# *“Performance evaluation of the Skorpion Zinc Pinned Bed Clarifiers”*

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## 1 Abstract

In June 2009, Skorpion Zinc commenced with hot commissioning of three Pinned Bed Clarifiers (PBC). The units are designed to clarify solution to 10 $g/m^3$ total suspended solids (TSS) from a pregnant leach solution containing 32 to 100 $g/m^3$ TSS at a linear rise velocity of 7.1 m/h. The minimum target period between backwashes is 24 h. This paper discusses commissioning and operational challenges of the full-scale units (*e.g.* sludge removal point, media particle size and flocculant dosing) with reference to parameters determined during piloting.

During commissioning the short period between backwashes was found to be a result of media blinding by fine media particles segregating on the lower media bed. The media was replaced in October 2009. In this period the sludge removal point was moved from the top of the cone to the tip to effect greater solids removal at nominal pump speeds. Loss of solids in the sludge recycle stream occurred with a concomitant reduction in the time between backwashes. It was found that the solids were sticking and accumulating on the cone wall. This is thought to occur due to over flocculation.

A marked improvement the quantity of clarified PLS provided to SX, was seen from March 2010 onwards. The improvement was a result of reducing the flocculent make-up strength from 0.3% to 0.2% and reducing the flocculent dosage to the PBC’s from 2 $g/m^3$ to 1 $g/m^3$. The period between backwashes increased from March onwards, with monthly averages ranging from 11 to 23 hours. The quality of PLS provided to SX improved from 32 $g/m^3$ to 16 $g/m^3$ (2.7 NTU) over the past 6 months. The solids removal efficiency of the PBC’s based on turbidity measurements in 95%.

# 2 Introduction

## *2.1. Skorpion Zinc process description*

Skorpion Zinc processes a zinc oxide orebody containing 9-11% zinc as carbonaceous and silaceous zinc-containing minerals smithsonite, hemimorphite and sauconite (Gnoinski *et al.*, 2005). The process makes use of a sulphuric acid leach and solvent extraction to produce a pure pregnant leach solution from which zinc cathodes are electrowon and cast into 25 kg ingots and 1 ton jumbos. The design Pregnant Leach Solution (PLS) clarity for the solvent extraction circuit is 10 g/m$^3$ Total Suspended Solids (TSS). However, since plant commissioning in 2003 this target was never been reached as the sand filters providing the polishing step to the thickener overflow consistently blocked with gypsum. In 2007, the capacity of the thickeners was increased and the PLS storage pond was brought online. This reduced the TSS carryover to SX from historic values of 32 to 100 g/m$^3$ to 32 g/m$^3$ (average for Jan 2008 to May 2009).

A number of PLS polishing units were trialled from 2004 to 2007 on site. The reasons for their rejection are given in Table 1 (Fuls and Nong, 2007; Fuls, 2008).

**Table 1: PLS polishing units trialed at Skorpion**

| ***Unit*** | ***Scale*** | ***Reason for rejection*** |
|---|---|---|
| Sand filters | Industrial | Excessive media blockage due to gypsum precipitate |
| Larox belt filter | Pilot | Irreversible blinding of filter cloth within 1 week |
| Bateman Pinned bed clarifer | Pilot | TSS target of 10 mg/l not maintained. |
| GL&V high rate clarifier | Pilot | Rise rates too low, target clarity not met |
| Fiber-Wakishimizu filter | Pilot | Projected costs of media replacement due to media blinding prohibitive. Media blinded within 30 days |

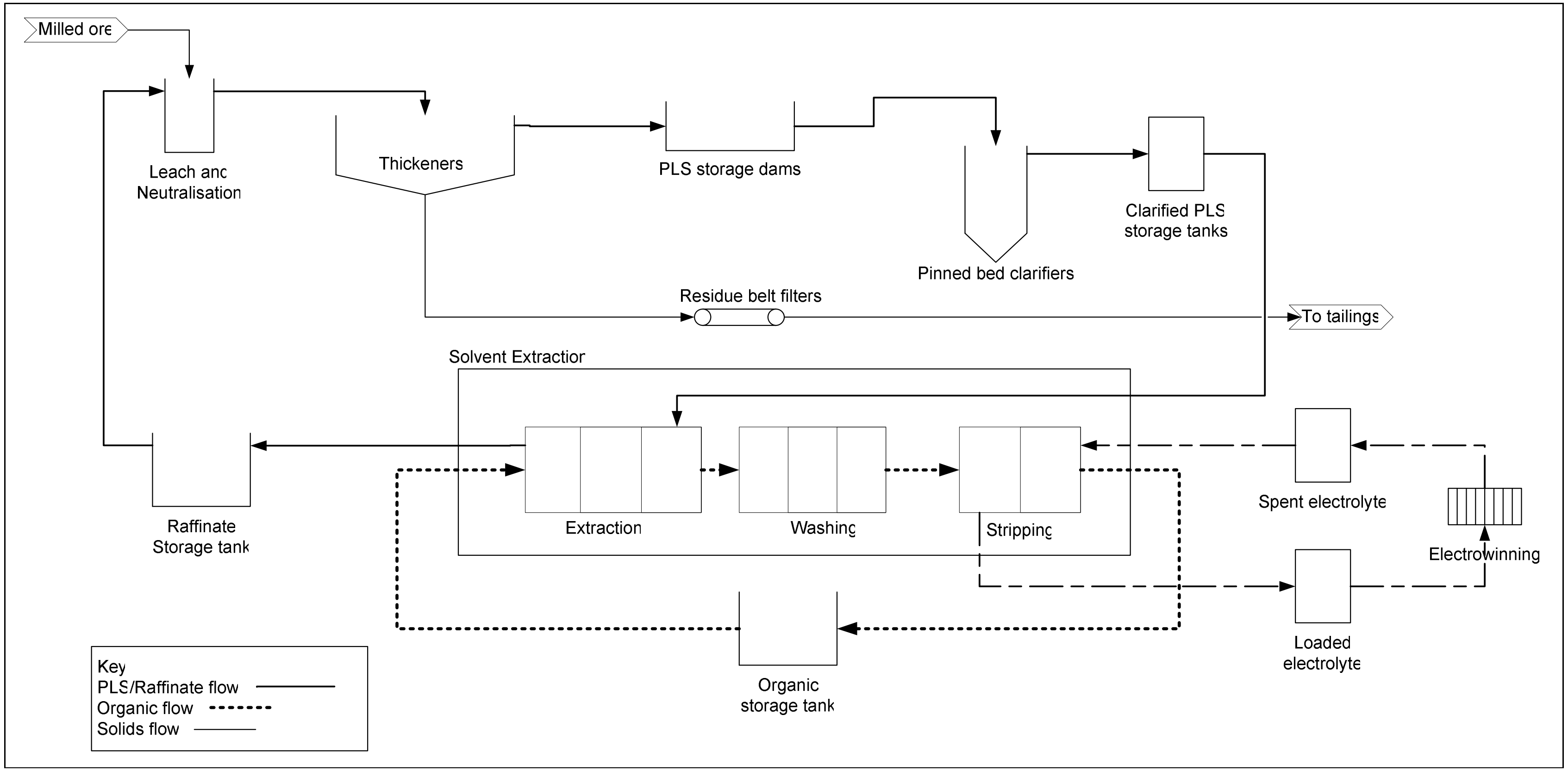
In 2007, Roymec Technologies approached Skorpion Zinc to trial a modified Waterex Pinned bed Clarifier (PBC). The advantages of this unit were: superior flocculation with the use of high and low shear flocculation system, fast backwash times, no moving parts and less expensive media (compared to the Fibre Wakishimizu Filter). Over the course of 3 pilot campaigns refinements were made to the process and in 2009 the full scale units were commissioned. This paper presents the developments in design over the piloting campaigns, the parameters used to scale up to industrial units, the operational learnings gathered from commissioning and the performance of the PBC's subsequent to their handover to plant operations. The location of the PBC's in the Skorpion flowsheet is shown in Figure 1.

