REDUCTION OF VINASSE VOLUME BY THE EVAPORATION PROCESS

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Abstract. *The perspective of increase in ethanol fuel production causes a worry about the vinasse destination, an industrial waste from ethanol distillation. Vinasse is a liquid of dark brown coloring, originating from the distillation of the fermented juice of sugarcane that presents elevated biochemical demand of oxygen and is produced in the medium proportion of 13 liters by liter of ethanol distilled. The vinasse is a pollutant with high concentrations in organic compounds and it needs to be treated. Nowadays, the use of vinasse "in natura" in the soil is a common practice; however there are controversies about increase in the salts concentration in soil and water table contamination. Among vinasse treatment processes, there are several scientific approaches about direct application in soil and anaerobic digestion, but not about vinasse evaporation, that can be carry on falling film evaporators. The proposal of this work was to study the decrease in the vinasse amount with the evaporation process, what does not eliminate the use of concentrated vinasse as a fertilizer. For this, it were elaborated the mass and energy balances for a multiple effect evaporation plant of vinasse based in Potirendaba city, São Paulo State. The obtained results were compared with the plant data. The evaporation plant has a process capacity of around to 100* m^3/h *of vinasse and it recovers around to 80* m^3/h *of water to the mill process. The balance will be obtained through process modeling and simulation software (Sugars* ^{TM}*), which is used by beet sugar and sugar-ethanol producers to help them to manage the industry and to design new equipments and processes. The results of simulation as the concentrated vinasse flow rate and its solids concentration (brix) agreed with plant data. It is possible to recovery 78% of water from vinasse evaporation. The calculated evaporation rate of 4.5 kg of generated vapor per kg of fed steam was near of the value informed by evaporators manufactures. The heat transfer coefficients and the areas for the evaporators were calculated from literature correlations for sugar juice evaporation, because there are not specific correlations for vinasse evaporation. It also was analyzed the water recovery of a fictitious sugar and ethanol mill that produces 1,000* m^3*/day of ethanol, in order to evaluate the vinasse evaporation as possible technology to be employed to attend the requirements of the law number 88 of Environment State Department, which determines a maximum water consumption of 1* m^3 *per tons of sugarcane processed. Finally, it was analyzed the use of evaporation as a potential reduction source of vinasse transport cost by tank trucks.*

Keywords: *evaporation, vinasse, process simulation.*

1. INTRODUCTION

During the last years, the fluctuations in oil prices, the projection for oil sources scarcity and the environment problems caused by the burning of these kind of fuel, it makes the world reflects about energy alternatives. The tendency is the use of renewable and less aggressive fuel as the Brazilian ethanol. During the distillation process of ethanol, occurs the vinasse production. It is a liquid of dark brown coloring, originating from the distillation of the fermented juice of sugarcane that presents elevated biochemical demand of oxygen and is produced in the medium proportion of 13 liters by liter of alcohol distilled according to Neto (2008). The perspective of increase in ethanol production is a fact due the increase in vehicle production (mainly flex fuel vehicles) and the anhydrous ethanol consumption in the national and international market, what causes a worry about the destination of vinasse (Siqueira, 2008). The vinasse is a pollutant with high concentrations in organic and inorganic compounds and it needs to be treated. Its eviction in any water body was prohibited by the law number 323 of the extinct Brazil Internal Department in November 29th of 1978. Nowadays, the use of vinasse directly in soil is a common practice and avoids evicting it in water bodies, enables the fertilization of the soil and the reduction of the plantation costs. However, there are controversies about the increase in the salts concentration in soil and water table contamination (Salomon, 2007).

The irrigation of vinasse promotes a dispersion of amount between 400 and 500 m^3/ha, increases the amounts of calcium, potassium, nitrogen and phosphorus in the soil. Considering this dispersion in areas near to the production units, during several consecutive years, due the transport reduction costs and the availability of adequate resources and equipments, the vinasse volume applied is bigger than the recommended according to Granato (2003).

