REFEREED PAPER

INVESTIGATION INTO THE CAUSE OF TURBIDITY AT MALELANE MILL 2013

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Abstract

The Malelane mill experienced major turbidity events during early spring 2005 and again in 2013. The 2005 events were investigated by a team of consultants, with the outcomes being inconclusive. With the 2013 event, a collaborative effort between the Tsb agriculture and factory teams led to the conclusion that the turbidity could be traced back to sources of cane supplied during the event.

The methodology included tracing every load of cane delivered to the mill over an extended period and then linking the load sources to subsequent turbidity events in the mill. The sequence and source of loads in the period prior to the events were analysed and it was found that deliveries from certain farms always occurred prior to turbidity events. By using a co-variance analyses derivative a strong correlation between specific deliveries and turbidity events, as well as severity of turbidity, was determined.

From these results a simple model was developed which was used for the balance of the season to develop a turbidity prediction system for the mill. The prediction system enabled the mill to pay attention to procedures during risk periods and thereby avoided further major disruptions in manufacturing.

The turbidity events were linked to deliveries from cane fields on very sandy soils. Where the deliveries from such farms were concentrated in time or as a series of extended sequential deliveries, turbidity events were triggered. The actual turbidity was linked to the formation of amorphous silica. Once the rainy season started the turbidity no longer occurred although some deliveries should have sparked events.

Keywords: sugarcane, sandy soils, amorphous silica, turbidity, mill delivery logistics

Introduction

An overview of turbidity

Turbidity, in the context of sugar processing, is insoluble matter in a sugar solution that is intended to be free of insoluble matter, particularly in the refinery. This was experienced from 18 August to 22 September 2013 by the Malelane Refinery. This is a problem reported regularly during this time of the year and previous occurrences were in September 2005, August to September in 2007, again for a brief period in 2008, and again in 2013.

Previous efforts to source the cause of turbidity in the Malelane mill concentrated on the processing, chemicals and additives, pH changes and other actions to mediate and eventually remedy the problem. Little attention was paid to investigating possible causes of turbidity external to the mill. The periodicity of the problem, namely early spring before the onset of the first major seasonal rain, was never fully investigated.

In 2013, sugar crystallised at both Komati and Malelane factories contained contaminants causing turbidity, although the situation with the Komati sugar did not seem to be as severe as at Malelane. Samples sent for analysis by the Malelane mill identified amorphous silica passing through the final 0.45 µm filter and remaining in solution as the cause of turbid solutions. A body of evidence exists showing that silica-related turbidity is a long-standing issue in sugar refining, and Australian and South African publications featuring turbulence are freely available (Steindl and Doherty, 2005; Farmani *et al.*, 2008; Ghada *et al*., 2010; Madho and Davis, 2011; Dezfuly *et al*., 2013).

Silicon is the second most abundant element in soils; it is the mineral substrate for most of the world's plant life. The soil water, or the ‘soil solution’, contains silicon, mainly as silicic acid, H_4SiO_4, at 0.1-0.6 mM-concentrations of the same order of those of potassium, calcium, and other major plant nutrients, and well in excess of those of phosphate (Epstein, 1994; Meyer and Keeping, 2000; Lionnet and Walthew, 2004).

Silicon is readily absorbed, leading to terrestrial plants containing it in appreciable concentrations, ranging from a fraction of 1% of the dry matter to higher percentages, and in some plants to 10% or even higher. Despite this prominence of silicon as a mineral constituent of plants, it is not counted among the elements defined as ‘essential’ growth nutrients. For that reason it is not included in the formulation of any of the commonly used nutrient solutions (Epstein, 1994).

Possible causes of turbidity

The failure to achieve a clear solution impacts on the final quality of sugar and will influence the ability to supply sugar of the correct specification to industries requiring high quality sugar (Madho and Davis, 2011).

During the extraction of sugar from cane in the milling and refining process the liquid solutions are repeatedly heated and cooled, and pH adjusted. All of these processes that include the addition of lime and flocculants can contribute further silicon to solutions (Lionnet and Walthew, 2004).

During the investigation of the 2013 event, it had to be assumed that, due to the periodicity of the events in previous years, an external event not related to normal milling practice could be causing the problem. Factors relating to the supply of raw material to the mill had to be considered. These factors included varieties, possible changes in agrochemicals sprayed on varieties, possible changes in fertiliser regimes, climate-related growth stage attributes and specific fields or farms.