### 2.2. Pinned bed clarifier piloting campaigns

The first pilot plant trail with a modified Waterex Pinned Bed Clarifier supplied by Roymec was carried out in May to June 2007 on site using a thickener overflow feed. The results from this campaign were unsatisfactory as the overflow clarity was 25 g/m$^3$ at rise velocities of 5 m/hr. The use of the recycle stream to seed flocculation was found to have a negative effect on operation as the solids in the recycle broke through the media bed to the overflow (Rampersad *et al.*, 2007).

Subsequent flocculation tests by Roymec showed positive results with the use of a coagulant. Based on this discovery a second pilot plant campaign was carried out in October to November (Blaauw and Sole, 2007). The unit was tied-in to the plant after the ponds to allow for a more consistent feed quality. The feed was first subjected to high shear mixing (10 kW/m$^3$) in the high energy mixing tank to fully contact the recycle sludge and coagulated feed with 50% of the flocculent. The balance of the flocculant was added to the low shear mixing tank. Quiescent condition in the low shear mixing tank (1 kW/m$^3$) allowed for floc agglomeration. Flocculent dosing at 2 g/m$^3$ was split between high and low energy mixing tanks. A 1 %(w/w) coagulant slurry was dosed inline at 25g/m$^3$. The setup of the reagent dosing system is shown in Figure 2. With the presence of the coagulant a seed recycle stream was effective in aiding floc formation. The average overflow TSS for the entire campaign period was 7.7 g/m$^3$ at a linear rise velocity of 10 m/hr.

**Figure 1: Skorpion Zinc process flow diagram showing location of PBC's**



A final pilot campaign was carried out in December to optimise the backwash cycle and reagent dosing and to measure the Zn losses across the unit (Blaauw, 2007). The bottom media bed retainer screen was removed as this had blocked in the second trial and was in fact redundant equipment. To backwash the pilot unit the sludge dump valve was opened for 24 s which removed 1.3 bed volumes of solution. The screens were then flushed for 2 min to remove ultra-fine solid particles. It was found that backwashing the units at 24 hour intervals prevented solids build up in the media bed. It was found that flocculent dosing into the high and low energy mixer at 2.1 g/m$^3$ and dosing the coagulent inline at 25 g/m$^3$ produced optimal results. The zinc absorbed onto the coagulent could be recovered by leaching at pH 2 for 30 min.

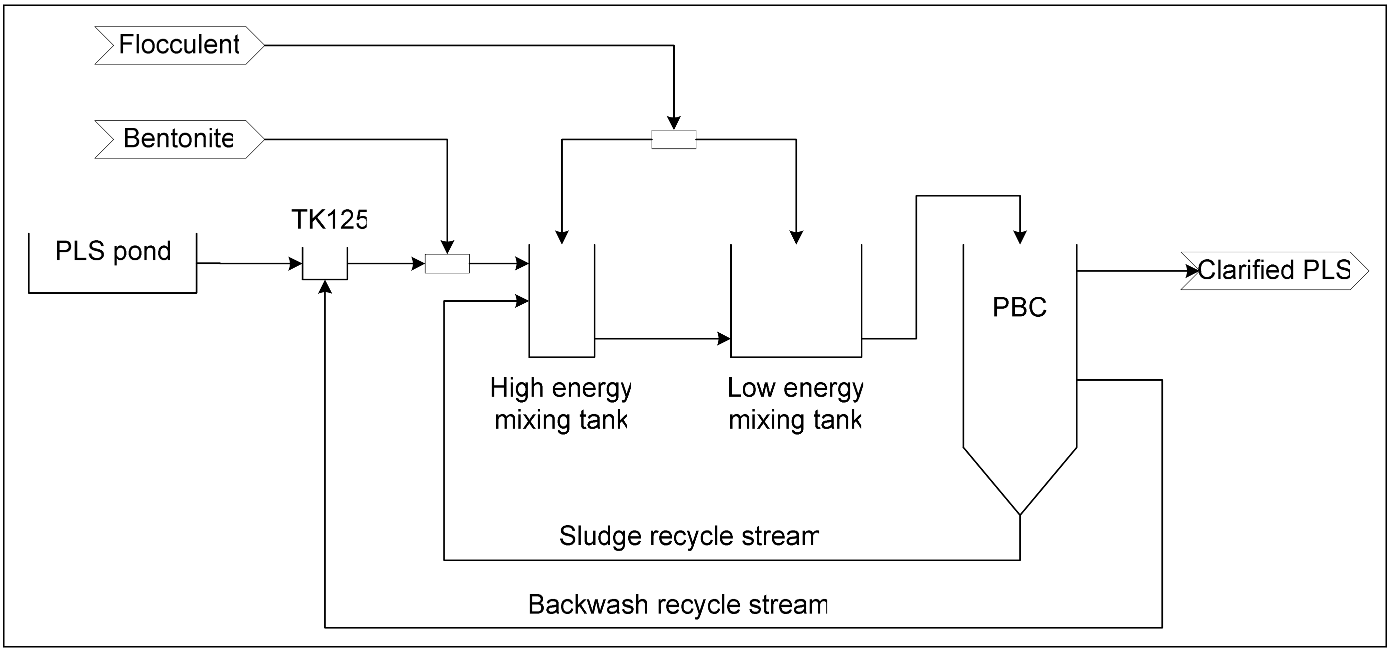



**Figure 2: PBC pilot plant reagent dosing points**

### *2.3. Motivation for the installation of the PBC's*

The business case for the installation of the PBC's was based primarily on improved SX capacity and availability. In 2007 SX was off-line for a total of 58 hours to remove crud from the settlers. SX capacity was also reduced in 2007 to 60% for 242 hours due to emulsion bands arising from TSS carryover (Fuls, 2008). It was assumed that with the

PBC's coming online no settler cleaning would be necessary and SX capacity would not need to be reduced. Other projected savings were a reduction in labour required for settler cleaning and crud skimming. Organic losses from crud were projected to decrease due to less solids carryover.

Floating CRUD in the extraction settlers was identified as the root cause of impurity carryover to electrowinning which led to a 3 week production delay in 2006. Reducing the solids transfer to SX will significantly reduce the risk of impurity transfer by means of floating CRUD. This was a major motivating factor for installation of the PBC's.

