

CHEMICAL CLEANING OF EVAPORATORS

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Abstract

Chemical cleaning of evaporators is not common in South Africa, mainly because mechanical cleaning is considered less expensive. There are advantages, however, and chemical cleaning is essential where certain new evaporator designs are used. Investigations into chemical cleaning at laboratory, pilot plant and factory scale were undertaken, and showed that the use of a surfactant can enhance the effects of sodium hydroxide and could make chemical cleaning more cost effective. General problems arising from chemical cleaning are discussed.

Keywords: evaporators, chemical cleaning

Introduction

The need for regular and efficient cleaning of the evaporator station has been an ongoing problem in the sugar industry. Previous studies have considered local scale composition (Walthew and Turner, 1995) and some methods of reducing scale formation (Walthew and Whitelaw, 1996). However, some cleaning will always be required and, in southern Africa, the most common method remains mechanical cleaning; a choice usually justified on the basis of cost. Mechanical cleaning costs about 10 cents per ton of cane compared with chemical cleaning costs of about 30c per ton of cane, due to the high price of sodium hydroxide. Nevertheless, there are several factors in favour of chemical cleaning systems:

- Evaporators are cleaned more efficiently with chemicals, leading to higher performance and throughput (Whitelaw, 1988).
- Chemical cleaning is less labour intensive.
- It can be automated, and/or carried out without stopping the factory.
- It is the only option for certain very large evaporator stations, and those using plate or falling film units where the heating surface is not accessible.
- The main disadvantages of chemical cleaning are:
- The need for added equipment - tanks, valves and control systems where required.
- Potential problems of effluent treatment and corrosion.
- Safety considerations.

This study is intended to examine chemical cleaning, with the aim of improving efficiency while reducing costs.

Theoretical considerations

The composition of southern African evaporator scale has been reviewed previously (Walthew and Turner, 1995) and is summarised in Table 1. The components are formed in layers in which one particular component predominates, and the rate of cleaning can be retarded by layers of oxalate which are not susceptible to sodium hydroxide. A comparison of the costs of chemicals is given in Table 2. The relative cost of chemicals which attack the calcium salts in scale are calculated in terms of the cost of a gram of H⁺, since this is a reasonable measure of the ability of the chemical to solubilise calcium compounds in scale (two H⁺ ions equivalent to the removal of one Ca⁺⁺ ion).

Examinations of chemical cleaning methods showed that most cane sugar evaporators outside South Africa are cleaned by means of an alkali boil followed by an acid wash (Walthew, 1994; Jullienne, 1985). Generally low strength alkali in the form of sodium hydroxide and/or carbonate, usually with the addition of a wetting agent, are used followed by one of a wide range of acids, including hydrochloric, phosphoric, sulphamic, formic, citric and sulphuric. Current practice for southern African mills using chemical cleaning is summarised in Table 3.

In comparison with practices in cane sugar mills around the world, the southern African industry generally uses a higher strength pure sodium hydroxide solution (>20%) (Whitelaw, 1988; Getaz, 1985; Jullienne, 1985). The use of high strength sodium hydroxide, while effective, has a number of drawbacks:

- The cost of NaOH is the greatest contributor to the cost of cleaning.
- The solubility of Na₂CO₃ decreases with increasing NaOH concentration (Figure 1) and therefore sodium carbonate cannot be used at high concentrations. With use and exposure to the atmosphere, some of the sodium hydroxide is converted to carbonate which then crystallises. In addition, the organic material dissolved tends to form a 'jelly' at high concentrations as the solution cools after cleaning. The cleaning solution then becomes difficult to pump, spray or separate from accumulated solids. Consequently cleaning solutions which still contain a large amount of potentially usable sodium hydroxide are discarded. This is illustrated in Table 4, which gives a typical composition of waste sodium hydroxide from Felixton (FX) mill.
- The high sodium hydroxide strength makes it difficult to follow the alkali clean with acid cleaning, since a large

Table 1
Main components of scale and chemical agents that can be used to attack scale.