Apart from carbonaceous compounds entering the mill, silica, a natural compound existing in nature in high quantities, is often a major contaminant and one of the causes of turbidity (Lionnet and Walthew, 2004).

The possible causes of turbidity could include but are not be limited to silica-contaminants brought with the cane into the mill, such as soil or a mud, agrochemicals and fertilisers. In the mill itself the quality of lime, the recycling of sugar rejected at the refinery, or other process issues such as poor pH control can also exacerbate the situation (Madho and Davis, 2011).

Investigations by the mill as to possible sources of turbidity identified amorphous silicon moving through 0.45 micron filters as the main cause of turbidity (Global Analytical Services[1]). A source of cause for the amorphous silica had to be identified. Several reasons for turbidity have been tabled previously. Although some references were made to possible agronomic factors such as varieties and other, no investigations were was carried out to determine whether such factors might have existed. Previous investigations into the turbidity issues experienced periodically at the Malelane mill always concentrated on possible issues in the mill. These included the fact that a lime source could contribute directly to the silica load in the sugarcane juice mixes. Mud contamination on cane could also contribute directly to periodic turbidity events. Other issues such as stale cane which could contribute to colour (phenolic compounds) rather than amorphous silicon, were also considered as the possible cause of turbidity during this study. Since harvest to crush delays were similar to previous seasons, this matter was not pursued further in this research.

Materials and Methods

Data Sources

The Malelane Cane Testing Service supplied a per consignment database for the period 8 July to 18 September 2013 totalling 11 320 entries, including detail to field level information. Malelane mill staff supplied a detailed daily sugar opportunities lost report for the same period.

Dr Neil Miles[2] supplied information regarding the silicon situation in terms of leaf and soil analysis for Mpumalanga and two local Pest and Disease control chemical suppliers provided information on product formulations and sales in the area from January to September 2013. Detailed weather data for 2005-2013 was obtained from the South African Sugarcane Research Institute (SASRI) Weather Web[3].

Data Analysis

Data was analysed with several iterations of Microsoft Excel 2010 spreadsheets and Statistica version10[4] . The analysis included basic sample statistics: mean, median, standard deviations, frequency tables, analysis of variance (ANOVA), correlation, regression analysis and co-variance analysis.

Hypothesises tested

Possible causes that could contribute to the occurrence of turbidity events in the milling process were investigated. The main themes could be described as follows:

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[3] http://portal.sasa.org.za/weatherweb/weatherweb.ww_menus.menu_frame?menuid=1

[4] www.Statsoft.com

Sugarcane: varieties, age at harvest, quality issues.
Production: fertilizers, pest and disease control chemicals, soil types.
Quality: Pol%, Brix%, Sucrose%, RV%, Non-sucrose%.
Logistics: harvest-to-crush delays, clustering and frequency of loads from fields or farms over a given time step.

Methodology

The methodology used was to rank the database of recorded turbidity events into severity classes ranging from 0-10. The ranking was based on the percentage of sugar budget lost due to rejection of out-of-specification sugar over a 24-hour period based on the following scale:

% loss to the daily sugar budget	Severity
0	0
20	2
40	4
60	6
80	8
100	10

Once these rankings were obtained the cane deliveries in a window 24-36 hours prior to an event were clustered and analysed as a group. The time cluster was selected since a batch of cane takes approximately 24-36 hours to move through the factory from spilling to the refinery (personal communication[5]). Typically 172 loads are delivered in a 24-hour period, which represents approximately 4780-5200 tons of raw material. During periods of turbidity events in the mill the number of loads dropped to 151 loads per 24 hours, representing approximately 4200 tons.

The deliveries in this 24-36 hour time slot prior to a turbidity event were then selected as a cluster and grouped according to fields per farm and subsequently according to any other criteria that needed investigation, i.e. per variety, age at harvest or any other factors included in the database. To use only the number of loads from a specific area in a 36-hour window would not be sufficient as a unit of measurement, since the bunching of deliveries should also be considered.

Once the pertinent turbidity risk factors were identified, a correlation analysis between clusters, and severity and frequency of turbidity events in the mill was done. The results informed the design of a predictive (‘early warning’) system for the mill based on the frequency and clustering of ‘risk loads’ in the delivery queue. A simple formula was devised to ensure that a direct comparison could be made between different days since the numbers of loads in a specific time slot could differ significantly. The formula took into account that the mill would not always run for a full 24 hours in a day and the eventual ‘turbidity risk’ would then be based on a per hour delivered base. The formula is calculated as follows:

Turbidity risk factor = (number of deliveries from risk farms/total number of deliveries in period/duration of period in hours) x 100

[5] Logan Govender, Production Manager, Tsb Sugar, Malelane Mill.

