SOIL IN CANE: ITS MEASUREMENT, ITS EFFECT ON MILLING, AND METHODS OF REMOVAL

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Abstract

The significant quantity of soil in the cane being delivered to sugar mills is a constant source of excessive wear and reduction in performance of the recovery process. This problem is considered from the point of view of the miller and of the industry as a whole. The various effects of the soil on the machinery and process equipment of the sugar mill are listed and discussed. An estimate of the total cost of these effects is given. Methods of removing soil from cane, such as wet and dry cleaning plants, are examined for South African conditions. A commercially available nuclear device has been evaluated for its ability to measure soil in shredded cane on a conveyor belt and in the laboratory, with very promising results. Some recent work on the determination of the levels of ash in clean cane is discussed.

Keywords: cane cleaning, soil in cane, ash content

Introduction

Total soil in cane delivered to South African sugar factories in the 1996-97 season was approximately 250 000 tons. Although rainfall during this season was above the long term mean, it can be considered typical. The transport required to deliver the soil to the factories was equivalent to 12 500 twenty-ton truckloads. All this soil ended up in the bagasse and the mixed juice and had to be discarded in the form of boiler smuts and filtercake which required another 12 500 twenty-ton truckloads.

In the factory, soil has a detrimental effect on processes such as cane preparation, diffusion, milling, clarification, filtration and steam generation. Soil is a direct cause of severe wear on cane knives, shredder hammers, diffuser screens, mill rolls, trash plates, scrapers, conveyor chains, conveyor slats, conveyor troughs, chute liners, juice screens, pump impellers, juice piping, clarifier scrapers, mud filter components, bagasse feeders, boiler tubes, boiler grates, boiler fans, ash disposal equipment and various parts of by-product plants.

This paper discusses the effect of soil in cane on factory performance and component wear. An estimate is made of the cost to the miller of replacement, maintenance and refurbishment of various milling components, the loss of sucrose in bagasse and filtercake, the loss of time efficiency and the loss of equipment capacity due to soil.

Source of the soil

For the 1996-97 season the industrial average for soil in cane was about 1,19% (after a 0,55% adjustment for soluble ash). Over the years this figure has increased (Figure 1), mainly as the result of a change in harvesting procedures favouring 'push-piling'. On a monthly basis much higher levels were found during the rainy season, peaking at 2,11% in January 1997. The season average for different factories varied between 0,53% for Amatikulu (AK) and 2,22% for Eston (ES). On individual consignments soil levels as high as 20% have on occasion been measured.

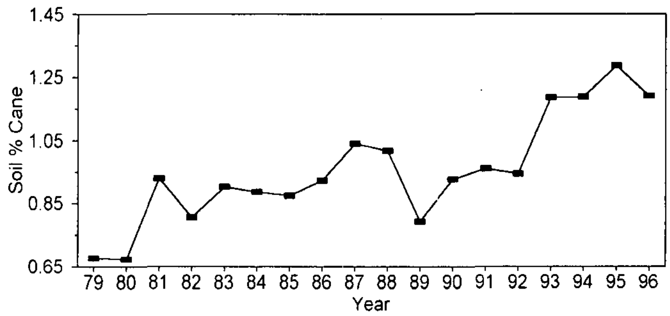

Figure 1. Percentage soil in cane, 1979 to 1996.

The soil arrives at the factory with the cane in two distinct forms. The first is fine sand or silt adhering to the cane stalk. This is more severe after rain or flooding, is affected by soil type and is almost impossible to avoid. Cane from the Umfolozi flats typically suffers from this form of soil. The second form is loose soil that is delivered with the cane and is to some extent avoidable. It is affected mainly by harvesting practices and the way they are performed. At a colloquium at the Sugar Milling Research Institute (SMRI) (Pillay, 1988), Thomson quoted the effects of different infield loading methods which, after adjustment for 0,55% soluble ash, are given in Table 1.