Corazza (2001) identified four groups of technological options to treat the vinasse: evaporation, aerobic fermentation, anaerobic digestion and others uses (direct use in the soil and the recycle in alcoholic fermentation). There are several scientific approaches about direct application in soil and anaerobic digestion, but not about vinasse evaporation. Nowadays, in Brazil, there are two sugar and ethanol mills with theirs vinasse evaporation plants in operation.

The proposal of this work is to study the decrease in the vinasse amount and the reduction in water consumption with the evaporation process, what it is not meaning the concentrated vinasse can not be use in soil, in order to decrease the costs for fertilizers purchasing.

2. BIBLIOGRAPHICAL REVISION

2.1. Vinasse and its evaporation

Vinasse: liquid derived from the wine distillation, which is the result from sugarcane juice fermentation or from molasses (secondary product from sugar production) fermentation (CETESB, 2005). It is a product constituted by salts and with high oxygen biochemical and chemical demand. During the 1940s and 1950s, the amount of produced vinasse was not so big than nowadays, and it was deposited in water tables and areas of sacrifice, but even so, it caused worry for the environmental departments and for scientific community (Corazza, 2001). In 1975, the Brazilian government created a program to incentive the ethanol production in order to produce a mixture fuel with gasoline and reduce the dependence from oil. In the middle of 1970s, the country produced around 580 million of liters and in 1980 the ethanol production reached 3,676 million (Paixão, 2006). This increment represented a proportional increment in vinasse production. In 1978, the law number 323 from the Brazilian Internal Department prohibited the vinasse eviction in water tables.

It was recognized the use of vinasse as a fertilizer due mainly the potassium, calcium and magnesium concentrations and the high level of organic mater, so its application in the soil became the solution more employed by the sugar and ethanol mills, however the contamination risk for the water tables (Viana, 2006). The actual Brazilian ethanol production reaches 27 billion of liters per year (UNICA, 2010), what represents a huge increment in vinasse production. In 2005, the COMPANHIA DE TECNOLOGIA DE SANEAMENTO AMBIENTAL (CETESB) ratified the technical norm P4.231 that establishes the maximum potassium concentration as 5% of the soil cationic capacity of exchange.

In 2008, the Environment Department of São Paulo State established technical directives for new undertakings in sugar and ethanol sector. Among these directives, there is one that establish a maximum consumption water of 0.7 m^3 to 1 m^3, depending of sugar mill localization. This fact favors water recuperation technologies as the vinasse evaporation (Secretaria de Estado do Meio Ambiente, 2008).

The first registers about vinasse evaporation are from 1954, when the Austrian company VOGELBUSCH installed a concentrator system that utilized thermosyphon evaporators. After that, the same company developed the falling film evaporator (Biase, 2007). At Brazil, the first installations to concentrate the vinasse were installed in 1978. One of them was installed in TIUMA Mill in Pernambuco State and was designed by Brazilian company called BORAG. The plant had many incrustations problems and the stoppages to cleaning complicated the distillery operation. Nowadays, the evaporation system and the mill are deactivated (Biase, 2007). The other unit was installed in SANTA ELISA Mill in São Paulo State and it was manufactured by Brazilian company CONGER, under license by VOGELBUSCH. The plant was maintained out of operation, but in 1999, the unit began to run continuously with a 3 m^3/h concentrated vinasse production. The system allowed a reduction cost for the vinasse transportation and a flexibility to control the application of concentrated vinasse according to the soil characteristics (Biase, 2007 and Barbosa, 2006).

In 1984, the SANTA IZABEL Distillery, at Novo Horizonte, São Paulo State, installed multiple effect evaporation for vinasse that allowed a 50% reduction in the total volume produced, witch was distributed by trucks directly in soil. Nowadays, the Brazilian company DEDINI has the VOGELBUSCH license to manufacture the vinasse evaporators and in association with the companies SIEMENS and CHEMTECH has sold a complete plant to distillate the ethanol integrated with a vinasse evaporation train to the company PETRÓLEOS DE VENEZUELA (PDVSA). The plant can produce 8,5 million liters of ethanol per year according to Biase (2007).