Any figure smaller than 1 represents a low risk, whereas values of 1 and more represent an increased severity of the risk directly linked to the numerical value obtained by the calculation. A higher number would imply a higher risk.

The clustered data was then analysed against the severity of a turbidity event or according to the frequency of occurrence of all events prior to a mill turbidity event, and then also between the events. A specific farm or variety could then be identified as always or frequently included in a cluster prior to a turbidity event. The identified farms were then analysed to find common denominators as to why they might be included in such clusters. The same procedure was followed to analyse all factors of relevance.

The data clustered in field per farm context was used to analyse the related quality data obtained from the Laboratory Information Sytem (LIMS) in order to determine whether any other factors could be directly linked to the occurrence of turbidity in the mill.

Data from the Fertiliser Advisory Service (FAS) at SASRI was also clustered in field and farm context and a comparison of the status of various nutrients and other attributes were made.

Results

From the investigation into which external factors could be linked to the occurrence of turbidity events in the mill, a pattern could be determined which showed that loads of cane from certain farms were often in the delivery queue prior to turbidity events. By calculating the number of times loads from such farms were in the queue and well as the number of times loads from the same farm were involved in a turbidity event out of total deliveries over the period, the data in Table 1 was generated. It is clear that loads from Farm A were frequently in the queue before events, and Farm A also had many loads in the queue because of the farm size. Farm U was in the queue prior to a turbidity event fewer times and only provided a small portion of total overall deliveries.

In this manner some farms were identified that were frequently in the queue prior to turbidity events and which, due to their size, also formed the major portion of deliveries during any given time period. Based on local knowledge of soils and farming practices, it was deduced that farms which had predominantly sandy soils were in this group. Based on this assumption other smaller farms with similar soils were selected, and it became clear that these farms were also in the queue in the majority of the instances before a turbidity event. Other farms on more loamy soils were either not in the queue before turbidity events or made up a very small portion of the loads on days that turbidity occurred.

Using the information in Table 1, a calculation of the turbidity risk was done for all deliveries from June to September 2013, using the sandy soils farms portion of the deliveries in every 24-hour period for this period. Based on this, a plot of turbidity risk versus actual turbidity events was drawn (Figure 1)

Table 1. Portion of a comparison between cane loads from specific farms in a delivery queue at the Malelane mill and subsequent severity of turbidity events in the mill.

Farm code	Average % loads in queue prior to events	Severity of turbidity event
A	82.76	10
B	72.41	10
C	72.41	10
D	55.17	10
E	48.28	10
F	27.59	10
G	10.34	10
H	10.34	10
I	10.34	10
J	10.34	10
K	6.90	10
L	6.90	10
M	48.28	7
N	24.14	7
O	13.79	7
P	13.79	7
Q	17.24	5
R	13.79	5
S	10.34	5
T	6.90	5
U	6.90	5
V	3.45	5
W	3.45	5
X	17.24	3