Compound found in scale	Composition	Characteristics	Susceptibility
Amorphous organic (AO)		Typically found in first effects, both scales are soft and porous. ACP contains a large amount of organic material which is trapped during precipitation.	Readily attacked by strong caustic agents. ACP and AO form the matrix which binds the scale together, and destruction of this matrix breaks up the scale.
Amorphous calcium phosphate (ACP)	Assumed composition of $Ca_{1.5}(PO_4)_2 \cdot 2H_2O$		
Silica	$SiO_2 \cdot xH_2O$ where $x = 0,5 - 3$	Increasingly found in later effects. Most problematic scale at certain installations. Physical range is from soft and powdery to hard and glassy.	Attacked by strong caustic alkali at a slower rate than ACP and AO. Not attacked by acids (except HF, which is NOT RECOMMENDED).
Hydroxyl apatite (HAP)	$Ca_{10}(OH)_2(PO_4)_6$	Formed from dehydration of ACP. Takes about three weeks to form.	Only slowly attacked by alkali. NaOH and carbonate will convert the calcium salts to carbonates which are then easily removed by acid cleaning. Soluble in acids and EDTA.
Calcium oxalate mono- and di-hydrate	$Ca C_2O_4 \cdot H_2O$ $Ca C_2O_4 \cdot 2H_2O$	Hard scale found in later effects.	
Lime	$Ca(OH)_2$	Found in varying amounts.	
Other calcium salts, such as aconitate		Found only occasionally.	

Table 2
Some chemical cleaning agents available.

Chemical	Availability and price	Corrosion problems	Disposal problems	Relative cost (cents/g H ⁺)
Sodium hydroxide	50% lye solution : R2 000/ton Transport costs can be considerable	Mild steel is generally suitable. Stress corrosion is possible in certain concentration and temperature ranges. Will attack aluminium, zinc and brass.	Yes	
Sodium carbonate	25 kg to 1 ton bags : R300/ton	Mild steel suitable.	Yes	
Sulfamic acid (NH ₂ SO ₂ -OH)	25 kg bags : R5,05/kg	Needs inhibitor, otherwise attacks all metals.	Yes	49 cents/g
Phosphoric acid (H ₃ PO ₄)	80% solution in polycans (25 L) or 1 ton quantity : R4,00/kg	Needs inhibitor, but less corrosive than sulfamic acid.	No	16 cents/g
Formic acid (HCOOH)		Needs inhibitor.	Yes	32 cents/g
EDTA tetrasodium salt [(CH ₂ N(CH ₂ COONa) ₂] ₂ ·2H ₂ O	25 kg bags : R14,00/kg	Slow attack on Cu alloys.	Minimal	290 cents/g
Commercial cleaner based on EDTA tetrasodium salt	Solution capable of dissolving 90 g of Ca/kg : R10,00/kg	No information provided.	Minimal	222 cents/g

Table 3
Current chemical cleaning practices at southern African mills.

Mill	Chemical	Strength	Application method	Chemical contact time (h)	Frequency: interval between cleans	Post-chemical procedure	Note
Malelane	NaOH	3%	Boil	2	2 weeks	Mechanical cleaning.	Good results. Degree of scale not as severe as KwaZulu-Natal mills.
Komatipoort	NaOH	22%	Spray	6-7	2 weeks	Flush, inspect.	
Pongola	NaOH	Max 10%	Circulate at 70-80°C	4-20	2-3 weeks	Flush, inspect. Mechanical cleaning.	Results vary. Some difficulty experienced in cleaning falling film evaporator.
Umfoloji	NaOH	20-30%	Spray 95-100°C	4	2 weeks	Flush, inspect. Mechanical brushing of 4th and 5th effect vessels to remove loose scale only. Cutters not used.	Results good if caustic strength maintained above 20% on vessels 1,2,3; effects 4 and 5 need mechanical brushing.
Felixton	NaOH	30-32%	Spray 85-105°C	3,5-4	Each Robert evaporator is cleaned every 2 weeks. Kestners cleaned every week.	Flush, boil water when possible.	Very good results. Vessels 3,4,5 are cleaned mechanically every 2 weeks, between chemical cleaning.
Glendale	NaOH	20%	Circulate	4-6	As required; normally 2 week intervals.	Flush.	Only the Alfa Laval plate evaporator is chemically cleaned. Acceptable results.

amount of acid is consumed by the residual alkali solution which is difficult to flush completely.

