaporators and pans.

### *3.1.2. Water for boilers*

Before the grinding operation, fresh water supplied for the boilers was pretreated using reverse osmosis membranes, and was reserved in a storage tank for initial application. During normal production, condensates from the first vessel of evaporation, the second heater of clear juice and the second vessel of evaporation (all having a sucrose content reaching the boiler water standard) were sent to the boiler water storage tank. With the recycling of these condensates, useful fresh water was prepared. The thermal balance of the evaporation process indicated that the collected condensates from the first and second vessels of evaporation could fulfill the required water supply for boilers, as well as generate a certain amount of surplus. The surplus condensate from the second vessel was sent to the evaporation hot water tank.

### *3.1.3. Water for the sugar making process*

The sugar making process uses water for milling imbibition, dilutions of phosphate acid and flocculants, lime slaking, pan boiling, centrifugation and other processes [7]. The imbibition water contains the evaporation hot water and the sweet water,and tank wash water, which has a relatively high content of sucrose. The dilution of phosphate acid and flocculants uses cooled water from the evaporation hot water tank. The water for lime slaking comes from the evaporation hot water tank and the cold water tank. The water for both boiling and centrifugation comes from the pan boiling hot water tank.

### *3.1.4. Water for vapor jet condensers*

At the beginning of production, the cooling water for the evaporating and pan boiling vapor condensers is obtained from the recycling water cooling pond that has been biochemically treated and reserved from the previous milling campaign. During the grinding season, a certain amount of condensates was biochemically treated to meet the need for grinding, and thereafter was circulated to the recycling water cooling pond to supplement the cooling water.

### *3.1.5. Water for equipment cooling*

The cooling water is used to cool crushers and pumps in the milling house, turbines, pumps, induced draft fans in the power plant and pumps in the boiler. The cooling water for the milling house and the power plant comes from the turbine recycling water cooling pond, as does the cooling water for pumps in the boiler.

### *3.1.6. Water for pressure tests, sulfur furnace, gas cooling and floor cleaning*

The water for pressure tests and tank washing comes from the cold water tank. The water for the sulfur furnace and gas cooling is the condensates from condensers, the water from the cold water tank, or the reclaimed water. The floor washing water comes from the recycling water cooling pond or reclaimed water.

## **4. Wastewater recycling system**

The wastewater recycling schemes are reasonably carried out according to the utilization of wastewater. The schemes include the condensates recycling system, the turbine cooling water recycling system,the recycling system of the boiler fly ash wash water and other wastewater recycling systems. Condensates from condensers of the evaporation and the pan boiling are characterized by large volume, high temperature, and traces of $SO_2$ (dissolved in water to form sulfurous acid) and sugars; thus, condensates easily turn "sour" and develop offensive odor after repeated use and concentration. To address these problems, the condensates were first sent to the recycling hot water pond, cooled to 30°C in the spray cooling tower,and then sent to the recycling water cooling pond. Approximately 300–400 $m^3/h$ of cooled water was pumped to the biochemical treatment and then recirculated back to the recycling water cooling pond. The pollutant concentration of the cooling pond water was controlled in a rather low range that met the requirements for use in condensers, ensuring the circulation of condensates for the entire grinding season.

### *4.1. The condensate recycling system*

The condensates recycling system was a closed circulation system. No raw water was needed to replace the water in the recycling ponds, thus, water was saved while condensers were provided with sufficient water, ensuring the vacuum and the stability of evaporation and pan boiling (Fig. 2).