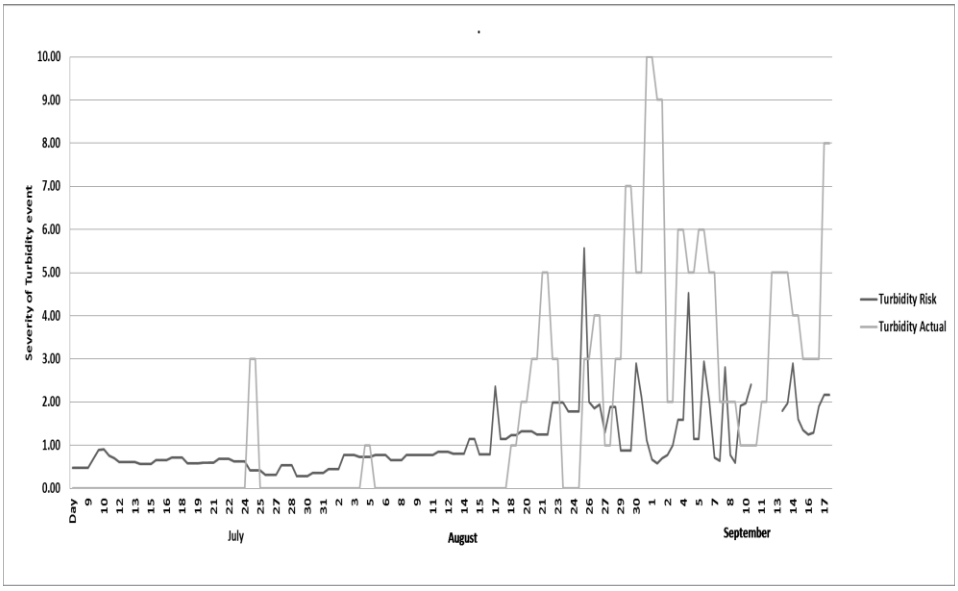

Figure 1. Covariance analysis of delivery frequency from 'risk farms' and actual subsequent turbidity events in the Malelane Mill from July to September 2013. The correlation coefficient obtained for this data was r²=0.41.

Although the correlation coefficient (r^2) value for the correlation at 0.41 is good for biological data, the relatively low coefficient is also due to the time lag between deliveries and actual events. If the peaks are moved together by removing the time lag, i.e. removing the 24-hour time step (Figure 2), the correlation improves significantly to an r^2 value of 0.74.

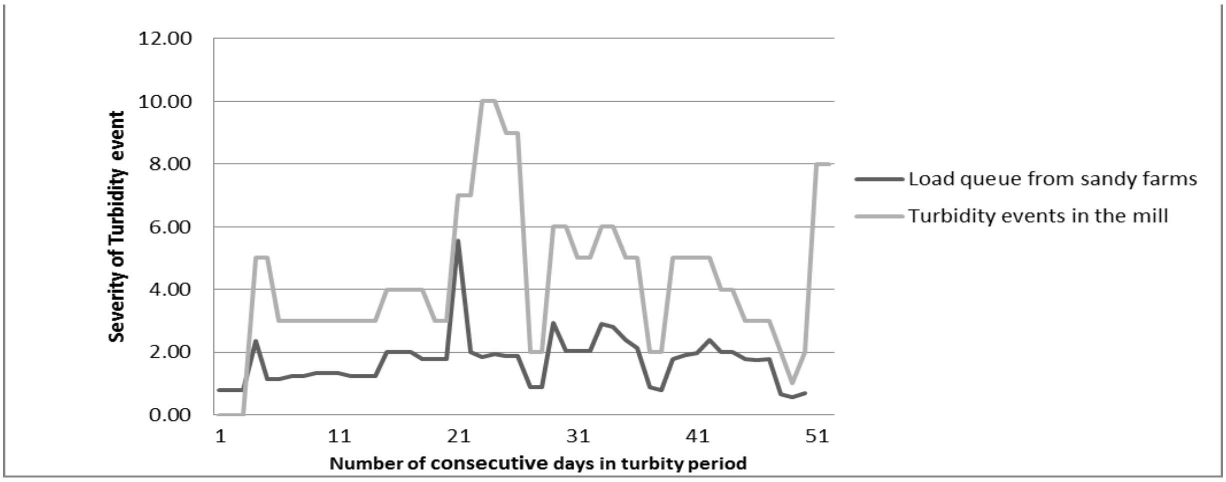

Figure 2. Removal of the time step prior to turbidity events in the mill improved the r^2 value from r^2=0.41 to r^2=0.74 and demonstrates a good correlation between the occurrence and frequency of loads from specific farms in the delivery queue and turbidity events in the mill.

When a scatterplot of the linearised data was drawn, it indicated that the 95% confidence interval would contain a statistically significant portion of the data, but that there were events occurring in the mill that could not be ascribed to the quality of input cane alone (Figure 3).

As a standard practice, high turbidity sugars were re-introduced to the crystallisation process in order to improve purities. This seems to have caused even higher turbidity values than the original batches. Once the effect of this practice became clear, different solutions were sought and applied which eventually brought the situation under control.