- Boiling cannot be used to improve the agitation due to the high boiling point elevation (BPE) at higher concentrations, as shown in Figure 2.
- Discarded sodium hydroxide becomes more problematic from an environmental point of view since the total sodium content is higher.

Table 4
Typical waste caustic analysis.

Species	% (m/m)
NaOH	26,9
NaCO ₃	3,6
SiO ₂	2,4
PO ₄	0,5
CaO	0,3
K ₂ O, Fe ₂ O ₃ , MgO	<0,1
Water/organic	66
Total	100

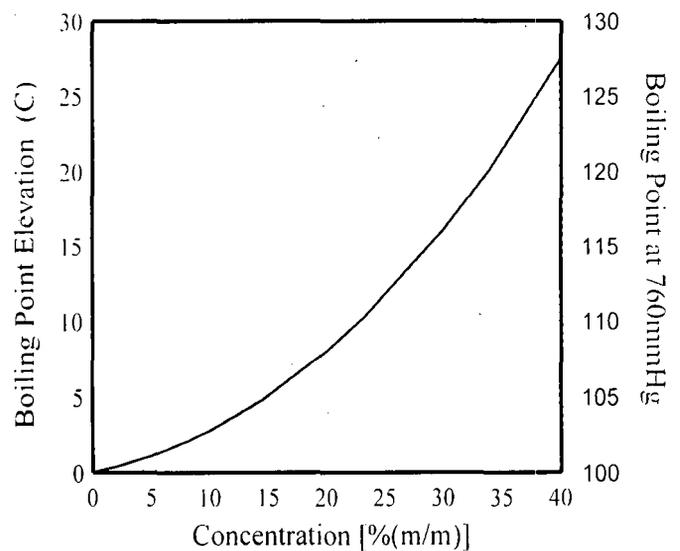


Figure 2. Boiling point elevation, and boiling point at one atmosphere of sodium hydroxide solutions at varying concentrations.

Experimental

Laboratory work

Initial tests involved samples of scale being examined visually in terms of their susceptibility to various agents tested as well as changes in the scale composition before and after leaching using analytical techniques described elsewhere (Walthew and Turner, 1995). While these tests were partly subjective, they indicated the following:

- Sodium hydroxide was more successful than acid at fragmenting all types of scale.
- Sodium hydroxide followed by acid is more effective than either agent on its own. Acid followed by sodium hydroxide does not appear as effective.
- The mechanism by which sodium hydroxide breaks up the scale seems to be through penetrating and swelling the scale, which then becomes fragile and breaks up when boiled.
- Amorphous organic material is more rapidly attacked than silica.

Quantitative batch tests on scale samples were carried out by mixing a known quantity of scale with a sodium hydroxide solution under controlled conditions of temperature and stirring rate. The rate at which the sodium hydroxide concentration changed then gave a reaction rate for a particular concentration and temperature. Using an initial rate method (Levenspiel, 1962) the reaction was found to be first order with respect to the sodium hydroxide concentration. The effect of temperature on the reaction rate was small, suggesting that the rate limiting step was a diffusion step (Levenspiel, 1962). The data obtained were used to develop the rate equation below:

$$R = [7,96 \times 10^{-2}] \times \exp(-977/T) \times [\text{concentration in mol/L}]$$

where R is a measure of the rate at which sodium hydroxide is destroyed (in moles per litre per minute) and T is the temperature