2.2. Evaporation Process

The evaporation is a unit operation very utilized by several sectors of chemical and processes industry and has the objective to get concentrated products, that is, with a lower percentage of volatile solute as the water. The evaporators are utilized in food, paper and cellulose, sugar and ethanol, polymers, fertilizers and others industries.

The energy for evaporation is often obtained from saturated steam originated in the boilers. The steam does not make contact with the evaporated product. For the sugar and ethanol mills, the sugar juice evaporation utilizes steam from generation turbines, it is saturated and with pressure of 1.5 kgf./cm^2 gauge, approximately 150 kPa gauge. In the mills, the vapor generated by the evaporators is used as energy source for heating sugarcane juice and for ethanol distillation.

Franco (2001) and Westphalen (1999) have descript the main kinds of evaporators and the utilized arranges as the solar, batch, natural recirculation, forced recirculation, falling film, agitated film and plates evaporators.

The evaporators are big consumers of energy and in order to decrease this consumption, several strategies are used, as the multiple effect evaporation. In this system, one evaporator is assembly in sequence the other, and the evaporated vapor from the first effect is the energy source for the second effect and like this successively. The evaporated vapor from the last effect passes by a condenser, finishing the process. This configuration allows utilizing only the provided heat to the first effect as the energy source to the total evaporation process.

The number of effects represents the energy saved for evaporation. The amount of energy saved is defined by the ration between the total evaporated water and the steam provided for the first effect. The multiple effect configurations also allow saving refrigeration water in the condenser, because this equipment operates only for condensing the steam generated in the last effect. On the other hand, a big number of effects cause lower temperatures gradients, what it is meaning bigger areas for heat exchanging, increasing the fix costs. Therefore, choose of the effects number is defined from an economic balance between the saved steam and refrigeration water and the investment cost.

2.3. Overall Coefficient of Heat Transfer in Evaporators

According to Rein (2007), for many years, it looked up on heat transfer coefficients of evaporators, reaching the conclusion that it is fairly difficult to get precise values, mainly due to the difficulty of obtaining adequate samples for measurement of solids mass concentrations (brix), precise measurements of temperature and / or pressure, absence of flow meters at the plant and the different ways of measuring the area and the boiling temperature of liquids.

It is known that transfer coefficients decrease from the first effect of evaporation for the latter, which is attributed to the increased viscosity of the liquid over the effects. Several researchers have attempted to determine correlations dependents of viscosity , concentration of dissolved solids ,temperature differences and boiling temperatures ,which is not easy according to Rein (2007), since all these variables are strongly correlated . The first three variables increase over the effects and the latter decreases. Unlink these effects is virtually impossible when analyzing measurements in industrial plants.

According to Rein (2007), the best known formula that tries to take these effects into account in the evaporation of sugar juice is the formula of Dessin, which is widely used with some success and gives the value of the rate of evaporation in English units (lb/(ft2.h.°F)). The evaporation rate expressed in Eq. (1) is the flow of vapor in an evaporator plant produced per area and temperature unit.

$$\tau_{evaporação} = \frac{(100 - W_{DS,s})(T_V(°F) - 130)}{18000} \tag{1}$$

The value in the denominator was originally 16000, but the equation found values too high and it was need to adjust the equation in order the values represent better the design specifications. The concentration of solids in the liquid is measured at the evaporator outlet, WDS, s. In SI units (kg/h.m2.K), the equation can be written as show in Eq. (2):

$$\tau_{evaporação} = 0.00089.(100 - W_{DS,s})(T_V - 54) \tag{2}$$

To convert this expression into an equation for overall coefficient of heat transfer, it needs to multiply it by the heat of vaporization. Considering the range of pressures that normally operate the evaporators and taking into account that the relationship is for the purpose of approximation, it can assume a value of 2300 kJ/kg as the heat of vaporization. Equation (2), after multiplied by 2300 kJ/kg and divided by 3600 s can be written as:

$$U = 0.000567.(100 - W_{DS,s})(T_V - 54) \tag{3}$$

Where U is the overall coefficient of heat transfer in kW/(K.m2) and TV is the temperature of steam fed into the calendar of the evaporator in °C.