The present harvesting practices in South Africa have evolved over many years, and are now considered to be the optimum for the current local circumstances. Most cutting is carried out manually, after which the cane is usually laid on the ground in windrows where the tops are removed. From there the cane is picked up and deposited in the infield trailer. This operation is usually carried out by a mobile hydraulic grab that drives along the row to pile the cane into a bundle (push-piling). Some of the cane is subsequently transloaded from field trailers into road vehicles at loading zones. These methods tend to entrain soil with the cane, particularly during wet weather. Union Co-op (UC) and AK are good examples of mills that have been successful in reducing the soil in cane by suitable care in execution of, and modification to, the harvesting process. At UC the present loading system, which starts with topping while standing, careful laying down of the cane in piles and using a Bell loader, is achieving about 0,67% soil in cane. At AK similar precautions, instigated by a cane quality bonus scheme and close interaction with the farming community, resulted in an all time low of approximately 0,53% soil in cane.

Table 1
Effect of loading on soil % cane.

Loading system	Soil % cane
Hand	0,8
Bell	1,2
Buck	1,4
Front end	1,5
Slewing	1,6

Soil measurement

Most South African sugar factories measure ash in cane. A subsample of the cane from the Cane Testing Service hatch sampling system is incinerated in an oven. This evaporates all the water, burns off all combustible material and leaves the total ash. This total ash consists of soluble ash (which is mainly inorganic salts) and insoluble ash (which is mostly soil). At present no direct measurement of soil in cane is made. The total ash in bagasse is measured for the purpose of calculating the nett calorific value (NCV) of bagasse.

In mixed juice the soluble ash is measured on a routine basis to determine the reducing sugars to soluble ash ratio. The total ash in cane, the total ash in bagasse and the soluble ash in mixed juice together make it possible to calculate ash mass balances around the extraction process, when it is assumed that the extraction of soluble ash is equal to the brix extraction. When this calculation was applied to various factories some unrealistic values were obtained. The reason for this must be inaccurate ash analysis and the small quantities of ash involved. Because of the filter action of the diffuser bed these mass balances are different for diffusers and milling tandems. Table 2 shows these balances for the 1996-97 season for Malelane (ML), a typical South African diffuser factory. The brix extraction for that season was 96,66%. From the table it can be seen that most (97,41%) of the insoluble ash or soil ends up in the bagasse and very little (2,59%) in the mixed juice.

For Darnall (DL), one of the few remaining factories in South Africa with a milling tandem, these mass balances are given in Table 3, based on a brix extraction of 95,36%. The soil in cane is split almost equally between the bagasse (51,45%) and mixed juice (48,55%) which confirms the assumption made by Smits and Blunt (1976).

Table 2
Malelane ash mass balance in tons per hour (percentage).

	Total ash	Soluble ash	Insoluble ash
Cane	5,84 (1,89)	1,78 (0,57)	4,07 (1,32)
Mixed juice	1,82 (0,47)	1,72 (0,44)	0,11 (0,03)
Bagasse	4,02 (4,02)	0,06 (0,06)	3,96 (3,96)

Table 3
Darnall ash mass balance in tons per hour (percentage).

	Total ash	Soluble ash	Insoluble ash
Cane	5,45 (1,84)	1,51 (0,51)	3,94 (1,33)
Mixed juice	3,47 (0,99)	1,44 (0,41)	2,03 (0,58)
Bagasse	1,98 (2,12)	0,07 (0,08)	1,91 (2,06)

The soluble ash calculated in this way agrees well with recent tests by Lionnet (1997) on the soluble ash levels of the various components of the cane plant (Table 4).

Table 4
Average soluble ash % cane.

Cane constituents	Soluble ash % cane
Clean stalk	0,5
Tops	1,8
Green trash	4,3
Dry trash	6,3

More direct and/or easy on-line measurements of soil in cane are presently being investigated. The SMRI, in co-operation with the Atomic Energy Corporation (AEC), are testing a nuclear device (Kangela) which is presently being used in the coal industry to measure ash in coal. Cane stalks were thoroughly cleaned, after which it was assumed that they were free of soil. They were subsequently shredded and spiked with typical sugarcane growing soil at levels of 0, 2, 4, 6, 8 and 10%. Early results of these tests are promising. Initial soil measurements by the Kangela showed a correlation between instrument reading and soil content of 0,98 (Figure 2). A prototype will be made available by the AEC for testing in a sugar factory.