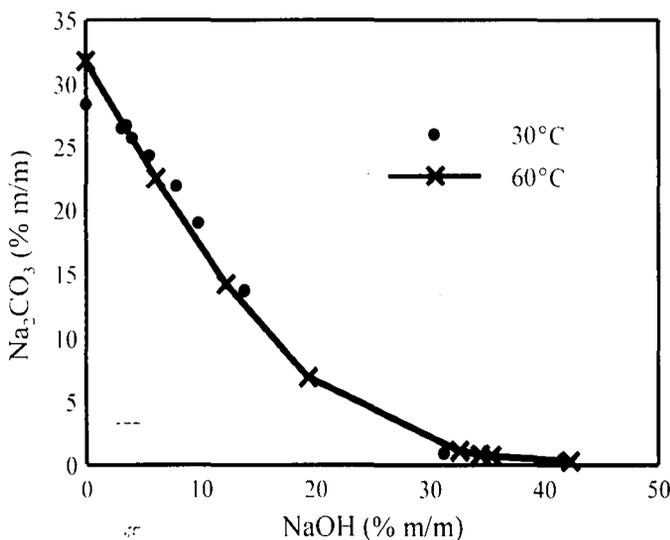


Figure 1. Solubility of sodium carbonate in a sodium hydroxide solution.

Although acid is rarely used by local mills it will dissolve calcium salts which are not removed but may have been more exposed by the sodium hydroxide clean (Walthew, 1994; Jullienne, 1985). Acid inhibitors are used to prevent corrosion. These coat the metal surface preventing attack and in the process are consumed and must be monitored and replenished if necessary. Acid cleaning is generally not carried out with boiling because of the increased risk of corrosion.

in °K. The reaction rate as a function of concentration and temperature, using the above equation, is presented in Figure 3. This indicates that the effect of increasing concentration is greater than that of temperature and shows that the sodium hydroxide cleaning should be carried out at as high a temperature as possible, with as strong a sodium hydroxide strength as possible. These results are of a relative nature only (the effect of surface area is not included) since the rate of reaction may not be directly related to factory conditions where the effectiveness of the cleaning is dependent on the ability of the cleaning chemical to remove scale from the tube wall. It is likely that the rate of reaction for factory evaporator cleaning will be diffusion rate limited, as in the batch tests, although the value for the temperature dependent term may not be the same. Surprisingly, the effect of scale composition on the rate of reaction was not found to be significant.

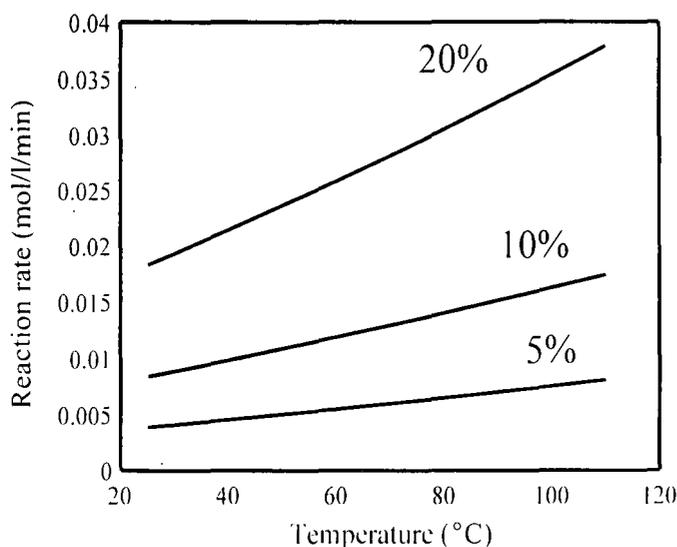


Figure 3. Rate of disappearance of sodium hydroxide when reacted with evaporator scale predicted from laboratory batch tests.

Further tests involved short pieces of fouled evaporator tube removed from the fourth effect evaporator at FX and leached under varied conditions using various solvents. These tests showed that the current practice at FX of using 30% (m/m) sodium hydroxide was the most effective at removing the scale from the tube, under the conditions tested, compared with a 5% phosphoric acid solution at 40°C, which in turn was better than 10% sodium hydroxide plus a 10% carbonate mixture. However, the tests also suggested that the four hour cleaning time used at FX may not be sufficient for all scale to be effectively removed.