Most of the correlations for calculation of transfer coefficients found in literature are expressions that incorporate the solids concentration in the liquid and temperature. Sometimes, the temperature difference is incorporated into the equation to take into account the fact that the transfer rate will be greater when the liquid is under boiling fully developed process.

According to Rein (2007), it is very unlikely that the U value is linearly related to the solids concentration and temperature, so he postulated a correlation to calculate the overall coefficient of heat transfer according to Equation (4).

$$U = a.(100 - W_{DS})^b.T_V{}^c \tag{4}$$

Also according to Rein (2007), Guo (1983) found an equation similar to this, based on laboratory studies, ignoring the effects of head loss, considering the optimal level of liquid in the evaporator tubes, but considering the boiling temperature of the liquid inside the evaporator. This equation is expressed as follows:

$$U = 0.16.(100 - W_{DS})^{0,4} . T_L{}^{0,25} \tag{5}$$

Rein (2007) also shows typical values of overall coefficients of heat transfer recommended for the design of evaporators and used for many years in South Africa for juice evaporators. These values are shown in Tab. 1.

Table 1. Overall Coefficients of heat transfer recommended for the juice evaporators design.

Effect	Evaporation with 4 effects (kW/m^2.K)	Evaporation with 5 effects (kW/m^2.K)
1st Effect	2.5	2.5
2nd Effect	2.2	2.5
3rd Effect	1.7	2.0
4th Effect	0.7	1.5
5th Effect		0.7

According to Rein (2007), changes in solids concentration and temperature in the first three effects are relatively small when compared with the latter effect. Thus, Smith and Taylor (1981) observed that the coefficients for the first three effects lay between 3.5 and 1.8 kW/(K.m2). But for the last effect, these researchers showed a correlation coefficient for the global heat transfer in terms of the temperature of the vapor generated in the last effect, TVG, N, according to Eq. (6).

$$U = 0.034.T_{VG,N} \ - 1,13 \tag{6}$$

3. MATERIALS AND METHODS

In order to reach the proposal of this work, it was used technical information and data from a sugar and ethanol mill (Usina Cerradinho, Potirendaba city, São Paulo State), where there is a evaporation plant for vinasse in operation, built by a Brazilian company called CITROTEC. The sugar and ethanol mill produces 500 m^3/day of ethanol and 250 m^3/day of vinasse.

The plant has five effects and uses as the energy source the vapor extracted from the sugarcane juice evaporation with around 170 kPa and 115 °C. The multiple effect plant receives around 100 m^3/h of vinasse and the surplus is applied in soil as a fertilizer. Separators are installed between the evaporators in order to avoid the flow of vinasse droplets into the vapor from an effect to the other. The Fig. 1 shows a picture of the vinasse evaporations plant.

Figure 1. Vinasse evaporation plant.

The vinasse "in natura" has 3% to 5% Brix and 3.37 kg/m^3 of K2O. After the evaporation, around 18 to 20 m^3/h of vinasse with 20% to 25% Brix and 30 kg/m^3 of K2O are produced according to Mill.

The data were collected from the plant and were processed by commercial software named Sugars TM, responsible by the evaluation of the mass and energy flows. Through interactive calculations, the software can calculate all the flows of mass and energy, which are in the balance equations.

Assuming an evaporation system for multiple effects as shown in Fig. 2, it can be defined equations for mass and energy balance of the system. The mass balance and energy for an evaporation system with N effects is done by considering each of the vessels of evaporation (individual balances) and all the effects (global balance), both in steady state. Equations (7), (8) and (9) describe the global mass and energy balance for the system. Initially, despises the use of vaporization of condensates as a source of energy for the next effect.