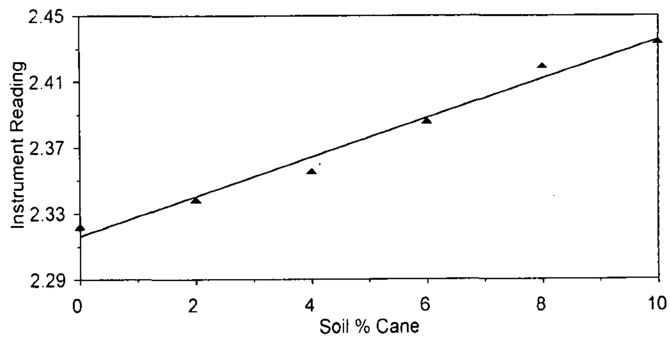

Figure 2. Soil % cane versus Kangela reading.

In Australia, an under-belt soil monitoring system based on the natural radioactivity of the soil has been developed (Mathew *et al.,* 1994). The measurement of soil in cane by means of near infra-red reflectance (NIR) is presently receiving attention as part of a study into the possible applications of NIR (Meyer *et al.,* 1994).

The effect of soil on factory equipment and processes

The influence of soil on factory equipment and processes is well documented and can be divided into four categories. Firstly it causes excessive wear on equipment components; secondly it leads to an increase in sucrose loss; thirdly it results in a loss of time efficiency due to breakdowns and chokes and fourthly it requires additional equipment and/or processes which would otherwise not be needed. Against all the negative effects of soil in cane, possible colour removal is the only benefit mentioned in the literature (Legendre *et al.,* 1996), and this benefit probably applies only to certain soil types. The soil affects the factory whilst it is in cane, in mixed juice and in bagasse.

Soil in cane

In a sugar mill, soil in cane causes severe wear of cane knives, shredder hammers, mill rolls, trash plates and scrapers. These components require constant refurbishment and/or replacement. The frequency is often dictated by a loss in performance. Worn knives and shredder hammers result in chokes and poor cane preparation. Soil polishes mill rolls and, without the continuous arcing of these rolls, throughput and extraction would quickly fall while the moisture in bagasse would rise. The conditions of the trash plate and scrapers determine to a large extent the level of suspended solids in mixed juice. In a diffuser, soil causes wear of the screen but more importantly it reduces the percolation. Other important components seriously affected by soil are inter-carriers, maceration pumps and chains. Failure of any of these components will lead to unnecessary mill stops and a loss in time efficiency. In extreme conditions, such as at Umfolozi (UF), soil forces the use of press-water clarification.

Soil in mixed juice

With its much higher concentration of soil, the juice from a milling tandem is more harmful than diffuser juice. Where high velocities are encountered, however, even juice with a low soil content has a damaging effect and causes wear on juice screens, pump impellers and juice piping. If not attended to, this wear not only leads to a direct loss of performance but also to equipment failure. The soil in the juice also puts an additional load on the clarifiers, rotary vacuum filters and filtercake disposal equipment. An increase in filtercake usually causes a proportional increase in sucrose loss to cake. Investigations are at present being carried out by Tongaat-Hulett Sugar Ltd, whereby the under-flow of the clarifiers is returned to the diffuser. This could eliminate the filtercake and make vacuum filters obsolete, but is dependent on having low levels of soil in mixed juice. The return flow past the mixed juice scales has, however, some implications for the present cane payment system.

Soil in bagasse

Diffuser bagasse contains much more soil and is therefore more damaging to the equipment it comes into contact with than bagasse from a milling tandem. Bagasse is usually used for fuel in the boilers but increasingly for by-products such as paper, board, animal feed and furfural. The soil in bagasse therefore causes wear to boiler components such as tubes, grates and fans as well as to various parts of by-product plants. Boiler efficiency is negatively affected by soil and boiler fires are sometimes extinguished by excessive soil. This was a major problem for some factories at the beginning of the 1996-97 season. Soil does not add to nor subtract from the NCV of the bagasse and, although the NCV on a MJ/kg basis decreases, on a MJ/h basis it remains unchanged. Eventually the soil finds its way into the boiler ash and as such loads the ash disposal equipment and increases factory waste products.

Estimated costs due to soil

For the 1996-97 season the total loss of revenue to millers due to soil in cane is estimated at about R63 million. Excluded from this figure are any costs to the farming community, such as additional transport and their share in the loss of income from a reduction in sugar production. This figure is based on a crop of almost 21 million tons of cane, a soil level of 1,19% and a cost of R2,50 per ton of cane per % soil. In Australia, Clarke *et al.* (1988) found that the total cost of one additional per cent of soil ranged from \$0,46 to \$2,65 (1987 Australian dollar) per ton of cane.