Pilot plant tests

To carry out larger scale tests directly applicable to the factory, the pilot plant at FX was used. This unit has been described previously (Walthew and Turner, 1995) and consists of three, 7 m evaporator tubes that can be run under controlled conditions, with performance being measured through calculation of the heat transfer coefficient (HTC). (The calculation is given in

Appendix A of Walthew *et al.*, 1997). By monitoring the rate at which the HTC was restored, the rate of cleaning could be measured. In each case the procedure was:

- The pilot plant was fouled up by operating the plant as a second effect, using first effect juice as feed and, raising the brix from 17 to about 40°. To check that the evaporator was fouled to the same degree in each case, the fouling resistance (an indication of the quantity of scale formed) was calculated from the change in the HTC value (Walthew and Whitelaw, 1996).
- Water was boiled to flush the system and establish a 'baseline' for further tests.
- The cleaning solution was pumped through the evaporator under similar operating conditions in each trial (DT, feed rate and feed temperature). The concentrated product and recondensed vapour were recombined in the feed tank, and in this way there was no change in concentration due to evaporation. The quantity of cleaning chemical (200 L) was large in comparison to the surface to be cleaned (7,2 m²) and there was thus little change in sodium hydroxide concentration due to 'consumption' of the sodium hydroxide by the scale.
- After cleaning with sodium hydroxide, water was boiled in the evaporator for comparison with the baseline test.
- When acid or other tests were required which could not be carried out while monitoring the HTC, these were followed by a repeat of the baseline test to measure any improvement.

For all tests it is important to recognise that, as a result of time constraints, the pilot evaporator was not as heavily fouled as factory evaporators. The degree of fouling on the pilot plant was about a quarter to a half of that found on the main plant. Consequently, the time required to clean the pilot evaporator is proportionally less than would be expected in a factory.

Several runs were carried out to examine the effect of concentration and wetting agents (WA) on the rate of cleaning. Wetting agents are surface active agents designed to improve the contact between the scale and the sodium hydroxide. Results of these tests (Figure 4) show that the use of a 6% (m/m) sodium hydroxide solution with a wetting agent (0,2% of total solution (m/m)) gave a cleaning rate equivalent to that of a 24% sodium hydroxide solution. The use of a wetting agent therefore presents an opportunity for cost saving since the additive is significantly cheaper than the increased quantity of sodium hydroxide.

The shape of the curves suggests that, for boiling, most of the cleaning takes place during the first three hours and, although not clean at that stage, a further three hours of boiling was required to clean the evaporator completely. The fact that at least three hours were required to remove most of the scale from the tubes, in a situation where the severity of fouling was probably about a quarter to one half that of main plant later effect evaporators, supports the earlier observation that the time allowed for chemical cleaning in the factory may not be

sufficient. Increasing the cleaning time will require a major investment in capital to enable 'online' cleaning, although de Viana and Wright (1996) have shown that it is justified in terms of reduced downtime. Similar calculations for South African mills would be of value. Another approach is to clean more frequently for shorter periods of time, giving a higher overall HTC due to the evaporators being cleaner. This would only be suited to factories with online cleaning systems, since the cost of total shut down time for more frequent cleaning is prohibitively high (Walthew, 1994).

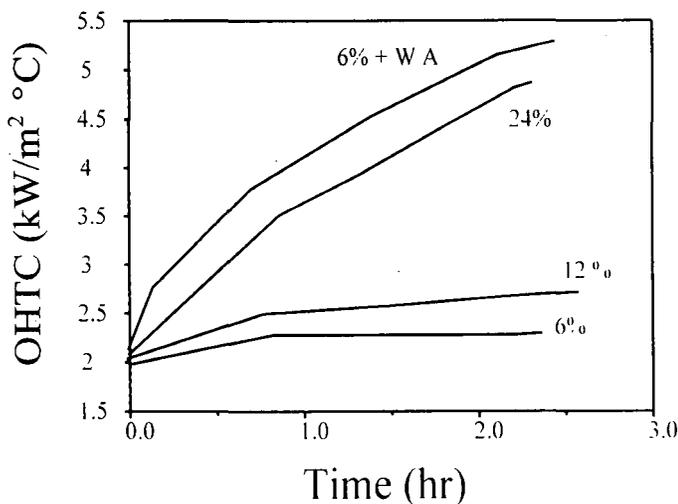


Figure 4. Pilot plant tests showing the effects of concentration and wetting agent (WA) on the rate of evaporator cleaning.