### *4.2. The turbine cooling water recycling system*

The turbine cooling water recycling system is shown in Fig. 3. The cooling water for turbines, induced draft fans, and cane crushers was recycled after being cooled in the 300 $m^3/h$ cooling tower. The cooling water from turbines was high in temperature but was not polluted, and could be recycled after it was cooled. Besides, considering that the required quality of the water was not high, the water could be recycled easily as soon as the temperature was sufficiently low. In contrast, the shaft cooling water from the crushers contained a certain amount of oils; these suspended oils were separated via an oil-water separator, and the water was then cooled and recycled. An evaporative

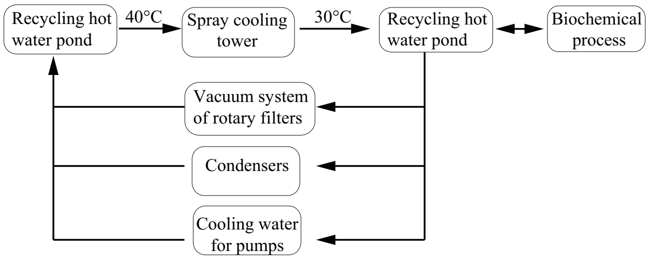

Fig. 2. The condensates recycling system.

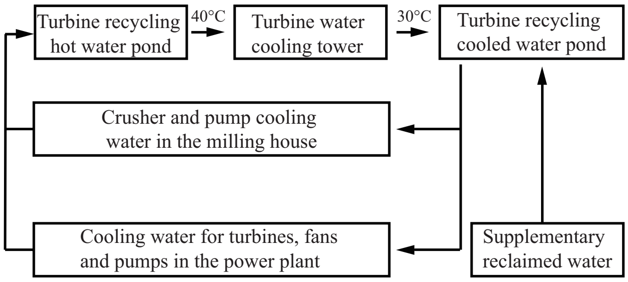

Fig. 3. The turbine cooling water recycling system.

loss took place during the cooling process, and this loss of water was replaced using reclaimed water.

### *4.3. The boiler fly ash wash water recycling system*

The recycling system for boiler fly ash wash water was a closed circulation system (as shown in Fig. 4). After the fly ash wash water flowed into the sedimentation basin, it was then further clarified by the ash-water separator, and the clear water was collected and recycled. The separated fly ash was transported out of the mill for other utilization. A quantity of water was carried away with flue gases in the process of water film precipitation of the fly ash, and another amount of water was carried away in the fly ash mud. The loss of this water was offset using reclaimed water.

### *4.4. Other wastewater recycling systems*

Other wastewater mainly included the water for the sulfur furnace cooling, tank washing, floor cleaning, and other tasks. The wastewater contained a high concentration of sugars, and was sent to the biochemical treatment system for cleansing, after which it was recycled as needed.

### *4.5. Recycling of sweet water as milling imbibition water*

In the sugar making process, the wash water of evaporators, heaters and pans contains sucrose, and is commonly known as “sweet water”. As sweet water contained no other pollutant, it could be recycled as milling imbibition water. In doing so, the impact of the pressure test and tank wash water on the end treatment, fresh water demand, effluent discharge volume and the energy consumption were reduced, whereas the sugar recovery was increased.

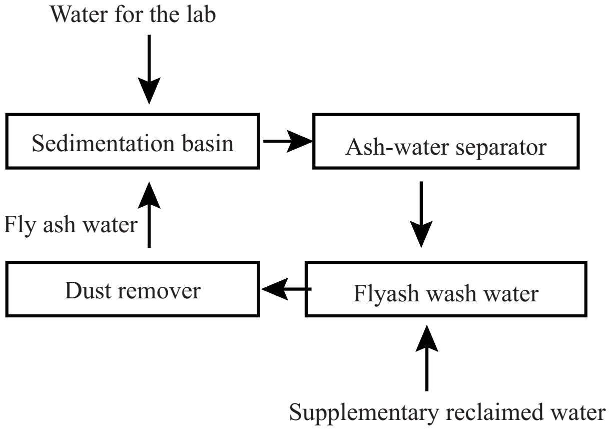

Fig. 4. The recycling system for boiler fly ash wash water.

### *4.6. Utilization of last effect vapor*

Before being drawn to the condenser, the vapor of the last effect was sent to a counter-current heat exchanger to heat the mixed juice. The uncondensed vapor was drawn to the jet condenser to maintain the vacuum. The system reduced both the steam consumption and the cooling water demand for the condenser, reducing the standard coal consumption by 0.26%.