# 3 Scale up of the pilot unit

Scale up was based on a linear rise velocity of 7.1 m/hr and 8.0 m/hr at nominal (1012 $m^3$/hr) and design flows (1173 $m^3$/hr) respectively. Nominal and design flows were set to provide SX with 950 to 1050 $m^3$/hr clarified PLS and allow for recycle of backwash and sludge removal streams. To optimise plant flexibility and capital expenditure three 8 m units were installed. Table 2 presents a financial trade-off of sizes and number of PBC units to be installed. Installing three 8 m units allows for operation of two PBC's at linear rise velocities of 12 m/hr which was tested during piloting. Costs rise exponentially when the numbers of units increases.

A media bed depth of 900 mm was chosen and the height of filtered PLS above the media retaining screen selected at 1.8m. This allowed approximately 2 bed volumes pass through the media bed per backwash. A backwash is effected by opening the 800 NB butterfly valve on the backwash pipe.

The internals of the PBC are designed such that the sludge is discharged through the tip of the feedwell cone and through side outlets. The cone angle of the PBC was set to 60° (same as the pilot unit) to allow free flow of sludge without the use of rakes. The sludge removal pumps are variable speed drive pumps which can withdraw 1 to 3 $m^3$/hr. Sludge recycle pumps withdraw sludge from the bottom of the cone at a rate of 0.2 $m^3$/hr sludge per $m^3$/hr feed.

**Table 2: Number of units *vs*. capital expenditure optimisation**

| PBC diameter (m) | Cost per unit [1.] | Number of units | Linear rise velocity with 2 unit online (at design flow) | Total cost |
|---|---|---|---|---|
| 8.0 | R 11,386,000 | 3 | 11.9 m/hr | R 34,158,000 |
| 7.4 | R 10,781,000 | 3 | 14.0 m/hr | R 32,344,000 |
| 6.5 | R 9,846,000 | 4 | 12.1 m/hr | R 39,383,000 |

1. Costs presented are indicative only

# 4 Commissioning of the industrial scale units

A commissioning team oversaw production from May 2009 to September 2009. The objectives during commissioning were:

- Achieve consistent overflow clarity of 10 g/m$^3$ TSS or less than 1 NTU
- Achieve 24 hr runs between backwashes
- Confirm the reagent concentrations and dosing points
- Undertake a solids mass balance over the unit
- Monitor the media for blinding
- Monitor conditions during backwashing
- Calculate the efficiency of the re-leach section

Cold commissioning was done in May 2009 and continuous operation started on 22 June 2009. Operation was stopped on the 9 September to load new media. The performance of the PBC's during this period is given in Table 3 and Table 4. From Table 3 it can be seen that runtime on the PBC's was good in June and July (greater than 80% PLS supplied to SX was treated by the PBC's) but in August the units were often bypassed to restore the levels in the PLS storage tanks after periods of excessive backwashing. The short period between backwashes (2.6 to 5.7 hrs) on PBC 2 and 3 for the latter half of July and the month of August is shown in Table 4. The quality of the PLS supplied to SX was best in July when the PBC runtime is highest. In September a number of TSS results greater than 100 g/m$^3$ were recorded. However inspection of the filter papers showed only a shiny layer of precipitate; no solids were seen. This is discussed further in Section 4.1.3.

Overflow turbidity results give a truer reflection of overflow clarity as the measurement is not influenced by precipitate formation. The average overflow turbidities for the three

PBC's during commissioning were 1.7 NTU, 1.2 NTU and 1.4 NTU respectively at an average feed turbidity was 50 NTU. This equates to 97% solids removal efficiency.

**Table 3: PBC performance during commissioning**

| | PLS flow through PBC's | Flow bypassed | % treated by PBC's | Clarity of PLS supplied to SX (g TSS/m$^3$) |
|---|---|---|---|---|
| 22 June to 30 June | 142,912 | 22,530 | 86.4% | 19 |
| Jul-09 | 564,135 | 120,518 | 82.4% | 17 |
| Aug-09 | 528,349 | 176,694 | 74.9% | 25 |
| 1 Sept to 9 Sept | 157,605 | 28,740 | 84.6% | 25<br>42 [a.] |

a.) Average if high TSS results included

**Table 4: Time between backwashes during commissioning**

| | Time between backwashes (hrs) | | |
|---|---|---|---|
| | PBC 1 | PBC 2 | PBC 3 |
| 22 June to 30 June | 6.5 | 7.2 | 7.4 |
| 1 July to 22 July | 8.7 | 7.3 | 6.4 |
| 23 July to 31 July | Very unstable operation | 2.6 | 5.7 |
| August 2009 | 11.0 | 2.8 | 4.7 |
| 1 Sept to 9 Sept | 28.6 | 3.7 | 5.1 |

### 4.1.1. The challenge of frequent backwashes

The period between backwashes affects the ability of the PBC's to deliver the required flow to SX. At design cycle times of 24 hours the equivalent recycle of clarified PLS is 3.6 m$^3$/hr. This increases exponentially to 21 m$^3$/hr at cycle times of 4 hrs and 43 m$^3$/hr at cycle times of 2 hours. To elucidate the cause of the short period between backwashes the following was investigated:

1. Flow restrictions due to media blinding or blockages in the PBC internals
2. Disturbance of the sludge bed during backwashes
3. Uneven flow distribution during backwash

To investigate if the media was blinded, "media drills" were done on a regular basis by extracting a column of media from the bed. The following observations were made:

- Only the lowest layer of media was blinded, *i.e.* suspended solids were not penetrating into the full bed volume.

- Predominantly fine media segregates at the bottom of the media bed.
- Large lumps of coagulent and media particles formed in the bed (more so in the lower layers).
- The lumps were strongly bound and did not break up in a jet of water and would hence not be broken up during the turbulence of the backwash.
- Particle size analysis of the media in the lumps showed they consisted of predominantly fine media particles (see Figure 3)

It was thus proposed that the media bed was blinding due to the segregation of fine media particles at the bottom of the bed. This prevented solids from entering and saturating the full media bed and hence reduced the time between backwashes.

To confirm it was the blinding of the media leading to the increased in pressure drop (and not due to other obstructions in the internals) a manometer was placed on the mid-bed sample point 1.2 m from the bottom of the media bed. This enabled the measurement of the pressure drop across the media bed only. This pressure drop was compared to the total pressure drop across the PBC. The results are shown in Figure 4. It can be seen that the pressure drop increase can be attributed to the blinding of the media bed and not due to other obstructions in the feedwell arrangement.

To investigate whether the sludge bed was disturbed during backwashing, turbidity readings from a sample point at the same height as the backwash pipe were taken before during and after a backwash. The results for PBC 1 2 and 3 are shown in Figure 5, Figure 6 and Figure 7, respectively. It can be seen that in general the turbidity increased during the backwash but after the backwash decreased to similar or slightly higher values than before the backwash. In some instances (possibly when the sludge bed has risen to the level of the backwash pipe) the turbidity after the backwash was less than before the backwash. This indicated that the backwash does not irreversibly disturb the sludge bed.
There is no flow control to each individual PBC; flow distribution depends on the static head in the individual PBC feedwell. The drop in head during a backwash means there is a potential for uneven distribution during a backwash which could potentially influence performance. Volume balances on the individual PBC's during backwashing showed that

the units were collectively receiving 40 $m^3$/hr during backwashing. This equates to 14 $m^3$/hr per PBC, or an increase in linear rise velocity of 0.3 m/hr which was considered to have minimal effect.