The technique of 'bursting' was also tested. This involves filling the tube with liquid and raising the steam side pressure while preventing boiling by allowing the vapour side pressure to rise. During this operation the liquid penetrates the scale. The vapour side pressure is then suddenly released and the rapid conversion of water to vapour in the body of the scale 'bursts' the scale. Tests under various conditions were done using normal sugar juice (i.e. periodic stopping and bursting to move scale on the run), sodium hydroxide solution at low strength (to improve performance) and juice. While in every case an improvement in the HTC was found, the greatest effect was from using sodium hydroxide. The effect of bursting during sodium hydroxide cleaning was nevertheless less than that achieved by the addition of the wetting agent.

To test the effect of spraying versus boiling the plant was configured as a falling film with a spray nozzle acting as a distributor. The operating conditions were as for operation as a rising film and the HTC values are comparable. Figure 5 summarises the results of tests with and without wetting agent compared to boiling with a 6% solution containing wetting agent. The graph suggests that the mechanism of removal in the case of spraying is different from that for boiling and, in the former, an induction time is required for the scale to be 'wet' before it begins to detach from the tube. Of some concern was the observation that where no wetting agent was used little scale was removed (i.e. the HTC was not appreciably improved) until

water was boiled in the evaporator. These results indicate that spraying can be as effective as boiling given sufficient time, provided the spraying is followed by boiling. In factory practice the amount of 'induction' time required before boiling is not known with certainty.

Since all evaporators are eventually boiled the scale should ultimately be removed but, where juice is the liquid boiled, most scale will be removed during the first juice boiling. This could present a potential problem with blockages of feed rings or distributors. An aspect of spraying not considered in detail thus far is that of wetting rate. A major drawback to spraying is the problem of adequate wetting of the scale, and this is difficult to assess on the pilot plant. Generally a value of between 0.5 and 1.0 L/min/tube (regardless of length or diameter) is used, but this is an average figure and does not take into account 'dry spots' which can arise. To ensure adequate surface wetting, boiling is preferable to spraying although this often requires much greater volumes of liquid.

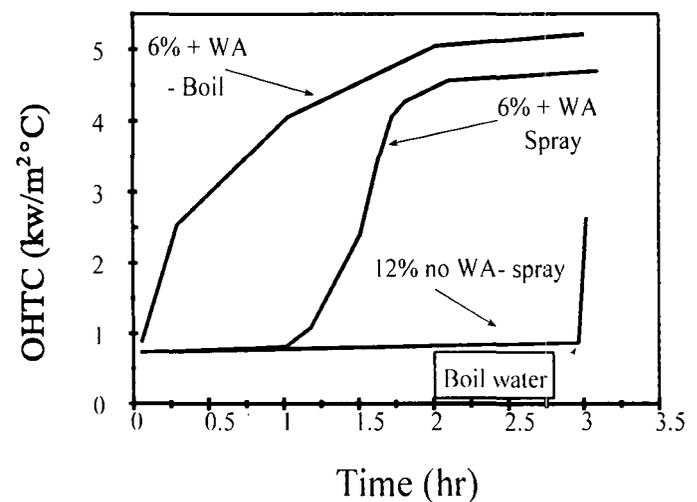


Figure 5. The effect of spraying versus boiling on evaporator cleaning rates.

The use of phosphoric acid was also tested and it was found that the phosphoric acid was efficient at breaking the scale into smaller flakes which were easier to dislodge and flush. The total time of the clean could also be reduced, although at additional expense in terms of chemicals and effort, by the use of acid. A three hour sodium hydroxide boil followed by a one hour 6% phosphoric acid wash at 50°C resulted in a completely clean evaporator. To achieve the same result with sodium hydroxide alone involved a five to six hour sodium hydroxide boil followed by a one hour water boil.