Costs of maintenance and refurbishment

Information on maintenance costs that could be attributed to soil in cane is not easily obtainable. Sugar factories do not usually differentiate their maintenance costs on this basis. It has therefore been necessary to extract costs that include component wear from a typical cost listing and then to estimate the proportion of those costs which could be attributed to soil. The major contributors to these maintenance costs are cane knives, shredders, mills and boilers. In the case of boilers, major refurbishment such as retubing or grate replacement may take place only once every 10 years. For a typical sugar factory these costs are about R1,70 per ton of cane per % soil, and vary from R0,80 to R2,50 for different factories (Reid, 1996). Mason and Garson (1986) estimated the annual factory maintenance cost of soil to be about \$0,62 (1986 Australian dollar) per ton of cane per % soil.

Cost of sucrose loss

In the 1996-97 season the average sucrose losses in bagasse and filtercake were 2,28% and 0,25% respectively. These losses are directly related to the quantities of bagasse and filtercake and hence to soil in cane. Undetermined losses for the season were 1,81%. A fraction of these losses is due to the degradation of sucrose during mill stops. Soil carries with it a small amount of soluble ash which has a detrimental effect on the boiling house recovery. This is accounted for in the sucrose losses in final molasses, which were 9,84% last season. It is difficult to estimate the total sucrose loss due to soil but, if this were 0,25% for each additional % of soil, which is not unreasonable, it represents a monetary value of about R10 million or roughly R0,40 per ton of cane per % soil. The cost to the farmer is about double that amount.

Cost of lost time efficiency

The cost of unnecessary mill stops is also difficult to estimate. This is because time lost during the season can be made up by lengthening the season by a corresponding amount. Allowing for this, it has been estimated that every hour of stoppage time costs the miller about R5 000. The average time lost due to soil in cane is estimated at 50 hours per million tons of cane. The cost is therefore about R0,25 per ton of cane for each additional % of soil (Reid, 1996). The cost to the grower must also be significant, but this cost falls beyond the scope of this paper.

Cost of loss in capacity

In general, the presence of soil reduces the effective capacity of various processes, and a reduction in soil would save on equipment. Throughput of cane preparation and extraction equipment decreases with an increase in soil. A drop in soil might reduce the required number of clarifiers and vacuum filters. If the soil in mixed juice is sufficiently low and the return of the clarifier under flow to the diffuser is a success, vacuum filters might become obsolete. Less soil will save on boiler ash and filtercake disposal equipment. The capacity of screens and filters is very much dependent on the solids in juice. The main reason for the use of press-water clarifiers is an abundance of soil in cane. Again these costs are difficult to estimate but an educated guess would be about R0,15 per ton of cane per % soil.

Soil removal systems

The best method of reducing soil in cane is to avoid entraining the soil with the cane during harvesting and loading, i.e. by leaving the soil in the field. Both UC and AK have proved that this is possible to some extent. It is however fully appreciated that some soil will always be associated with the cane, particularly during rainy periods. With this in mind it is necessary to consider various methods which may be available to remove the soil. Although soil removal in the field is by far the best solution it is only economically viable in conjunction with mechanical harvesting under dry conditions. Since in South Africa harvesting is mainly done manually, only central systems at the factory will be considered. These systems, however, have ramifications for the cane payment system presently used in South Africa. Many papers have been written on cane cleaning both locally (Cassim, 1991; Lucht, 1992; Bernhardt, 1994; du Plooy, 1994) and abroad (Cabrer *et al.*, 1967; Covas, 1968; Clayton and Roberts, 1971; Middleton *et al.*, 1972; McElhoe and Lewis, 1972; Hunwick, 1977; Vignes, 1980; Clark, 1991; Plaza *et al.*, 1994; Hobson *et al.*, 1996), a summary of which is given.