The following conclusions were drawn from these investigations:

- Media is blinding due to the segregation of fine media particles at the bottom of the bed
- The internals of the PBC were not causing an obstruction to flow
- The sludge bed was not irreversibly disturbed during backwashing
- The flow distribution between the PBC's did not increase significantly during backwashing

The media supplied was not to specification, as a large amount of media was found below the specified 2 to 3 mm. It was thus decided to replace all the media in the PBC's to the correct size fraction.

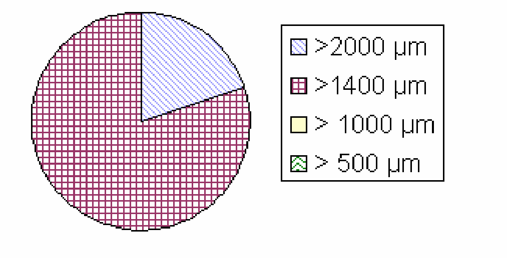
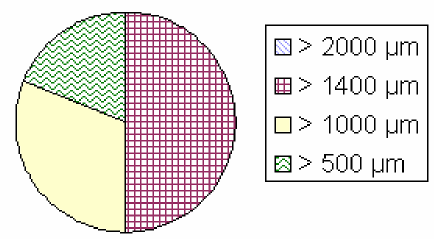
| | |
|---|---|
|  |  |
| ***Reference media*** | ***Media from lumps*** |