Factory measurements and tests

Minimum sodium hydroxide requirement

Based on the results from the pilot plant it is clear that it would be useful to establish the amount of sodium hydroxide actually required to clean an evaporator since mills generally use a vast

excess, most of which is discarded for reasons outlined above. Measurements of the change in sodium hydroxide concentrations taken at FX, Komatipoort (KM) and Umfolozi (UF) provide useful information in this regard, since the total amount of sodium hydroxide consumed can then be calculated and related to the surface area. It should be recognised that the calculation is by its nature inexact, but does provide a practical guide to sodium hydroxide consumption. Data from UF is of particular interest since individual evaporators were cleaned on each stop day (personal communication) allowing the information to be related more closely to a particular effect. The results (Figure 6) show that the amount of sodium hydroxide consumed during cleaning of the later effects is significantly greater than that used to clean early effects. This is not surprising since fouling is heavier in the later than the earlier effects. During 1996, FX experienced a reduction in the severity of scaling and this is reflected in Figure 6. The relatively low sodium hydroxide consumption of KM can also be explained as a result of lower rates of fouling. Although subject to error as a result of dilution effects, these figures provide a basis for determining the minimum amount of sodium hydroxide that could be used to clean an evaporator, although there will continue to be some losses. Wetting agents will improve the rate of cleaning at lower chemical strength, but not the amount of sodium hydroxide required to clean a given surface area. Although specific cost savings to mills currently using chemical cleaning need to be worked out on an individual basis, preliminary calculations indicate that the cost of chemical cleaning could be reduced substantially. A sample calculation is given in Appendix A.

Case studies

Plate evaporators have been installed at Ubombo Ranches (UR) for the past season and, since these cannot be cleaned mechanically, a chemical cleaning system was established. A process of experimentation revealed that a suitable procedure was to boil a 10% sodium hydroxide solution with a WA (Arkem, Astrowet 608) for six hours, followed by circulation of a hot (80°C, using residual evaporator heat) phosphoric acid solution for two hours. HTC measurements showed that the acid cleaning was essential in restoring the previous HTC values. This procedure was used for most of the season and during the off-crop the plates were opened. Inspection of the plates showed that, where the chemicals had contacted the plate surface, the cleaning was good. Unfortunately the design of the plate is such that certain areas develop particularly heavy scale which cannot be reached by flooding, and these areas were not effectively cleaned. This is a fault with the design of the plates rather than with the cleaning system. The cleaning results are therefore considered encouraging. The need to use acid cleaning after sodium hydroxide cleaning on plate evaporators is supported by work carried out on the Gledhow (GH) pilot evaporator, which is reported separately (Walthew *et al.*, 1997).

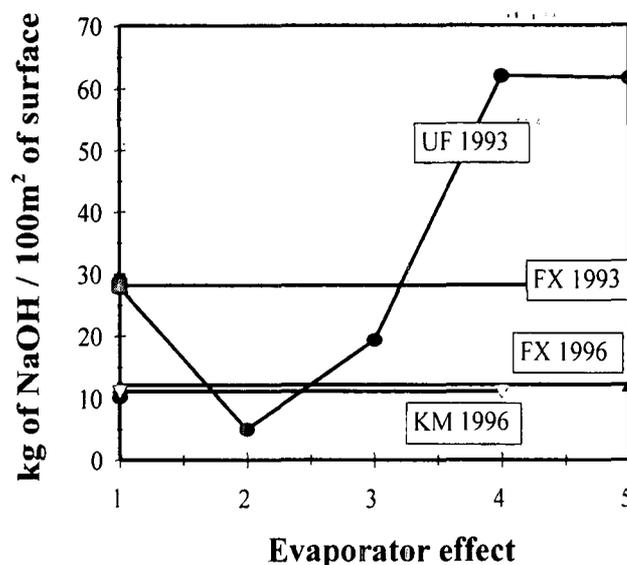


Figure 6. NaOH consumption during evaporator cleaning at various mills. The variation with effect is shown for Umfolozi mill.

Wetting agent (Busperse 47, Buckman Laboratories) was also used at a Mauritian mill using sodium hydroxide at a strength of 10% for 4-6 hours followed by water boiling for two hours. Some soft scale was removed mechanically from selected tubes after each cleaning. The performance of the evaporator station was improved in comparison with that when the vessels were cleaned mechanically. Measurements of the sodium hydroxide strength reduction in relation to the surface area cleaned gave a consumption figure of 21 kg/100 m², which supports the assumption that the actual sodium hydroxide consumption will be similar to that when no wetting agent is used. The low strength sodium hydroxide liquid could be easily separated from the waste sludge, with minimal loss of sodium hydroxide.