### *4.7. Recycling of condensates*

The condensates recycling system is shown in Fig. 5. Because the energy consumption was quite low, after recycling condensates as boiler feed water and process water and offsetting the water losses, there remained a surplus of condensates. Overflowing from the evaporation hot water tank, the surplus condensates were pumped to and cooled by the efficient cooling tower, and once cooled were sent to the cold water tank to be reserved as process cold water, for high pressure washing and other usages. All evaporators were equipped with highly efficient save-alls to reduce the sucrose content in the condensates, and to ensure that the 2nd-effect condensates met the qualification of boiler feed water, reducing consumption of fresh water.

## **5. Biochemical treatment of wastewater and recycle of reclaimed water**

### *5.1. Wastewater biochemical treatment system*

The wastewater treatment system at the mill had a design capacity of 14,400 $m^3/d$ and used the Carrousel oxidation ditch process. The Carrousel process has advantages that include a small space requirement, easy installation and maintenance of aeration equipment, stable and reliable operation, and effective treatment, facilitating the closed recycle of the reclaimed water.

The treatment system processed the high-concentration wastewater (process wastewater with a high concentration of contaminants) and a portion of the condensates from the recycling water cooling pond during the grinding season. After the grinding season, the system treated the wastewa-

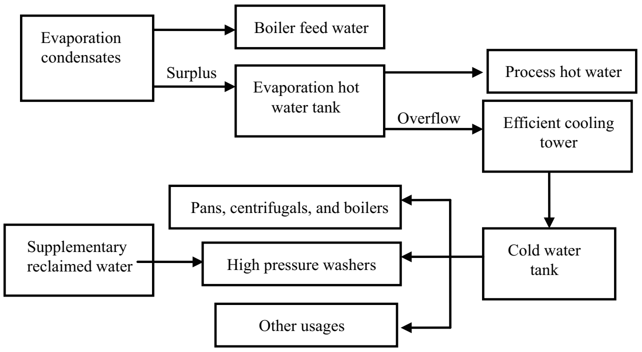

Fig. 5. Recycling of condensates.

ter from process, the recycling water cooling pond, and the turbine recycling water cooling pond.

### *5.2. Reclaimed water recycling*

After treatment in the biochemical treatment system, water satisfied the "grade one" standard of the China GB8978-1996 "Integrated Wastewater Discharge Standard" and met the requirements of GB21909-2008 "Sugar Industrial Water Pollutant Discharge Standards" for seven parameters (pH, suspended solids, ammonia, dichromate chemical oxygen demand, biochemical oxygen demand, oils, and color). The influent and effluent water quality for the treatment system is given in Table 1. The effluent water was recyclable and is commonly known as the "middle water" or "reclaimed water" to differentiate it from the feed water and discharge water. During the grinding season, the reclaimed water was used to supplement the cooling water for turbines and milling crushers and replace the water lost in the boiler flyash wash circulation loop. Reclaimed water also served as the cooling water for sulfur furnaces and gases and as the floor wash water. Any surplus reclaimed water flowed to the recycling water cooling pond to reduce the concentration of the condensates in the pond and ensure the pond water quality met the requirement for the condensers. After the grinding season, the reclaimed water was used for maintenance, and any surplus was reserved for use in the next grinding season.

## 6. Water balance in the process

According to the conservation of mass, in an isolated system, regardless of any change or process, the total mass remains unchanged. Accordingly, in the sugar production process without any supply of fresh water, when the moisture in the product and by-products and the evaporative loss of water are balanced by the intrinsic water from cane, there should be no surplus of water. Thus, the zero discharge goal is realized, as is shown in Fig. 6.