**Figure 3: Particle size analysis of reference media and media found in lumps**

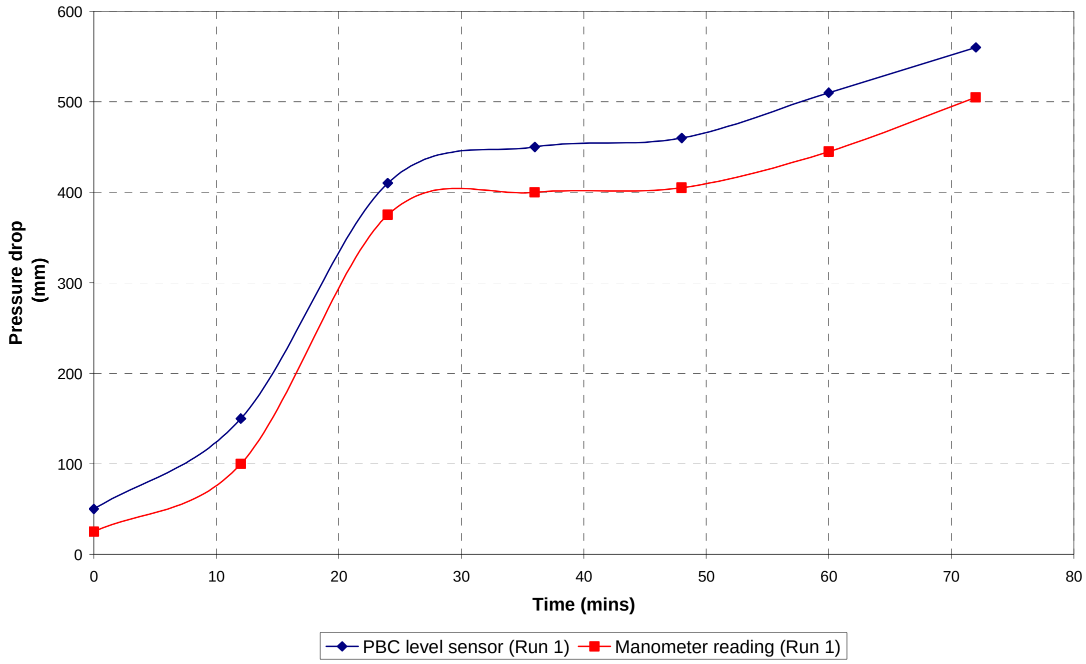



**Figure 4: Pressure drop over PBC as given by feedwell level sensor and manometer (taken from Le Riche, 2009)**

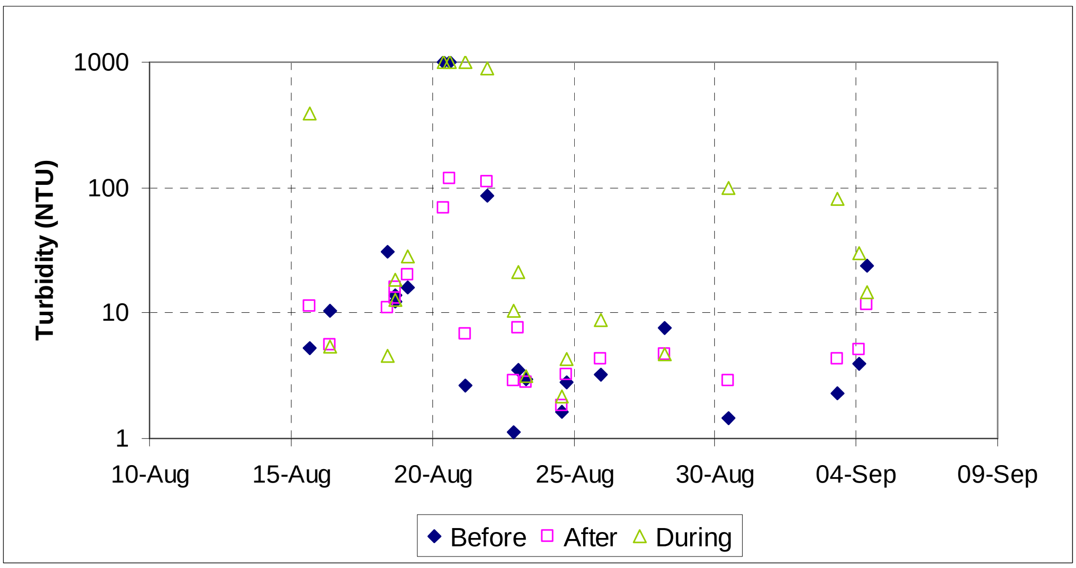



**Figure 5: PBC1 turbidity analysis before, during and after backwashing**

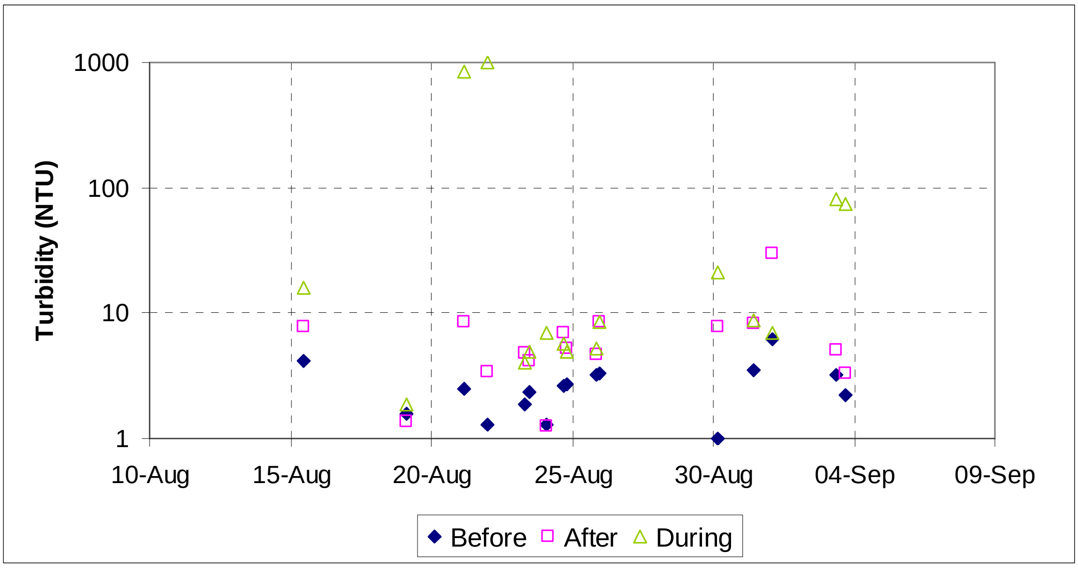



**Figure 6: PBC2 turbidity analysis before, during and after backwashing**

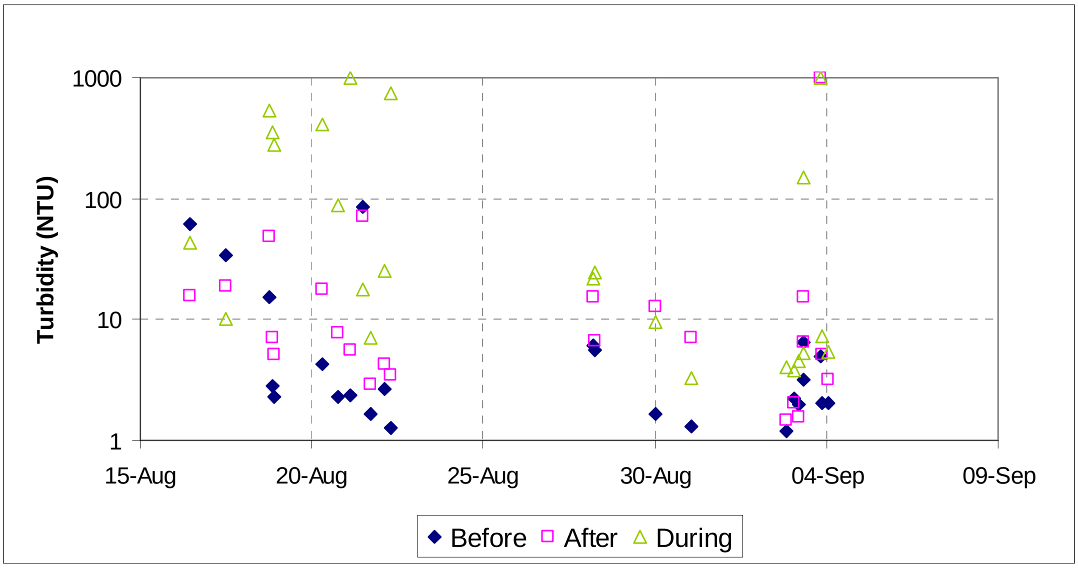



**Figure 7: PBC3 turbidity analysis before, during and after backwashing**

### 4.1.2. Sludge removal point optimisation

During commissioning it was seen that the backwash solution had a high solids content. The purpose of backwashing was to loosen the solids in the media bed so they may fall back into the sludge bed, not to remove solids from the system. The sludge removal point was situated at the top of the cone as in the pilot plant there was not a concentration gradient of sludge within the cone. However, on the large scale units a large concentration gradient existed as seen in Figure 8. Carrying out mass balance over the system showed there was insufficient solids removal when running the sludge removal pump at its maximum speed. It was proposed that the sludge removal be moved to the tip of the cone to effect better solids removal at nominal sludge removal pump speeds. The mass balances for the two situations are shown in Figure 9.

The risk in moving the sludge removal point from point N6 to point N11 is that the sludge bed may be pumped out. To mitigate this risk the turbidity analyser at point C needs to be closely monitored. A controlled test was done prior to moving the sludge removal point whereby sludge was drained out of the cone at ~2 $m^3$/hr and the turbidity at point C was monitored to see if it could be used as a control. As seen in Figure 10, turbidity readings could be used as a control system provided the turbidity sample pots are kept clean

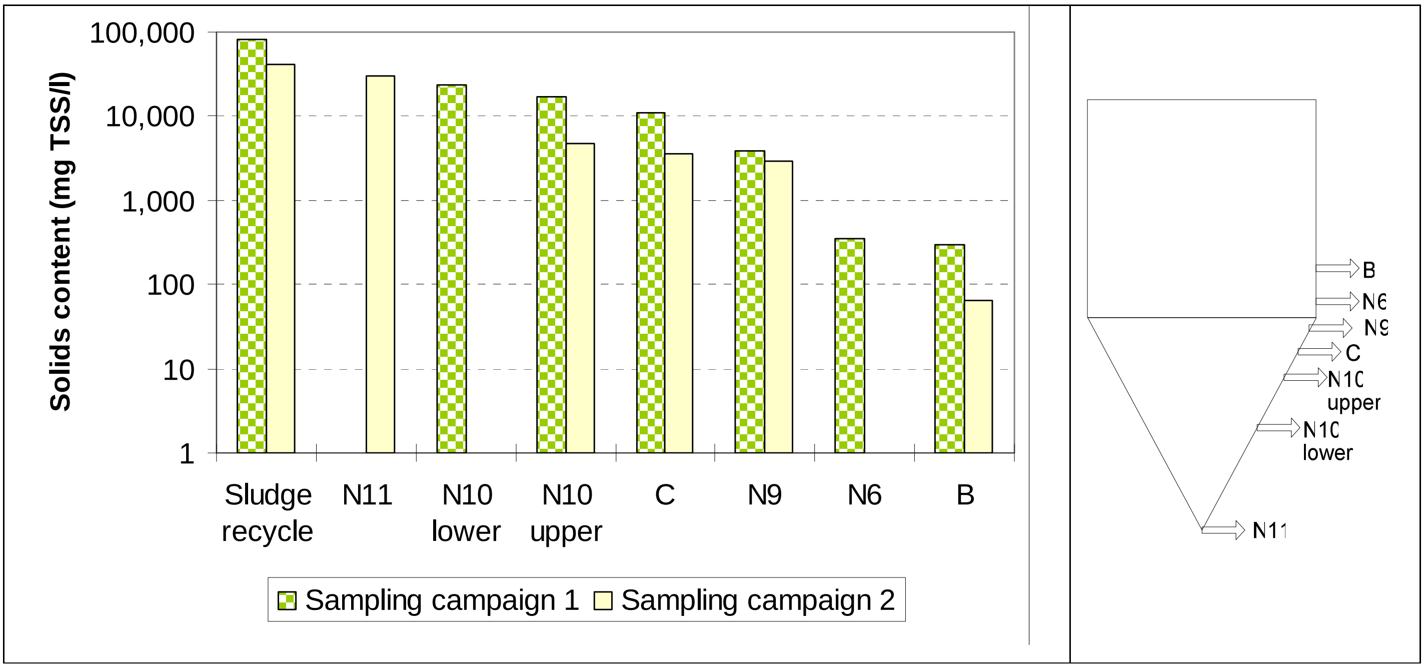
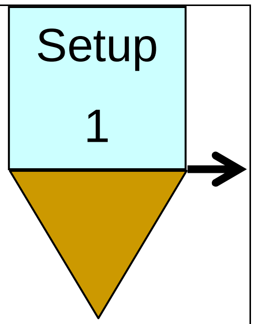