Malelane (ML) mill normally boils with 3% sodium hydroxide for two hours prior to mechanical cleaning. Towards the end of the 1996 season two chemical cleanings were done with no mechanical cleaning. A 3% sodium hydroxide solution containing WA (Astrowet 608) was used with positive results. At off-crop the evaporators were inspected and no heavy scale build-up was found. During the period of normal operation following chemical cleaning the evaporator performance was reported to be very good, indicating the effectiveness of the cleaning operation. Although ML generally experiences less severe scale than the KwaZulu-Natal mills, the results from these tests are most encouraging.

Effluent considerations

The use of sodium hydroxide cleaning will become more common as evaporators that cannot be cleaned mechanically are introduced. Current legislation limits the amount of sodium salts that can be discharged into rivers, and mills will have to consider methods of dealing with the effluent generated as part of the chemical cleaning installation. A detailed investigation

¹J Sithole, CG Smith Sugar Ltd Internal Report, 1993

on this aspect has been reported elsewhere (Walthew 1995). Essentially the options for effluent disposal will be strongly influenced by the concentration and volume of the sodium hydroxide waste stream, and solutions at one factory may not be suitable to all mills. If acid cleaning is used phosphoric acid appears to be the easiest to dispose of since the phosphate can be mixed with lime and used as a fertiliser.

Conclusions

The main findings of this investigation can be summarised as follows :

- Strong sodium hydroxide solution, at as high a temperature as possible is required to clean the evaporators effectively. There are, however, a number of serious drawbacks to operating at higher strengths, including substantial cost penalties.
- The use of a wetting agent enables a sodium hydroxide solution of 5-10% to be used as effectively as the high strength sodium hydroxide at >20% currently used. The minimum amount of sodium hydroxide required to clean an evaporator is between 10 and 30 kg/100 m² of surface area. Decreasing the sodium hydroxide concentration while maintaining sufficient chemical for cleaning should result in substantial cost savings.
- Limited factory trials have confirmed the positive results from the pilot plant.
- Where sodium hydroxide solutions are sprayed onto the tubes it is advisable to boil water to dislodge the scale. With spray systems there is a risk of inadequate coverage and boiling is preferable to spraying, where the opportunity exists, since wetting of the fouled surface is ensured.
- Acid cleaning using phosphoric acid is effective in breaking up larger flakes and is essential in the effective cleaning of plate evaporators. Acid cleaning after a shortened period of sodium hydroxide cleaning may offer a reduced cleaning time.
- The current typical contact period of about four hours for cleaning may be insufficient. Increasing the cleaning time will require substantial capital investment that could be justified on the basis of reduced down time (de Viana and Wright, 1996).

The results of using lower strength sodium hydroxide with wetting agent have thus far been encouraging. Further factory trials over an entire season will nevertheless need to be performed. The results obtained have contributed to the achievement of the initial aim of reducing costs and improving the efficiency of cleaning.

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APPENDIX A

Calculation of the potential saving for Felixton mill if wetting agent is used and sodium hydroxide consumption is based on minimum estimates.

Current situation

Surface area cleaned per month	101 720 m
NaOH price for 50% lye	R1 800/ton
Cleaning consumption	400 tons 50% lye/month
Current cleaning cost	<u>R72 000/month</u>

Calculation of minimum amount

Assume NaOH consumption of	12 kg NaOH/100 m ²
Minimum consumption of NaOH is	12,2 tons NaOH/month
equal to	24,4 tons of 50% lye/month
New NaOH cost	<u>R43 943/month</u>

Add cost of wetting agent

added at	0,2% of total solution (assume two 60 m ³ tanks/month treated)
equal to	240 kg WA/month
at R9/kg, total cost of WA is	<u>R 2 160</u>
New cleaning cost	<u>R46 103/month</u>

Overall savings: R25 897/month or 36%

Typical cleaning solution will then be 6 tons of NaOH plus 0,2% wetting agent per weekly clean in a 60 m³ tank, giving an initial NaOH solution of 10%, falling to a 5% concentration at the end of the cleaning session, if the consumption figure above is used. The following week the solution will be brought back to 10% by adding 3 tons of NaOH.