According to the chemical analysis, the cane was composed of moisture (70–75%), fiber (11.5–12.5%), sucrose (12.5–14.5%), and non-sugar components (2–4%), the latter of which included reducing sugar (1–1.5%), pectin and organic acids (0.3–0.4%), nitrogen compounds (0.4%), wax and fat (0.2%), and ash (0.4–0.6%). The moisture contents of the products and by-products and the evaporative loss of water of the sugar mill are shown in Tables 2 and 3, respectively.

Table 1
The inlet and outlet water indexes of the Guangxi Yongxin Du An Sugar Company biochemical wastewater treatment system

| | Inlet water | | Outlet water | |
|---|---|---|---|---|
| | Design basis | Actual average | Design basis | Actual average |
| Volumetric flow rate | 14,400 $m^3/d$ | 10,800 $m^3/d$ | 14,400 $m^3/d$ | 10,800 $m^3/d$ |
| $BOD_5$* | ≤ 400 mg/l | 120 mg/l | ≤ 20 mg/l | 10 mg/l |
| $COD_{Cr}$* | ≤ 1000 mg/l | 300 mg/l | ≤ 100 mg/l | 30 mg/l |
| SS* | ≤ 100 mg/l | 56 mg/l | ≤ 70 mg/l | 15 mg/l |
| pH | 6–8 | 6–8 | 6–9 | 7–8 |
| $NH_4$–N* | ≤ 30 | 8–10 | ≤ 15 mg/l | 4 mg/l |

*$BOD_5$: 5-day biochemical oxygen demand; $COD_{Cr}$: dichromate chemical oxygen demand; SS: suspended solids; $NH_4$–N: ammonium nitrogen.

### *6.1. Evaporative loss of water in the cooling tower*

$$E = \mu \times \Delta t \times R \tag{1}$$

where $E$: evaporative loss, $m^3/h$; μ: coefficient, 0.0016; Δt: temperature difference between the inlet and outlet water, °C; and R: water flow rate, $m^3/h$.

The evaporative loss was calculated as the following:

(1) Three (two in use and one in stand-by mode), 2000 $m^3/h$ no-filler spray cooling towers (special type: WGPL)were installed in the condensates recycling system. The inlet and outlet temperatures of the water were 40°C and 30°C, respectively, and the water flow rate was 2800 $m^3/h$. According to Eq. (1), the evaporative loss is:

$E_1 = 0.0016 \times (40–30) \times 2800 = 44.8\ (m^3/h)$.

(2) Two, 300 $m^3/h$ spray cooling towers were installed in the turbine cooling water recycling system. The inlet and outlet temperatures of the water were 40°C and 30°C, respectively, and the water flow rate was 600 $m^3/h$. According to Eq. (1), the evaporative loss is:

$E_2 = 0.0016 \times (40–30) \times 600 = 9.6\ (m^3/h)$.

(3) Two, square counter-flow high temperature cooling towers, each with 200 $m^3/h$ capacity, were installed in the process hot water (condensates) recycling system. The inlet and outlet temperatures of the water were 75°C and 35°C, respectively, and the water flow rate was 150 $m^3/h$. According to Eq. (1), the evaporative loss is:

$E_3 = 0.0016 \times (70–35) \times 150 = 8.4\ (m^3/h)$.

### *6.2. Water loss in the boiler fly ash washing process*

Two sets of Venturi granite water film dust collectors and four ash-water separators were installed in the boiler flue gas treatment system. The temperature of the flue gas at the inlet of the dust collector (180°C) was rather high, thus

