OPERATION AND PERFORMANCE OF THE GRANULAR ACTIVATED CARBON PLANT AT NCHALO

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Abstract

The Nchalo mill used to have a phosphatation/sulphitation (light sulphitation followed by Talo phosphatation) back-end refinery. To improve the quality of its refined sugar, a full-scale granular activated carbon (GAC) plant was installed during the 1999-2000 off-crop to replace the sulphitation process. A carbon reactivation kiln was also installed. The performance of the granular activated carbon plant and the reactivation kiln over its first season of operation are described. A maximum pH drop of 0,4 unit across the column was recorded and an average of 65% colour removal was achieved. Reactivation produced carbon with an average iodine number of 894 at a carbon usage of 0,12 kg per ton brix in filtered liquor going through the GAC plant.

Introduction

The colour of refined sugar at Nchalo mill used to be high (100-200 ICUMSA units) since its installation in 1966. This was primarily due to the fact that the old sulphitation/phosphatation process could not give adequate colour removal, resulting in fine liquor colours of 600-1300 ICUMSA units being used for first boiling. In order to become competitive on both domestic and international markets, it became necessary for Nchalo to investigate other means of decolourisation. After considering all the technical and economic factors, the choice for the decolourisation process turned out to be the use of granular activated carbon. This was further supported by the fact that high (83%) levels of liquor decolourisation had been reported by a refinery using this technology (Mabillot, 1996). Pilot plant trials at Malelane had also confirmed the effectiveness of granular activated carbon in decolourising refinery liquors to produce low colour sugar (Moodley *et al.*, 1998).

Chemviron Carbon, through their agents - Vivendi Water (Chematron Division), who had been involved in similar work in Europe, were selected to carry out the project at Nchalo. This involved the outsourcing of an on-site electrically heated rotary kiln to effect the regeneration of carbon. The plant was installed during the 1999/2000 off-crop and was fully operational during the 2000/2001 crushing season. The type of activated carbon chosen was Cane Cal, which has high adsorption capacity for colour bodies and is bonded with magnesite to enhance its buffering capacity. A schematic diagram of the Nchalo refinery is given in Figure 1.

Table 1. Plant specifications.

Characteristic	Value
Flow rate	30 m^3/h
Contact time	3 h
Solid concentration	65^0 Brix
Temperature	70^0C
Inlet colour	800 ICUMSA units
Outlet colour	350 ICUMSA units

Description of the plant

This manually controlled GAC plant consists essentially of six lagged mild steel adsorption vessels, one spent carbon silo, a kiln, a quench tank, two cloth pre-filters and two cloth post-filters.

Running characteristics

The decolourising plant is preceded by a phosphatation clarification stage and filters, and was designed for the liquor characteristics shown in Table 1.

Decolourising unit

The station consists of six adsorbers each capable of holding 22 m^3 of activated carbon. Each column is equipped with a pressure gauge, a temperature indicator, a flow meter, a safety valve and sampling points. The adsorbers are installed in two lines of three adsorbers linked to each other with interconnecting pipe work. The pipe system for each adsorber is made in such a way that it can be connected to any other adsorber thereby making any adsorber configuration possible. There is also a common recirculation line equipped with a trace heating tape used for maintaining liquor temperatures during stop days (Figure 2.)

The liquor enters the system through the dome at the top of an adsorber and is uniformly dispersed throughout the bed of carbon. The liquor flows from the top to the bottom and leaves the adsorber through underdrains which have dimensions that allow the decolourised liquor to pass through but retain the particles of active carbon. The adsorbers are designed to receive reactivated carbon by fluidisation transfer from the quench tank. To guarantee the best possible performance, the vessels are coated with a glass lining. The purpose of the coating is to prevent the formation of iron-based colour bodies and contamination with rust.

The reactivation plant

The framework of the electrically fired kiln is fabricated from a number of rolled mild steel sections which are welded together to form a robust and stable structure. It has a retort tube manufactured from 321 stainless steel. The retort tube accommodates a heating zone, cooling zone, charge section, drive arrangement, support roller and a discharge hopper. The discharge hopper opens into a quench tank. This tank is manufactured from stainless steel and is simply there to quench the reactivated carbon and to facilitate fluidisation transfer of the carbon into the columns.