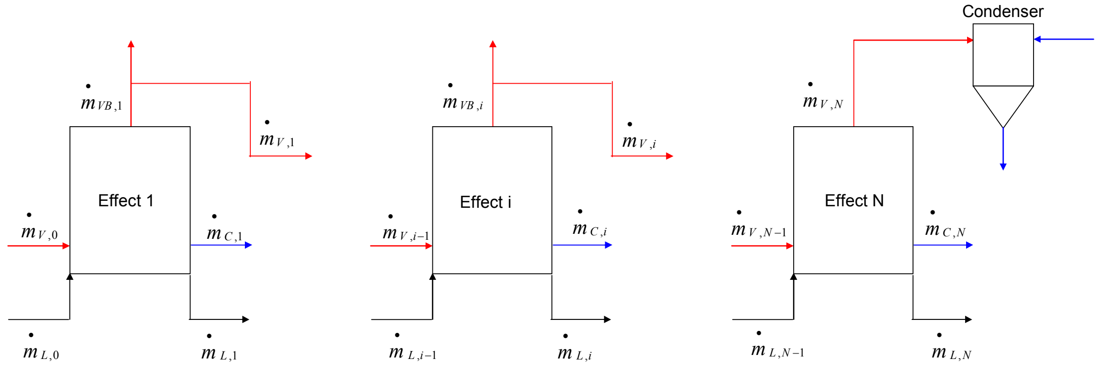

Figure 2. Typical scheme for multiple effects evaporation.

$$\dot{m}_{V,0} + \dot{m}_{L,0} = \dot{m}_{V,N} + \dot{m}_{L,N} + \sum_{i=1}^{N} \dot{m}_{C,i} + \sum_{i=1}^{N} \dot{m}_{VB,i} \tag{7}$$

$$\dot{m}_{L,0} \cdot w_{DS,0} = \dot{m}_{L,N} \cdot w_{DS,N} \tag{8}$$

$$\begin{aligned} \dot{m}_{V,0} \cdot h_{V,0} + \dot{m}_{L,0} \cdot h_{L,0} &= \dot{m}_{V,N} \cdot h_{V,N} + \dot{m}_{L,N} \cdot h_{L,N} \\ &+ \sum_{i=1}^{N} \dot{m}_{C,i} \cdot h_{C,i} + \sum_{i=1}^{N} \dot{Q}_{transf,i} + \sum_{i=1}^{N} \dot{m}_{VB,i} \cdot h_{V,i} \end{aligned} \tag{9}$$

Where:

$\dot{m}_{V,0}$: Mass flow rate of steam fed to the first effect, kg/h;
$\dot{m}_{L,0}$: Mass flow rate of liquid fed to the first effect, kg/h;
$\dot{m}_{V,N}$: Mass flow rate of steam generated in the N effect and directed to the condenser, kg/h;
$\dot{m}_{L,N}$: Mass flow rate of concentrated liquid of the effect N, kg/h;
$\sum_{i=1}^{N} \dot{m}_{C,i}$: Sum of mass flows of condensate from the first effect to the effect N, kg/h;
$\sum_{i=1}^{N} \dot{m}_{VB,i}$: Sum of mass flows of steam extracted from the first effect to the effect N, kg/h;

$w_{DS,0}$: Mass concentration of solids (Brix) in the liquid fed to the first effect, %;

$w_{DS,N}$: Mass concentration of solids (Brix) of concentrated liquid in the effect N, %;
$h_{V,0}$: Enthalpy of steam fed to the first effect, kJ/kg;
$h_{L,0}$: Enthalpy of the liquid fed to the first effect, kJ/kg;
$h_{V,N}$: Enthalpy of steam generated in the N effect, kJ/kg;
$h_{L,N}$: Enthalpy of the concentrated liquid in the effect N, kJ/kg;
$h_{C,i}$ Enthalpy of condensate from the effect i, kJ/kg;
$h_{V,i}$: Enthalpy of steam generated in the effect i, kJ/kg;

$\sum_{i=1}^{N} \dot{Q}_{transf,i}$: Sum of heat transferred rates to the environment from first effect to the effect N, kW.

4. RESULTS AND DISCUSSION

The average actual data of the plant used to feed the software are shown in Table 2. These values were measured through information collected online or by instruments in the plant or laboratory measurements of the mill. The effects operate continuously under vacuum and the temperature decreases from one effect to another.

Table 2. Average values of the vinasse evaporation plant used as input data for the software.