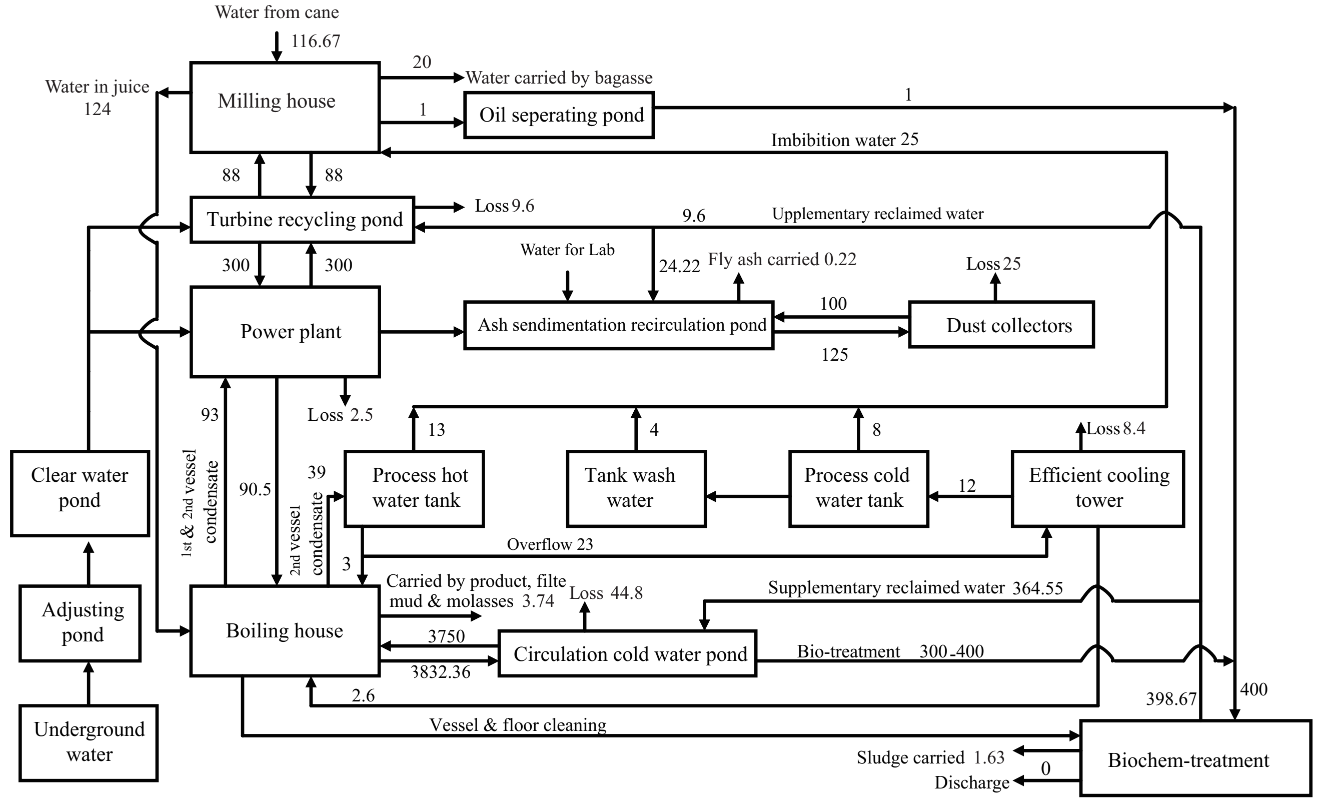

Fig. 6. Water balance of Du An Sugar Company sugar mill (m$^3$/h).

Table 2
Moisture contents of products and by products (based on 4,000 t/d throughput)

| No | Item | Mass content (%) | Mass content in cane (%) | Volume (m$^3$/h) |
|---|---|---|---|---|
| 1 | White sugar | 0.05 | 12.5 | 0.01 |
| 2 | Brown sugar | 0.1 | 0.1 | 0.0002 |
| 3 | Molasses | 20 | 4 | 1.33 |
| 4 | Bagasse | 50 | 24 | 20 |
| 5 | Filter mud | 72 | 2 | 2.4 |
| Total | | | | 23.74 |

the flue gas carried away substantial water. Based on the operating data for the last several sugar production seasons regarding the supplementary water for the flyash wash, the amount of water carried away by the flue gas was estimated to be approximately 25 m$^3$/h. Fly ash mud that was taken from the mill for further comprehensive utilization carried away substantial water. Supposing that the bagasse burned per ton cane was 0.13 metric tons, that the ash content of cane was 2%, and that the moisture content of the fly ash mud was 70%, the water carried away by the fly ash mud was estimated as $E_4 = 0.13 \times 4000 \times 2\% \times 70\% = 5.2$ m$^3$/d (based on the mill capacity of 4,000 t/d), namely 0.22 m$^3$/h. Thus, the total water loss from the fly ash wash system was approximately 25.22 m$^3$/h.