Dry cleaning

In Cuba, pneumatic cleaning systems are used whereby the cane passes through a high velocity air stream. The different trajectories of rocks, soil, trash and cane and the suitable positioning of splitter plates direct the various constituents to different conveyors (Eguiluz, 1983). A widely used piece of equipment in cane cleaning is a set of cleaning rolls placed parallel to each other to form a live screen. Soil falls off the cane by the bumping action of the rolls and passes between them (Clayton and Roberts, 1971). A rotating steel mesh drum was tried in Brazil. This was designed to separate the soil through blowing and/or mechanical action (Anon, 1993). In South Africa, the KM system consists of a tyned drum positioned near the base of an inclined feeder table. The cane is carried over the drum by the tynes, whereas rocks and soil fall between the drum and table onto a conveyor (du Plooy, 1994). Under normal conditions a dry cleaning plant removes most of the loose soil which is between 30 and 40% with sucrose losses of about 0,4% (Eguiluz, 1983). During rainy periods, when soil levels are high and cane cleaning is needed most, dry cleaning is less effective.

Wet cleaning

Most countries do not practise wet cleaning of cane and this method is used mainly in Hawaii, Louisiana and Latin America, where the amounts of soil and rocks are extremely high. Wet cleaning plants normally consist of a rock bath, a washing feeder table or a combination of the two. Soil removal efficiency is between 75 and 95% (Chen, 1980) and depends on the quantity of water being used, the initial amount of soil in cane and the ratio between loose and adhered soil. The quantity of wash water varies between two (Vignes, 1980) and 10 (Chen, 1980) times the amount of cane, depending on the number of recycles. The solids loading of the wash water fluctuates between 2 and 10% (Hunwick, 1977) and sucrose losses range from 2 (Clarke, 1991) to 10% (Paty, 1981). For washing tables the best results are obtained with water applied to the top of an inclined conveyor table. This creates a counter current flow whereby the water cascades down the table against the flow of cane. A critical aspect is the thickness of the cane bed. If the bed is too deep the soil from the top layer will settle on the bottom cane and hardly any soil will be removed. Daigle (1973) describes a wash table placed at an angle of 45° providing a self levelling bed height between 0,30 and 0,45 metres.

Cleaning in South Africa

With ever increasing soil levels in cane, South African sugar factories have to consider some sort of cane cleaning process. It is suggested that this take the form of a combination of a dry and a wet cleaning plant. This could consist of a rock and sand removal system, similar to that at KM, fitted with high pressure water sprays to operate only during wet weather. The appropriate treatment and recycling of the wash water to make it suitable for imbibition water might solve the problems of sucrose loss and effluent disposal normally associated with wet cleaning.

This requires a thorough investigation into the effects on extraction and boiling house recovery. Any cane cleaning operation will affect the present cane payment system.

Conclusions

Total ash consists of insoluble ash (soil) and soluble ash (inorganic salts). Soil in cane has been increasing over the years mainly due to a move in harvesting practices towards push-piling. The South African industrial average soil level for the 1996-97 season was about 1,19%. This soil finds its way into final bagasse and mixed juice. Soil levels are not measured directly but can be calculated from total ash in cane, total ash in bagasse and soluble ash in mixed juice. For a milling tandem the soil splits about equally between the bagasse and mixed juice, whereas for a diffuser most of the soil ends up in the bagasse. In the cane, bagasse and mixed juice the soil has a detrimental effect on both process and equipment. The total cost of soil in cane to the South African sugar millers for the 1996-97 season is estimated at about R63 million based on R2,50 per ton of cane per % soil. This can be divided into the costs of maintenance (R1,70), sucrose loss (R0,40), decrease in time efficiency (R0,25) and reduction in equipment capacity (R0,15). To minimise these costs a cane payment system with an incentive for the farmer to supply clean cane to the factory, together with some sort of cane cleaning, has to be considered. Dry cleaning removes only the loose soil which under normal conditions is 30 to 40%. During wet periods more sand adheres to the cane and dry cleaning becomes less effective. Under these conditions wet cleaning is much more suitable, with a reduction in soil varying between 75 and 95%. The problems of existing wet cleaning plants, however, are the high sucrose losses of between 2-10% and the production of huge quantities of effluent, which are two to 10 times the amount of cane. For the South African industry a combination of dry and wet cleaning could be feasible, with wet cleaning being applied only during rainy periods. The use of wash water as imbibition after suitable treatment could solve the problems of sucrose loss and effluent production.

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