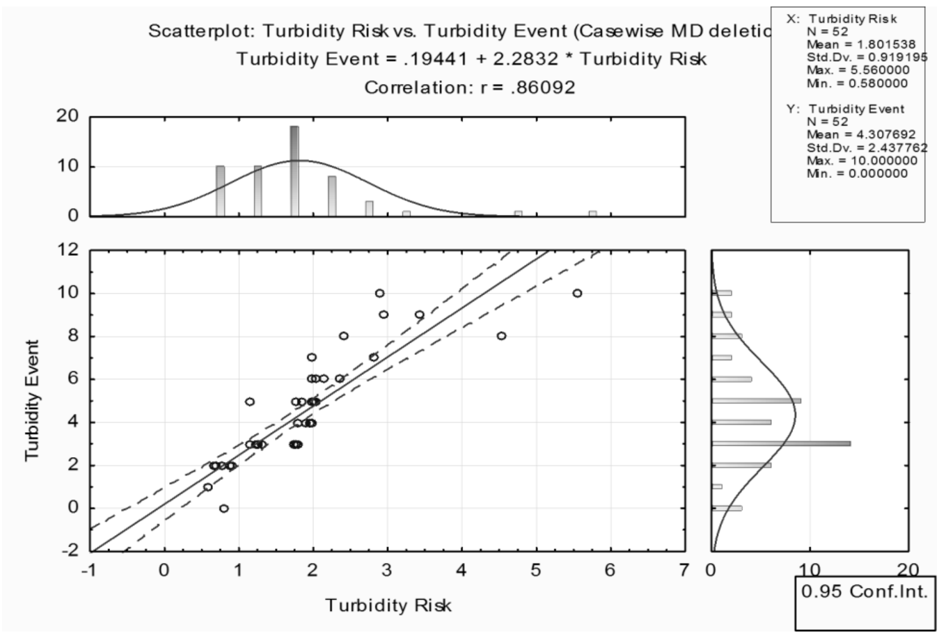

Figure 3. Statistical analysis of scatterplot data confirms a correlation between loads from sandy soil farms and turbidity events in the mill.

Other parameters analysed did not show similar significant relationships between the loads in the input queue and turbidity events in the mill. Table 2 shows the various factors tested and the related correlation co-efficients. The factors that did show significant differences at the 0.95% confidence level were the Pol % and Ash% of loads related to Turbidity events these tended to be significantly higher, but no other factors were significant at this level.

Table 2. Quality factors related to loads in the input queue and the resultant t-test results versus loads where no turbidity occurred.

Factors compared	Mean non-turbid	Mean turbid	t-value	df	p	Std.Dev. non-turbid	Std.Dev. turbid	Significance at 95%
Pol % vs Pol % Event	17.36185	18.23636	-2.734	20	0.012778	0.682488	0.812013	S
Brix vs Brix % Event	13.28512	13.65273	-2.070	20	0.051633	0.380950	0.449268	NS
Moisture vs Moisture % Event	68.80212	68.11000	1.251	20	0.225491	1.667323	0.767333	NS
Purity % vs Purity % Event	87.20066	86.82273	0.896	20	0.380734	0.717923	1.200084	NS
Sucrose vs Brix % Event	13.94459	13.65273	1.153	20	0.262438	0.709096	0.449268	NS
RV vs Sucrose % Event	15.19908	14.64273	1.756	20	0.094386	0.721716	0.763716	NS
RV vs RV % Event	15.19908	15.84182	-1.977	20	0.061993	0.721716	0.801122	NS
Ash vs Ash % Event	2.24186	2.39273	-2.112	20	0.047480	0.111064	0.209289	S

The variety distribution in loads was according to the frequency of plantings in the Malelane area and did not differ significantly to other times during the season. The dominant varieties in the area were the dominant in the queues during the major turbidity events and no single variety or varieties could be linked to the events (Figure 4).

An investigation into the agrochemicals applied to cane delivered during July-September 2013 to Malelane mill yielded no evidence of abnormal or unregistered products being applied. The silicon-containing products sometimes used elsewhere in the South African industry to control infestations of the stalk borer *Eldana saccharina* are not used in the Nkomazi area.

The soil analysis of farms in the Nkomazi area shows a naturally high concentration of silicon in the soils. The norm for adequate silicon in leaves is any value greater than 0.75% of the dry mass. For soils the threshold is 15 mL/L. In Nkomazi these values are virtually always exceeded. From Table 3 it is clear that there are some elements that are significantly higher in the soils of farms where the fields have been associated with turbidity. Of interest is that the levels of silicon and some of the other micro-elements are not significantly different and also very variable between the two groups of fields.