Variables	Values
Fed vinasse flow rate (m^3/h)	105
Temperature of the fed vinasse (°C)	80
Brix of the fed vinasse (%)	4,5
Temperature of the fed steam (°C)	115
Temperature of the first effect (°C)	94
Temperature of the second effect (°C)	91
Temperature of the third effect (°C)	84
Temperature of the fourth effect (°C)	78
Temperature of the fifth effect (°C)	62

In order to allow Sugars ^{TM} to calculate the mass and energy balance, it was necessary to elaborate a graphical model in Visio ^{TM} for Windows ^{TM} as showed in Fig. 3. This model should represent the plant, that is, the mass and energy flow connections between the effects.

There are five evaporation effects and a final condenser after the fifth effect. The vinasse comes from the mill and passes by two shell and tube heaters before to be fed into the first effect. The condensate from the second, third and fourth effects are sent to flash tanks in order to evaporate and to provide vapor to the third, fourth and fifth effects. The use of the condensate energy is very common in multi effect evaporation system because contribute to save steam fed into the first effect. The condensate from the first effect is sent to the mill boiler and the final condensate is sent to cooling towers in order to be used as dilution water for fermentation process of the mill.

According to information from mill, the vinasse evaporation plant is capable of producing 18 to 20 m^3/h at 60 °C with a concentration of vinasse from 20 to 25 Brix from about 100 m^3/h of vinasse “in natura” with 3 to 5 Brix, producing about 80 m^3/h of condensate, which returns to the mill process. Therefore, the results calculated and presented in Table 3 are close to the information provided by the plant, which demonstrates that the model simulates fairly well the evaporation plant.

Table 3. Average values of the vinasse evaporation plant used as input data for the software.

Variables	Values calculated by Sugars ^{TM}	Values obtained from mill
Concentrated vinasse flow rate (m^3/h)	20.37	18 - 20
Temperature of the concentrated vinasse (°C)	62	60
Brix of the concentrated vinasse (%)	21.44	20 - 25
Final condensate flow rate (m^3/h)	81.73	80
Generated vapor per fed steam (kg/kg)	4.5	4.3
Brix for 1st effect (%)	5.40	-
Brix for 2nd effect (%)	6.55	-
Brix for 3rd effect (%)	8.40	-
Brix for 4th effect (%)	11.92	-

To calculate the overall coefficient of heat transfer, it were used the Eq. (3), (5) and (6) presented earlier and concerning to the evaporation of the sugarcane juice. The concentrations of solids (brix) obtained from sugarcane juice evaporators are close to concentrations obtained by evaporation plant vinasse, thus, approximately, decided to use these equations to calculate the coefficients in evaporation of vinasse. No correlations were found in the literature specific to the evaporation of the vinasse. It was not informed by the plant and by the equipment manufacturer the values of coefficients used to design the evaporators. For future scientific work, it would be interesting to determine specific correlations for evaporation of vinasse. The determination of overall coefficient of heat transfer is extremely important to check the efficiency of any heat exchange equipment as heat exchangers and evaporators. It is known that the determination of these coefficients depends on a thorough survey of data about the flow inside the tubes of such equipment. Table 4 shows the calculated values by Eq. (3), (5) and (6) for overall rates of heat transfer for each effect.

Table 4. Values for overall coefficients of heat transfer calculated for vinasse evaporation plant.

	U, kW/m^2.K				
Equation number	1st Effect	2nd effect	3rd Effect	4th Effect	5th Effect
3	3.27	2.12	1.92	1.5	1.07
5	3.07	3.03	2.95	2.85	2.57
6	-	-	-	-	0.98

Observing the values in Table 4, it is possible to conclude that Eq. (5), developed by Guo (1983), presented coefficients more conservative, that is, values that result in larger areas of evaporation. The values suggested by Rein (2007) in Table 1 are even more conservative.

For the fifth effect, the value presented by Rein (2007) in Table 1 (0.7 kW/m^2.K) is less than the value calculated by Eq. (6) of Smith and Taylor (1981), 0.98 kW/m^2.K, resulting in a greater area of heat transfer.

It was also noted that the values calculated by Eq. (3) and (5) approach the values reported by Smith and Taylor (1981) for evaporation of sugarcane juice, from first to third effect, 3.5 to 1.8 kW/m^2.K.