**Figure 8: Solids content profile in PBC cone**

| | IN | | OUT | | |
|---|---|---|---|---|---|
| Setup 1 – actual mass balance | Feed | Coagulent | Overflow | Backwash every 7 hours | Sludge removal |
| Flow ($m^3$/hr) | 337 | | 322 | 12 | 3 |
| Concentration ($g/m^3$) | 85 | 25 | 1 | 1,700 | 2,000 |
| Mass (kg/hr) | 29 | 8 | 0.3 | 21 | 6 |
| Total | 37 | | 27 | | |




| | IN | | OUT | | |
|---|---|---|---|---|---|
| Setup 2 – proposed mass balance | Feed | Coagulent | Overflow | Backwash every 12 hours | Sludge removal |
| Flow ($m^3$/hr) | 337 | | 329 | 7 | 1.0 |
| Concentration ($g/m^3$) | 85 | 25 | 1 | 1,000 | 30,000 |
| Mass (kg/hr) | 29 | 8 | 0 | 7 | 30 |
| Total | 37 | | 37 | | |

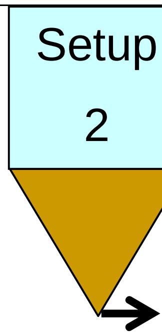



**Figure 9: Solids mass over the PBC's for different sludge removal points**

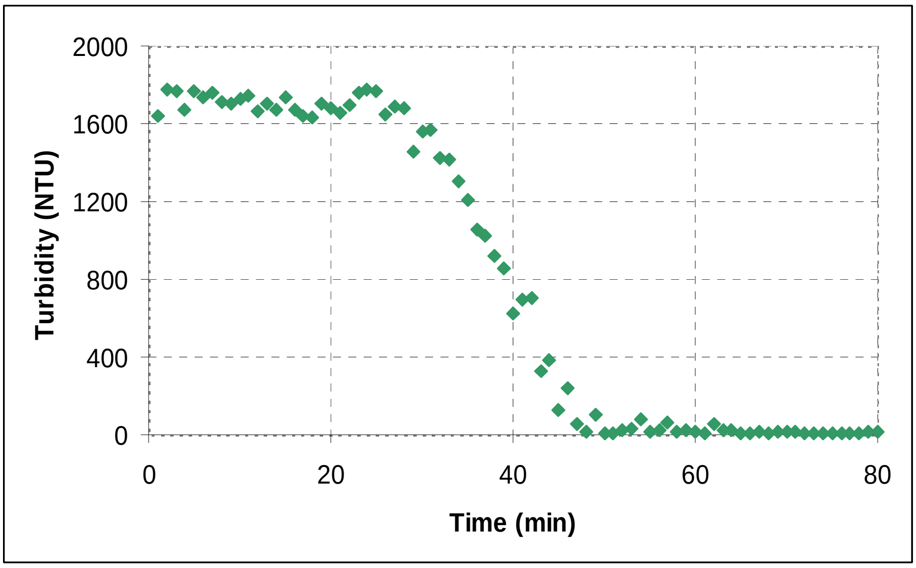



**Figure 10: Change in "B" turbidity reading as sludge is withdrawn**

### 4.1.3. Investigation into high overflow TSS

The problem of high TSS values reported in the overflow was also seen on the first pilot campaign. In the pilot campaign it was attributed to the formation of a silica precipitate on the filter paper. Recent testwork shown in Figure 11 found a strong correlation between filtration time in the laboratory during the gravimetric procedure to determine TSS and flocculent concentration in the sample being analysed (Plaatjies, 2010). From Figure 11 it can also be seen that a PLS sample records higher TSS values at higher flocculent concentrations. Although the exact mechanism of how flocculent is influencing the results, is not clear, it is concluded that flocculent concentration is interfering with the method. Thus turbidity measurements are taken in conjunction with TSS analysis.

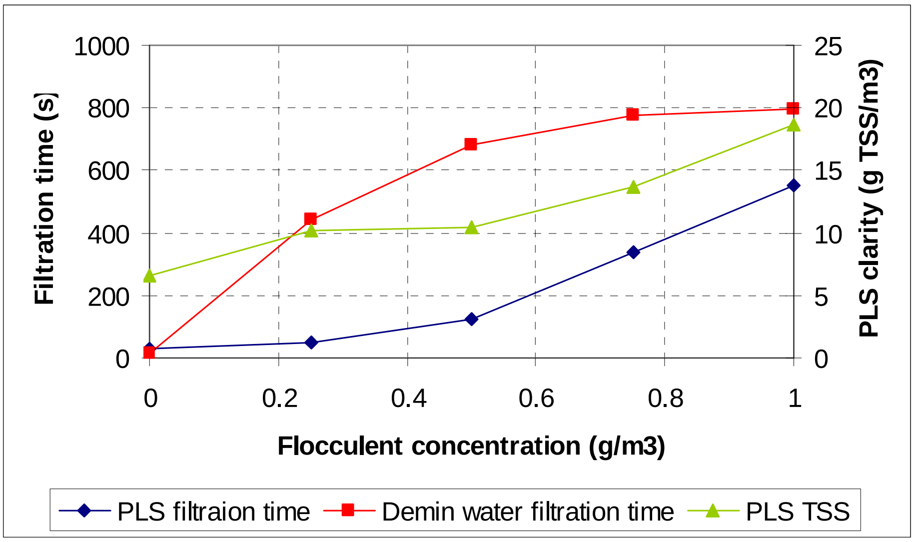



**Figure 11: Effect of flocculent concentration on filtration time and TSS (adapted from Plaatjies, 2010)**

### 4.1.4. Solids accumulation on the PBC cone

The reduction in backwash cycle time was generally associated with a loss in solids in the recycle stream. In general the following sequence of events happens:

- Solids in the recycle stream drawn from the cone “disappear”. This is seen by a clear discharge into the high energy mixing tank and a lack of flocs in the low energy mixing tank.

- This is often accompanied by the formation of a scum layer (coagulent in appearance) in the feedwell and/or the low energy mixing tank.
- In general the mid-bed samples remain clear but the time between backwashes decreases.

The “disappearance” of the solid particles in the recycle stream happens concomitantly with the formation of a sticky layer of coagulent coloured solids on the sides of the cone. It was concluded that solids settled out and stuck to the cone walls and building up in the cone till a “wormtail” or “rat-hole” has formed in the sludge bed. Once this wormtail has formed, solution with low solids content is drawn from the bottom of the cone. When no solids are recycled as seed to the PBC feed, fine flocs are formed that have a reduced settling rate. This results in more flocs reaching the media bed, increasing the load on the media bed hence increasing backwash frequency. Solids sticking to the side of the cone could be caused by several factors, including cone angle, roughness of the cone surface and surface characteristics of the solid particles. It was proposed that over-flocculation causes the solids to stick to the cone. In February the flocculent make-up was changed from 0.3% to 0.2%. The flocculent dosage to the PBC’s was reduced from 2 $g/m^3$ to 1 $g/m^3$.

### 4.1.5. Reagent dosing

Reagent dosing positions as laid out in third pilot campaign (as shown in Figure 2) were confirmed to be optimal as measured by overflow turbidity and period between backwashes. The coagulent dosing rate of 25 $g/m^3$ was also confirmed to be optimal (Plaatjies, 2010). Following the testwork on the high TSS values and occurrence of sticky solids in the cone the flocculent dosing rate was reduced to 1 $g/m^3$.