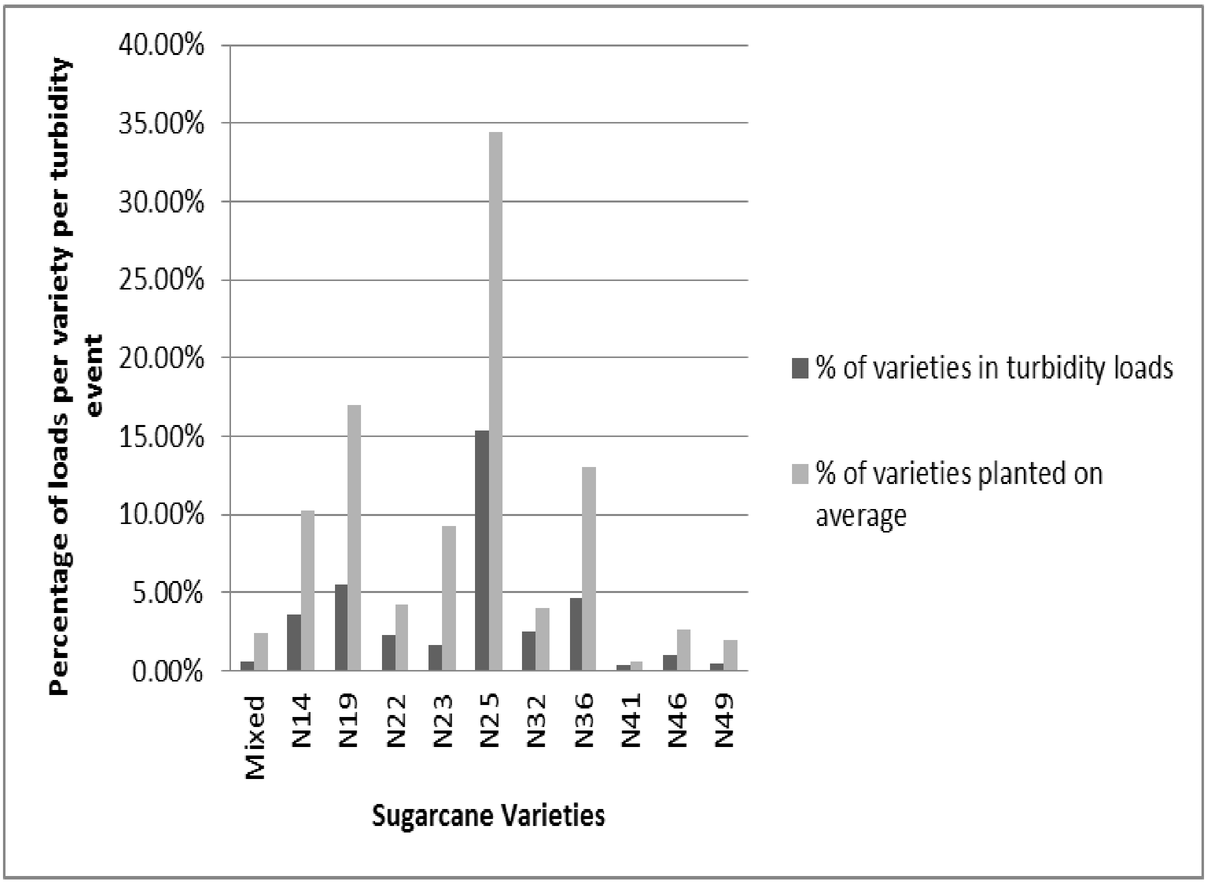

Figure 4. Frequency of varieties in the mill queue prior to turbidity events compared to the variety distribution for all fields delivered during the period July to September 2013.

Table 3. Statistical analysis of two groups of fields, with the one group associated with turbidity events and the other not. Data based on analyses results provided by the Fertiliser Advisory Service (FAS) of the South African Sugarcane Research Institute..