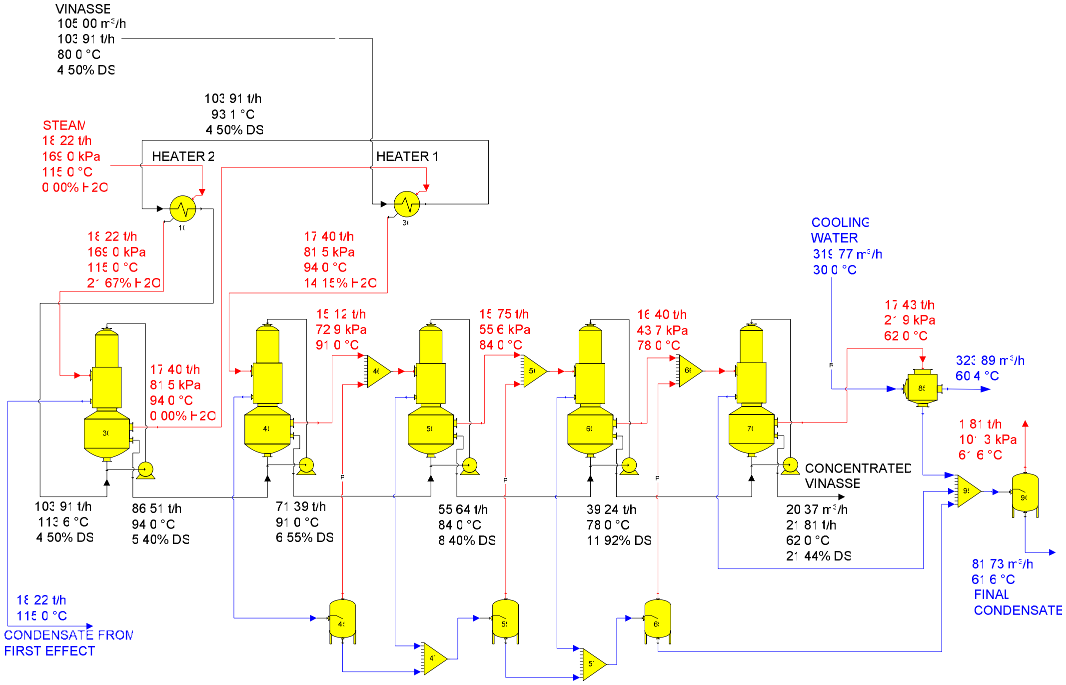

Figure 3. Graphical model for the vinasse evaporation plant.

The software Sugars ™ can calculate the area of each effect of evaporation, simply informing the overall coefficient of heat transfer for each case. In order to calculate a range of values for the area (A) of each effect, it was reported to the software the lowest and highest value of coefficients (U) between those reported in Table 1 and calculated in Table 4. Table 5 shows the area values calculated.

Table 5. Values for effects area and overall coefficients of heat transfer for vinasse evaporation plant.

	1st Effect	2nd Effect	3rd Effect	4th Effect	5th Effect
U, kW/m^2.K	2.50 – 3.27	2.12 – 3.03	1.92 – 2.95	1.50 – 2.85	0.70 – 2.57
A, m^2	165 - 126	1460 - 1422	707 - 460	1130 - 595	956 - 261

Unfortunately, the area of each effect was not informed by the plant nor by the equipment manufacturer and thus it was not possible to verify if the calculated area approached of the actual areas.

A mill that produces 1,000 m^3/day of ethanol can produces 325 m^3/h to 815 m^3/h of vinasse, depending of the ethanol concentration of raw material to mill distillation and of the heating used in distillation, indirect or direct heating. Considering the lower production of vinasse, that is, 325 m^3/h, and assuming the project to develop an evaporation system which operates under the same conditions of Potirendaba plant, it was made a simulation in Sugars ^{TM} to check the consumption of steam and the condensate returning to the process. Table 6 shows the calculated values.

Table 6. Values calculated for a fictitious evaporation plant to process 325 m^3/h of vinasse.