Table 3
Water and vapor loss in the process (m$^3$/h)

| No | Item | Quantity of loss (m$^3$/h) |
|---|---|---|
| 1 | Evaporation from the 2000 m$^3$/h no-filler spray cooling towers | 44.8 |
| 2 | Evaporation from the 300 m$^3$/h spray cooling towers | 9.6 |
| 3 | Evaporation from the efficient cooling tower | 8.4 |
| 4 | Evaporation from water film dust collectors | 25 |
| 5 | Carry away by fly ash mud | 0.22 |
| 6 | Carry away by sludge mud | 1.63 |
| 7 | Process circulation loss | 2.5 |
| Total | | 92.15 |

### 6.3. Water carried away by the sludge

The wastewater treatment system included a sludge storage tank. Through a sludge pump, the sludge was recycled to the Carrousel oxidation ditch, from which the surplus sludge was pumped to the dehydration plant where it was first flocculated and then dehydrated by the belt dewatering press into dry mud, which was sent by conveyor belt to the filter mud yard. Supposing that the water throughput of the wastewater treatment system was 400 m$^3$/h, the production of dry mud from surplus sludge was estimated to be 1.92 $m^3/h$, and because the moisture content of the mud was 80–85%, the water carried by the dry mud was approximately 1.63 $m^3/h$.

### 6.4. Water loss in process circulations

In the production process and the circulation of steam, a certain amount of water was lost, which was estimated to be 2.5 $m^3/h$. Supposing that the intrinsic moisture content of sugarcane was 70%, the water brought by the cane into the mill with a throughput of 4,000 t/d was 116.67 $m^3/h$. Tables 2 and 3 show that the water lost through evaporation in the process and the water carried away by the product and by-products was 115.89 $m^3/h$; therefore, the water remaining in the system from sugarcane was 0.78 $m^3/h$. Because the grinding season occurred in the winter, the weather was dry with relatively little rain and the open-air pool naturally evaporated moisture into the atmosphere. Thus, no water was discharged directly from the mill into receiving waters, achieving the zero $COD_{Cr}$ emission of both water and potential pollutants).

## 7. Concluding remarks

To achieve a zero emission of dichromate chemical oxygen demand from a sugar production facility, the following steps should be taken. First, strengthen the control of process indicators and eliminate losses of pollutants during production in run-offs, overflows, drippings and drainages, thus avoiding the impact of high-strength wastewater on the biochemical treatment system. Second, assure that only appropriately trained personnel operate and manage the biochemical treatment system to ensure its efficient operation and compliance with discharge standards. Third, recycle wastewater to the greatest extent possible according to a classification process, and considering the recirculation of wastewater to be a resource that improves production efficiency.

By introducing advanced technology and equipment and strengthening the management of process indicators, the Guangxi Yongxin Du An Sugar Company sugar mill realized the goals of zero water demand and zero $COD_{Cr}$ discharge in an energy efficient and cost-effective manner, thus realizing great social and economic benefits. The techniques described in this paper can help similar mills in the sugarcane industry achieve zero water demand and zero $COD_{Cr}$ discharge.

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## References

[1] R. Chen, Z. Yuan, Sugarcane production and research in China, Int. Sugar J., 112 (2010) 452–457.

[2] L. Lin, Z.Y. Li, C.J. Hu, X.C. Zhang, S.P. Chang, L.T. Yang, Y.R. Li, Q.L. An, Plant growth-promoting nitrogen-fixing enterobacteria are in association with sugarcane plants growing in Guangxi, China, Microbes Environ., 27 (2012) 391–398.