Element	Mean Turbid	Mean Non-turbid	t-value	df	p	Statistically significant at .95 confidence	Std.Dev. Turbid	Std.Dev. Non-turbid
Potassium	197.16	272.97	-3.37	121.00	0.00	y	124.72	124.46
Calcium	2170.38	3415.38	-8.33	121.00	0.00	y	783.34	871.83
Magnesium	701.17	968.94	-3.75	121.00	0.00	y	288.47	480.85
Zinc	3.39	2.51	1.77	121.00	0.08	n	3.56	1.56
Silicon	35.90	37.78	-1.03	121.00	0.31	n	10.88	9.37
Manganese	16.33	14.65	0.74	121.00	0.46	n	13.27	11.79
Copper	6.20	10.03	-4.11	121.00	0.00	y	4.11	6.04
Iron	56.50	23.09	6.08	121.00	0.00	y	37.89	20.29
Clay estimate	25.97	38.52	-15.13	121.00	0.00	y	4.98	4.17
Organic matter estimate	2.77	3.35	-6.24	121.00	0.00	y	0.57	0.44

Silicon deficiency is not common in the irrigated cane growing areas of Nkomazi. This abundance is because soils are not highly leached by rainfall. In the Nkomazi area soils with higher clay and organic matter content (Table 3), laboratory measured silicon values tend to be higher.

Following the results obtained from the initial studies, a tool was devised to give the mill an early warning of turbidity risk in order to manage the risk and prevent major turbidity issues.

Use of the turbidity risk tool

With the risk farms identified, delivery reports were drawn three times per day to assess the number of possible risk loads in the milling queue, as well as the total number of loads since 00h00. The turbidity risk factor was calculated as described earlier and any values above 1 caused a turbidity risk warning to be raised. The risk in loads would manifest in turbidity events 24-36 hours later in the mill, giving the mill ample warning to be able to respond. Table 4 shows actual operational data and the link between the predictions and actual events.

During the time of operation of the warning system, it became clear that a turbidity event could actually strike earlier than 24 hours after the cane was tipped. This is due to the various factors influencing throughput in the mill and, since the warning system came into operation, the crush speed was not affected as much as before the system was in place. This assisted with an acceleration of loads though the mill from an average of 150 loads per 24 hours during turbidity events to 170 loads per 24 hours, which is in line with the normal tempo during non-turbidity periods.

Once the warning system started operating towards the end of September, no further major turbidity events were recorded. This was attributed by mill staff to the fact that they had pre-warning of potential risk and could put management actions in place to limit the turbidity risk.

The turbidity events ceased after the onset of rain in October 2013. Table 5 shows the history of early season rain from 2005 to 2013. It is clear that the previous turbidity events could be linked to a dry post-winter period and that during years with an extended dry period, turbidity was recorded during the spring period.

Table 4: Turbidity risk warning system and improved event handling of Malelane mill after 6 September 2013. With the onset of rain at the beginning of October 2013, the predictions and events were no longer linked and no further turbidity events occurred.

Date	Delivery turbidity risk	Predicted event	Actual event
30-Aug		0	0
01-Sep	0.82	0	2
02-Sep	0.86	0	0
03-Sep	0.99	0	0
04-Sep	1.07	0	0
05-Sep	0.89	1	1
06-Sep	2.22	3	8
07-Sep	1.15	0	2
08-Sep	0.85	4	2
09-Sep	0.69	2	0
10-Sep	0.87	0	2
11-Sep	1.58	0	0
12-Sep	1.36	0	0
13-Sep	1.09	3	1
14-Sep	1.64	2	2
15-Sep	1.28	1	1
16-Sep	1.41	4	1
17-Sep	1.14	2	2
18-Sep	1.21	3	0
19-Sep	0.96	2	1
20-Sep	0.75	3	1
21-Sep	1.14	0	1
22-Sep	0	0	2
23-Sep	0.85	2	0
24-Sep	0.94	0	0
25-Sep	0.47	0	0
26-Sep	1.22	0	2
27-Sep	1.38	0	2
28-Sep	0	2	0
29-Sep	1.95	3	1
30-Sep	0.96	0	1
01-Oct	0.83	4	1

Table 5. Rainfall per week (in mm) for the period Aug-Oct 2005-2013.

Month	**August**				**September**				**October**				**Turbidity issues**
Year	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
2005	0	0.2	0	0.6	0	0	0.1	0	0.1	0	1.1	2.5	Yes
2006	8	0.1	3	1.2	1.2	0.1	1.6	0	32.1	1.2	2.4	2.3	No
2007	0	0	0	0	0	0	0	16.9	12.7	2	3.2	3.2	Yes
2008	0.2	0	0	0	0	0.5	3.3	0	0	0	23.6	7.5	Minor
2009	25.8	6.9	0	3.4	0	0	1.7	0	9.4	0.7	3.5	2.5	No
2010	0.1	0.8	2.2	0	0	0.1	0	0	10.7	13.2	0.4	26.1	No
2011	0	1.1	0	2	0	0	0	9.9	19.8	1.5	6.2	41.8	No
2012	0	0	0	0	125.6	14.3	1.3	0	1.4	66.2	45.8	9.8	Minor
2013	0	6	0	0	0	0	0	23.4	0	0	49	82.5	Yes