Description of the process

The plant utilises five columns at all times with three in parallel lead and two in parallel polishing modes. The sixth column is under regeneration or standby mode. When one of the adsorbers becomes saturated and the outlet colour reaches an unacceptable level, the oldest polishing adsorber replaces the oldest lead adsorber and the standby unit becomes the polishing column. This process is carried out manually by simply changing the valve configuration. The complete cycle for a column involves de-aeration, back-flushing, preheating, sweetening on, normal trailing mode, lead mode, sweetening off, carbon discharge, reactivation and carbon charging.

De-aeration

De-aeration is required to remove air from the carbon pores. This air would result in a high pressure drop through the bed of carbon' its incomplete utilisation and a premature colour breakthrough. This process is carried out by an up-flow of hot water (65^{0}C) during which air moves from the pores to the intergranular spaces.

Backflushing

Backflushing is required to remove carbon fines which can lead to excessive pressure drop and flow restrictions in the carbon bed. The rate of water is adjusted to create a fluidisation of the bed and enough turbulence to free fines without causing an overflow of the carbon.

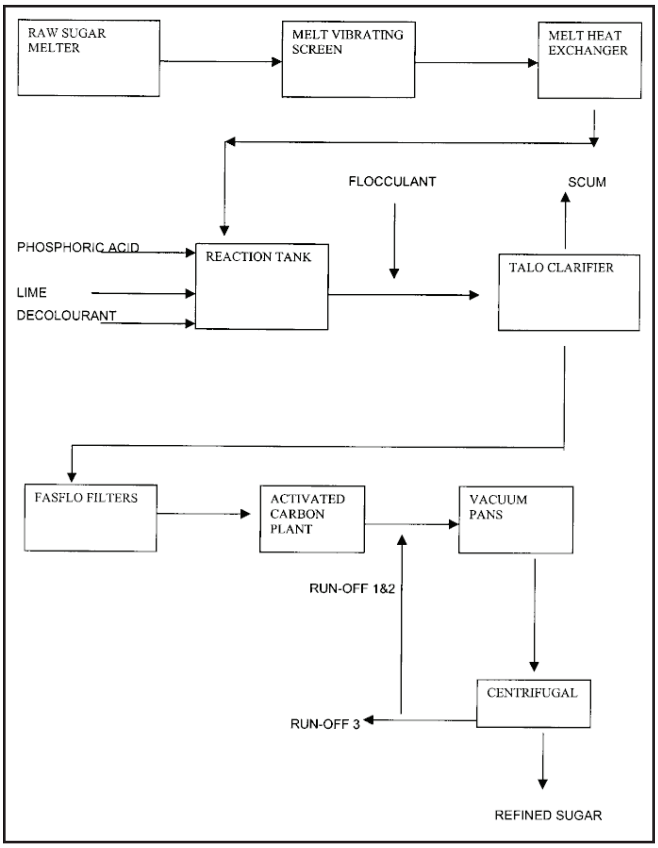

Figure 1. A simplified flow diagram of the Nchalo refinery.

Preheating

Preheating is required to ensure good liquor distribution through the carbon bed. This is done by an up-flow of hot water to attain a temperature greater than 60^{0}C.

Sweetening on

The preheated adsorber is then sweetened on with liquor from the lead adsorbers until the Brix reaches 40^0 when it is put back on circuit in the polishing mode. The oldest polishing column then becomes a lead and the oldest lead column is taken out of the circuit for sweetening off and regeneration.

Sweetening off

The objective of sweetening off is to avoid losing any liquor and to prepare the carbon for reactivation. This is achieved by pumping hot water down the column. The diluted liquor is then directed to the fine liquor tank until the Brix reaches 40^0, when it is directed to the melter.

Discharging of carbon

This is done by connecting a flexible hose from the outlet nozzle on the sweetened off adsorber to the inlet of the spent carbon tank. This adsorber is then pressurised to approximately 200 kPa, with condensate forcing out the carbon (as slurry) into the spent carbon tank.

Reactivation

The gate valve at the base of the spent carbon tank is opened to fill the dewatering screw and the feed screw hopper with spent carbon. The kiln is then switched on. The kiln settings as recommended by the suppliers are given in Table 2. Operator input during reactivation is only limited to maintaining carbon levels in the kiln screw feed hopper, such that the screw is fully loaded with carbon and that the hopper does not overflow.