[3] G.S. Association, Guangxi sugar industry annual report, (2013) 10–13.

[4] O. Yinggang, M. Wegener, Y. Dantong, L. Qingting, Z. Dingke, W. Meimei, L. Haochun, Mechanization technology: The key to sugarcane production in China, Int. J. Agr. Biol. Eng., 6 (2013) 1–27.

[5] Y. Zhao, L. Guo, J.B. Liang, M. Zhang, Seasonal artificial neural network model for water quality prediction via a clustering analysis method in a wastewater treatment plant of China, Desal. Water Treat., 57 (2016) 3452–3465.

[6] J.Y. Liu, J. Basnayake, P.A. Jackson, X.K. Chen, J. Zhao, P.F. Zhao, L.H. Yang, Y.D. Bai, H.M. Xia, F.G. Zan, W. Qin, K. Yang, L. Yao, L.P. Zhao, J.R. Zhu, P. Lakshmanan, X.D. Zhao, Y.H. Fan, Growth and yield of sugarcane genotypes are strongly correlated across irrigated and rain fed environments, Field Crop. Res., 196 (2016) 418–425.

[7] V. Jegatheesan, L. Shu, G. Keir, D.D. Phong, Evaluating membrane technology for clarification of sugarcane juice, Rev. Environ. Sci. Bio., 11 (2012) 109–124.

[8] H.V. Amorim, M.L. Lopes, J.V.D. Oliveira, M.S. Buckeridge, G.H. Goldman, Scientific challenges of bioethanol production in Brazil, Appl. Microbiol. Biot., 91 (2011) 1267–1275.

[9] C.C.D. Thai, L. Moghaddam, W.O.S. Doherty, Calcium phosphate flocs and the clarification of sugar cane juice from whole of crop harvesting, J. Agr. Food Chem., 63 (2015) 1573–1581.

[10] C.C.D. Thai, W.O.S. Doherty, Characterisation of sugarcane juice particles that influence the clarification process, Int. Sugar J., 114 (2012) 719–724.

[11] G. Eggleston, D. Legendre, K. Pontif, J. Gober, Improved control of sucrose losses and clarified juice turbidity with lime saccharate in hot lime clarification of sugarcane juice and other comparisons with milk of lime, J. Food Process. Pres., 38 (2014) 311–325.

[12] V. Jegatheesan, L. Shu, D.D. Phong, D. Navaratna, A. Neilly, Clarification and concentration of sugar cane juice through ultra, nano and reverse osmosis membranes, Membr. Water Treat., 3 (2012) 99–111.

[13] M. Saska, B.S. Zossi, H. Liu, Removal of colour in sugar cane juice clarification by defecation, sulfitation and carbonation, Int. Sugar J., 112 (2010) 258–264.

[14] E.P. Borges, M.L. Lopes, H. Amorim, Impact of sugar cane juice chemical composition on clarification and VHP sugar quality, Int. Sugar J., 114 (2012) 552–558.

[15] H. Susanto, A. Roihatin, I.N. Widiasa, Production of colorless liquid sugar by ultrafiltration coupled with ion exchange, Food Bioprod. Process, 98 (2016) 11–20.

[16] O. Tzschaetzsch, Fractal applications for sugar decolorization processes, Int. Sugar J., 111 (2009) 286–291.

[17] J.Q. Luo, X.F. Hang, W. Zhai, B.K. Qi, W.J. Song, X.R. Chen, Y.H. Wan, Refining sugarcane juice by an integrated membrane process: Filtration behavior of polymeric membrane at high temperature, J. Membrane Sci., 509 (2016) 105–115.

[18] G. Eggleston, M. Heckemeyer, E. St Cyr, L. Wartelle, Case study: commercialization of sweet sorghum juice clarification for large-scale syrup manufacture, Sugar Tech., 18 (2016) 249–257.

[19] B. Van der Bruggen, L. Braeken, The challenge of zero discharge: from water balance to regeneration, Desalination, 188 (2006) 177–183.