### 4.1.6. Sludge releach efficiency

The difference in zinc tenor between feed and product streams of re-leach do not show any appreciable change. However, at pH 2, other elements such as magnesium are leached from the coagulent. The decision was thus taken to increase the re-leach setpoint to pH 3.

# 5 PBC operational performance

## *5.1. Quantity and quality of PLS supplied to SX by PBC's*

The performance of the PBC's under operations control is tracked from 26 October 2009, after the PBC's had been loaded with new media, to August 2010. From Figure 12 it can be seen that from October to February the PBC's struggled provide SX with clarified PLS, treating between 34% and 83% of the total PLS requirement. The performance of the PBC's improved markedly after February and this is thought to be due to the reduction in flocculent dosage which reduced the occurrence of solids accumulating in the cone and hence the amount of downtime associated with cleaning and draining the cone. From March to August 2010 the PBC's were occasionally bypassed which resulted in less than 100% clarified PLS supplied to SX. Approximately 50% of the time the PBC's were bypassed to increase the level in the PLS storage tanks. The bypassing of the PBC's appears unnecessary as seen in Figure 14 the PBC's have not yet been operated at the design linear rise velocity of 8 m/hr. The average linear rise velocity for March to August 2010 is 6.9 m/hr. Discussions with production management confirmed that the PBC's are not operated beyond nominal flows of 1011 $m^3$/hr (7.1 m/hr).

Figure 12 compares the PLS clarity of the feed to the PBC's to the clarity of the PLS supplied to SX. The PLS clarity supplied to SX is clearly affected by the amount of PLS treated by the PBC's. From March to August when the PBC treated in excess of 90% of PLS required by SX the average clarity was 16 g TSS/$m^3$ or 2.7 NTU. The solids removal efficiency is 95% based on an average feed turbidity of 50 NTU.