Discussion

The periodicity of turbidity events at Malelane mill, i.e. post-winter before the onset of spring rain, seems to indicate a natural climate-related source for turbidity. The probability of sources of chemicals used in processing or other factors occurring at the same period in a sequence of years is unlikely. The possible biological factors, i.e. the cane source and associated climate, appear more likely to be causes of turbidity events. Although mud-related events or mishaps with liming or pH balances could lead to sporadic events, sustained events as experienced at Malelane during the spring of 2013 seem to have a different source.

This study shows that cane derived from sandy soils could contribute directly to turbidity events in the mill. Silicon deficiency is very uncommon in the irrigated areas. This is because the soils are not highly leached from rainfall (Miles *et al*., 2011).

Soils in general contain huge amounts of silicon. However, little silicon is plant-available, since the bulk is locked up in the crystalline structure of the clay component. Small amounts dissolve off the clay edges and become available to the crop, and this fraction is measured by soil tests. It follows that the plant-available silicon is related to the amount of clay present in the soil and hence sandy soils indicate less available silicon. A further factor is that the silicon released from the clays is readily lost from the soil profile by leaching. Consequently, sandy soils with less water holding capacity than loams and clays, have an increased Si loss due to leaching (personal communication[6]).

An extensive analysis of the various possible contributing factors led to the conclusion that silicon found in sandy soils before leaching by spring rains was at the core of the problem.

Limited stalk samples taken from sandy versus clay soil fields and tested for silicon levels were inconclusive in terms of silicon levels, and testing needs to be repeated with more extensive samples. In nature, amorphous silica occurs near submarine volcanic vents, under conditions of high heat and rapidly changing pH (Furukwa and O'Reilly, 2007). Such conditions are emulated during the processing of sugarcane to sugar in a mill. If high levels

[6] Dr Neil Miles, Senior Soil Scientist, Plant and Environmental Resource Centre. SASRI.

of silicon, a precursor of amorphous silica, are present during the sugar milling and refining process, the conditions would favour the formation of amorphous silica.

Since silicon is such an abundant element in nature, and the Nkomazi area soils have a significantly higher plant available silicon level than elsewhere in the South African sugar industry, the risk of amorphous silicon forming during sugar processing in the Nkomazi Mills seems to be high.

At the onset of growth after winter and before silicon built up over the dry period is leached from the soils by spring rains, the silicon could be taken into the growing cane at high rates, which could then lead to an overabundance of silicon at the mill. The clay soils bind silicon more strongly and the silicon might not be as readily available, as is the case with more sandy soils.

The problems with turbidity at the Komati mill are significantly lower than at Malelane. This could be attributed to the significantly fewer loads derived from sandy soils that are processed by the Komati Mill.

There are questions raised regarding the mobility of silicon in cane during different growth cycles, as well as whether silicon would be more available to the plant under specific conditions. This falls outside the scope of this paper, but would be interesting to pursue.

Conclusions

The analysis of a database of all deliveries to Malelane mill during the period July to October 2013 led to the conclusion that under the dry post-spring period experienced, silicon related turbidity events could be sparked in the mill by a large number of cane loads being delivered and processed by the mill in a short time period from fields with predominantly sandy soils. During previous turbidity events in 2005, 2007 and 2012, the possible link between sandy soils harvested during the dry period of the season and turbidity was not formed. The conditions surrounding the events in terms of climatic conditions could imply that similar conditions existed at the time.

Other factors relating to how such events are managed in the mill contributed to an exacerbation of turbidity. This was predominantly related to the practice followed initially to re-circulate sugar rejected at the refinery.

None of the agrochemicals or fertilisers used during normal cane operations seem to contribute to elevated silicon levels.

No clear links could be found between specific varieties and turbidity events and no reasons for slightly elevated Pol % and Ash % in loads prior to turbidity events were evident.

The ability to predict turbidity events with relatively high accuracy assisted in the management of the turbidity problem in the mill and although high risks occurred at stages after the identification of the possible source, the events were controlled more efficiently and with fewer losses refined sugar.

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