Quench tank operation

The kiln starts discharging carbon into the quench tank approximately one hour after the kiln is started. The carbon is transferred back through an eductor and is routed back to the adsorber.

Table 2. Kiln settings.

Parameter	Setting
Carbon feed rate	105 kg/h
Kiln set temperature, zone 1	850^{0}C
Kiln set temperature, zone 2	850^{0}C
Kiln set temperature, zone 3	800^{0}C
Kiln retention time	30 min
Kiln preheating time	30 min (approximately)

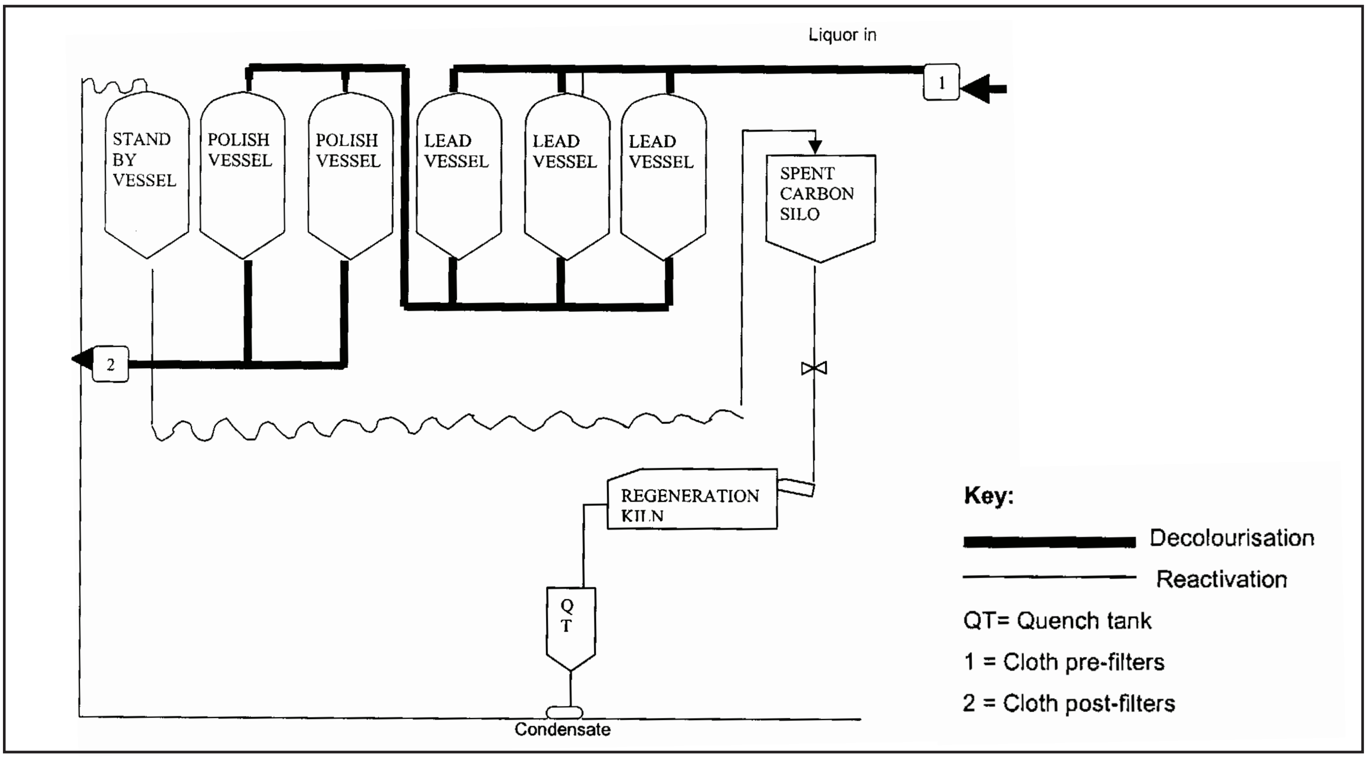

Figure 2. Schematic diagram of the granular activated carbon plant showing the decolourisation and reactivation operations.