Variables	Values
Concentrated vinasse flow rate (m^3/h)	63.02
Temperature of the concentrated vinasse (°C)	62
Brix of the concentrated vinasse (%)	21.44
Final condensate flow rate (m^3/h)	252.98
Brix for 1st effect (%)	5.36
Brix for 2nd effect (%)	6.50
Brix for 3rd effect (%)	8.35
Brix for 4th effect (%)	11.87

According to the simulation, it is necessary to provide 57 t/h of steam with about 170 kPa and 115 °C to ensure evaporation of the vinasse to 21.44% Brix. It is recover about 250 m^3/h of condensate that can be reused in the process of the mill.

Mills that produce 1,000 m^3/day of ethanol can process 21,600 tons/day of sugarcane and produce 36,000 bags/day of sugar. Thus, the deployment of a vinasse evaporation system at that plant would represent a return of 0.28 m^3 of water per ton of cane, 28% of water consumption required by the law number 88 of Environment State Department for areas classified as adequate or appropriate to environmental constraints. Thus, the evaporation of vinasse becomes a technology to be considered in order to achieve the established consumption, together, of course, with other actions such as: the use of closed circuit cooling water in the fermentation, the operation of the distillery indirect heaters and the use of raw material to mill distillation with higher ethanol concentrations. While the potential for recovery of water through evaporation of vinasse is large, the applications should be studied to use condensate recovered in the process. It is also necessary to study if any condensate treatment is required for its use.

The mill transports the concentrated vinasse to distant cane fields by tanks truck. The cost of this kind of transport increases with the distance that separates the industrial plant and the sugar cane fields where the vinasse is applied. According to Rocha (2007), there is an economic distance, as a function of the brix of vinasse that has lower costs in relation to the application of chemical fertilizer. The higher the brix of vinasse, the lower the volume to be transported, and the greater the economic distance. Table 7 shows the variation in distance as a function of economic brix vinasse.

Table 7. Economic distance versus the vinasse brix.

Vinasse brix (%)	Economic distance (km)
3	30
5	35
10	39
15	40
20	40
25	41
30	41
35	41
40	41
45	41
50	41
55	41
60	41

According to Tab. 7 for values greater than 25-30% brix, the economic distance does not increase. This means that to concentrate the vinasse more than 25-30% brix not result in a growing economy of transportation through the truck. This is because from 25-30% brix, the volume of concentrated vinasse not diminishes much, not significantly reducing transport costs.

For the case of vinasse evaporation plant studied, it was observed a reduction in the flow of vinasse from 105 m^3/h to 20.37 m^3/h, that is, a decrease of 5.15 times, a number that also reflects the reduction transport costs for the same distance from the areas of application.

5. CONCLUSIONS

The flow rate, brix and temperature data of concentrated vinasse and flow rate of condensate obtained by simulation of Sugars TM are very close to the actual data collected in the evaporation plant. The evaporation rate calculated by the simulation is close to the rate of evaporation informed by the manufacturer of evaporators. Thus, the model can be used to simulate the plant.

It is possible to recover 78% of water present in the vinasse, thus reducing its volume by evaporation process. This represents direct savings in collecting water for the process and reduces the costs of vinasse storage and transport to distant cane fields. Thus, the technology of evaporation of vinasse should be evaluated in order to attend the law number 88 of Environment State Department, since it has the potential to recover large quantities of water for the process plant. However, the use of the water should be carefully considered, since the condensate of vinasse may contain components such as salts and acids, which may require treatment depending on the use of reclaimed condensate.

There is a range of concentrations of vinasse (brix 20-25%), from which the radius of economic distribution does not increase and that is the same concentration range in which it operates the evaporation plant studied.

The concentrated vinasse is obtained with 60°C from its evaporation, which eliminates the need for cooling before forwarding it to the cane fields.

The vinasse, even concentrated, is transported by the plant via trucks to be used as fertilizer for sugarcane crop, which indicates that evaporation did not impair the vinasse distribution at the sugarcane fields. However, it should be studied whether the concentration of vinasse not cause the precipitation of salts, changing its fertilizers properties.

6. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of Usina Cerradinho and Zilor Energia e Alimentos for provide the data and the software for calculations respectively.

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