Sampling and analyses

Hourly samples were taken from the feed, intermediate and product lines of the GAC plant each day. A daily composite sample for each product was then analysed for colour at 420 nm. In the case of carbon, one daily catch sample each of the spent and the reactivated carbon was taken for three days and composited. These were analysed for iodine number and ash according to the standard procedure.

Results and discussion

The GAC plant was run for 22 weeks under the conditions shown in Table 3. The colour results obtained during that period of operation are also shown in the same table. The reactivation kiln, operated under the settings described in Table 2 gave the results shown in Table 4. The results of the inlet and outlet liquor colours throughout the 22 weeks of operation are plotted in Figure 3.

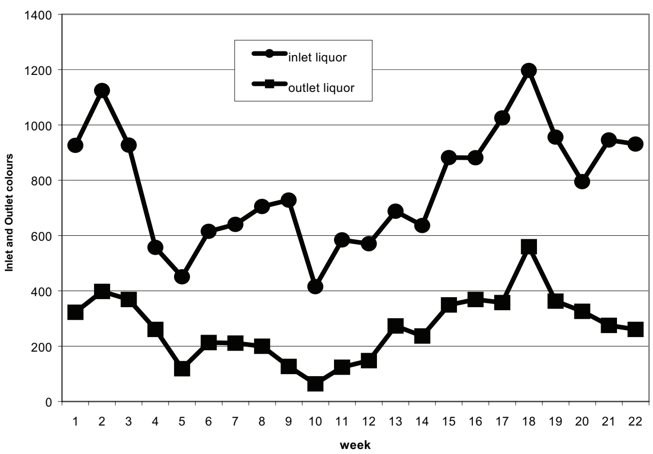

Figure 3. Inlet and outlet colours for the GAC plant.

The results (Table 3) show a marked (269 versus 800-1300) improvement on the decolourised liquor colour with respect to the previous years. It can also be appreciated from the table that 65% colour removal across the columns was achieved as compared to 60% as specified by the design. However, this value of percent colour removal could be misleading, as it does not take into account the brix loading across the station. The best method is to look at colour units removed per hour, which is based on the colour balance across the station. The station removed 11 889 colour units per hour (on average) which complies with the design specification. This value was maintained throughout the year, which seems to suggest that the carbon did not lose its colour removing capacity. Figure 3 shows an expected relationship between inlet liquor colour and the decolourised liquor colour. The colour of the decolourised liquor changes in step with the filtered liquor colour suggesting that the plant could be removing a constant amount of colour units.

Reactivation results in Table 4 imply that the carbon was not being fully exhausted. This was as a result of fouling of the carbon bed due to solid carry-over from the preceding filtration stations because of filter inefficiency. As a consequence, the carbon bed in the vessels became fouled and resulted in high differential pressures. This necessitated constant backwashing of the carbon to remove the solids or a premature reactivation of the carbon in some cases. This is also the reason for operating the plant at a lower Brix (58-63^0) than the normal 65^0 Brix. The results further show that the spent carbon was being slightly over-reactivated with respect to the set target (11% more than the target). This value is, however, not critical to the

Table 3. Actual operating conditions and results.

Parameter	Design	Operating
Flow rate (m^3/h)	30	25-35
Brix	65	58-63
Temperature of inlet liquor (^{0}C)	70	72-77
pH		6,8-7,4
Average inlet liquor colour (ICUMSA)	800	768
Average outlet liquor colour (ICUMSA)	350	269
% colour removal	60	65
Colour units removed per hour	11846	11889

Table 4. Reactivation results.

	Iodine number		Ash
Sample	Target	Actual	Actual
Spent carbon	500	632	12,2
Reactivated carbon	800	894	12,2

life of the carbon. Carbon make-up was 0,12kg of carbon per ton dry solids in melt, which is markedly lower than the targeted value of 3 kg per ton dry solids in melt.

Challenges met during operation of the plant

The greatest problem was the fouling of the carbon bed as a result of solid carry-over from the preceding filtration station as discussed in the preceding paragraphs. The installation of two Deep Bed Sand Filters as primary filters and repairing of the current filters to prevent suspended solid from bypassing will help improve the operations of the GAC plant in the coming season.

Conclusions

The installation of the GAC plant at Nchalo has greatly improved the colour of the fine liquor at Nchalo and indeed, the GAC plant has met its design specifications.

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