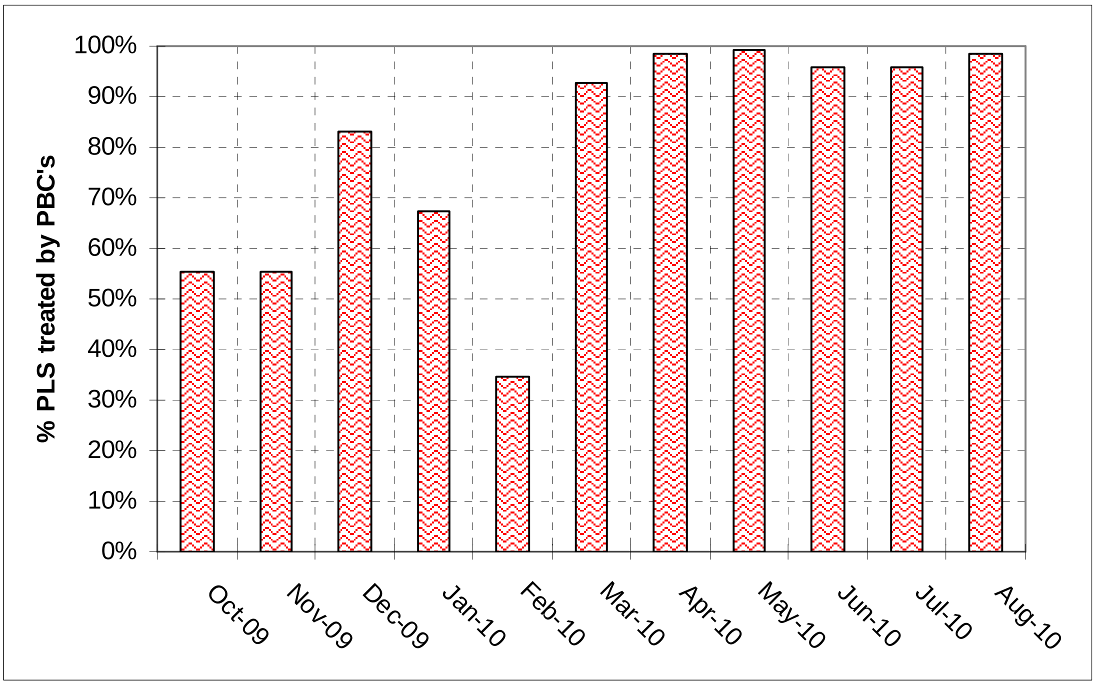



**Figure 12: PBC performance as a function of % PLS delivered to SX**

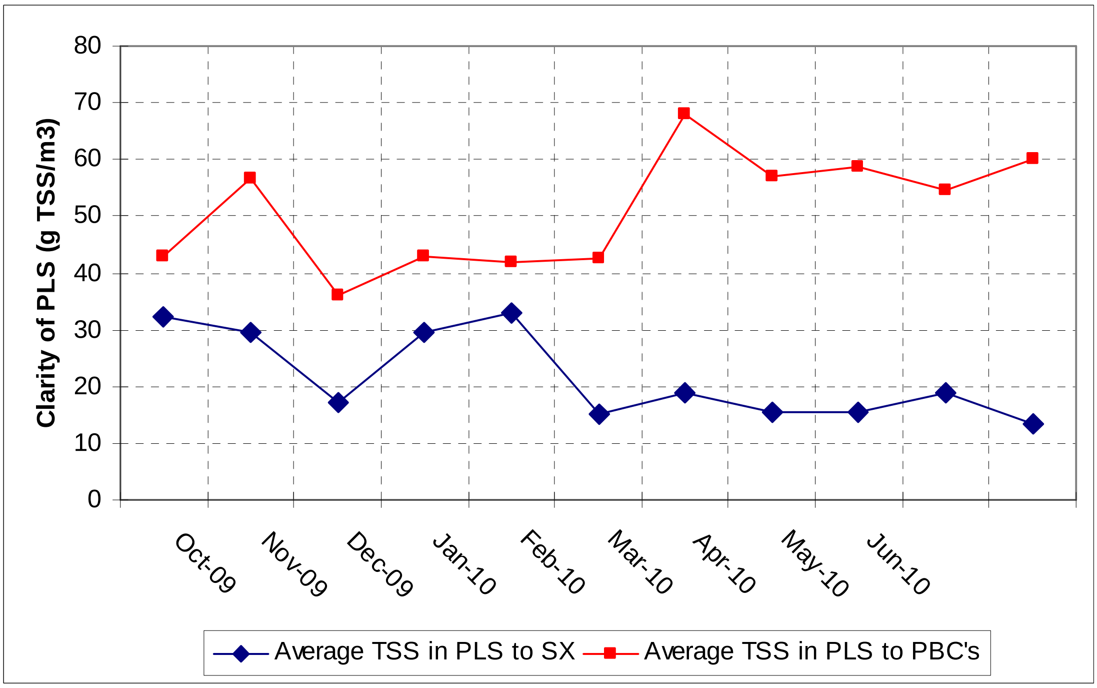



**Figure 13: PBC feed TSS compared to TSS carryover to SX**

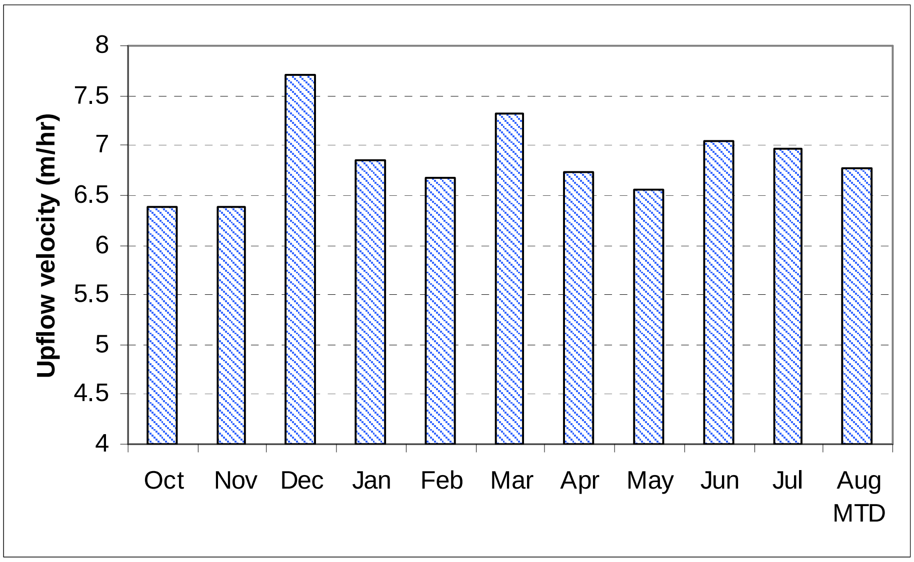



**Figure 14: Monthly average linear rise rates for PBC's**

### *5.2. PBC downtime analysis*

The reasons for the PBC downtime are shown in Table 5 and it is seen that from November to March at least 1 PBC was taken offline for 6 to 12 days and drained to remove solid build up in the cone. Removing the solids on the cone requires draining the PBC through the cone, cleaning the bund of the discharged slurry, scraping the media out with a wooden "gwala" and then spraying the internals with a high pressure hose. The media is then reloaded following the supplier's procedure. The whole process takes ~5 days per PBC.

At the beginning of March it was decided to replace the media in PBC 1 as the media had blinded. The replacement of the media was done with the other two PBC's online and over this period these units provided 93% of the clarified PLS requirement. The units operated at a linear rise velocity of 9.6 m/hr for approximately 1 week. Figure 15 shows the effect of higher linear rise rates on time between backwashes. The decrease in time between backwashes at the higher linear rise velocities and its subsequent increase at lower linear rise velocities when PBC 1 came back online show that operation at higher linear rise velocities is possible for short periods only.

From November 2009 to February 2010, considerable mechanical downtime was experienced. The two major jobs were replacing the seals on the media retaining wedges and repairing holes in PBC 1 and PBC 3. It is thought the lining of the PBC's were damaged during media removal and thus softer implements were brought into use. This downtime was mainly due to construction related issues and is not expected to occur in future.

**Table 5: Reasons for extended PBC downtimes**

| ***From*** | ***To*** | ***Units taken offline*** | ***No of days offline*** | ***Reason for process downtime*** | ***Reason for mechanical downtime*** |
|---|---|---|---|---|---|
| 09-Sep-09 | 26-Oct-09 | All | 47 | New media installed in all PBC's | |
| 13-Nov-09 | 17-Nov-09 | All | 4 | Drain and clean cone of PBC3 PBC 1 media-retaining screens cleaned | Repair hole in PBC 3 Seals installed on all PBC's media-retaining screens |
| 20-Nov-09 | 03-Dec-09 | All | 13 | | |
| 23-Dec-09 | 05-Jan-10 | PBC3 | 17 | Drain anc clean cone of PBC 3 | Repair hole in PBC3 |
| 18-Jan-10 | 25-Jan-10 | All | 7 | Drain and clean cone of all PBC's | Repair hole in backwash return line and PBC 1. Inspect and repair PBC1 backwash valve. |
| 10-Feb-10 | 02-Mar-10 | All | 20 | Drain and clean cone of all PBC's. Remove lumps from media. | |
| 10-Mar-10 | 19-Mar-10 | PBC1 | 9 | Drain, clean cone and replace media in PBC1. | |

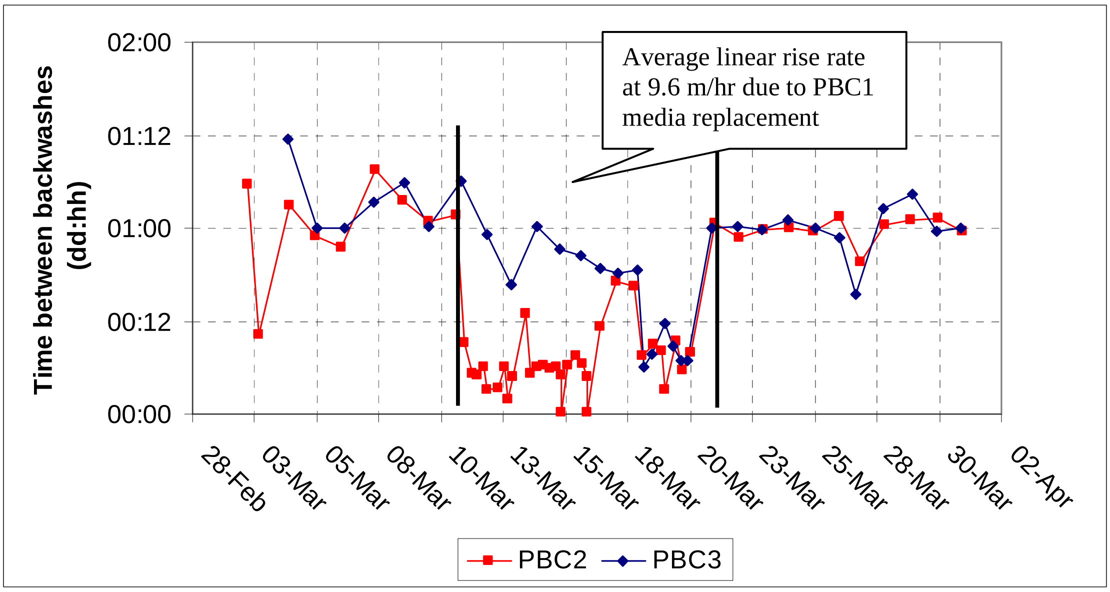



**Figure 15: Period between backwashes for PBC 2 and 3 before during and after PBC 1 media replacement**

### *5.3. Backwash frequency*

The monthly average time between backwashes is shown in Figure 16. Operation from November to February was erratic and in general the following trend was seen:

- Periods between backwashes are initially good approaching the target of 24 hours.
- Thereafter, the time period decreases and the unit is taken offline and cleaned
- The performance is restored temporarily

The operation from March to August has been excellent with times between backwashes averaging 11 to 22 hours. The improvement in time between backwashes is thought to be linked the reduction in flocculent concentration and the concomitant reduction in solids build up on the cone. The decrease in time between backwashes from May to August requires monitoring and should this trend be caused by loss of solids in the recycle due to accumulation on the cone then a mechanical solution may be necessary *e.g.* cone rake.

It has been found that cleaning the screens of the PBC's can often help restore the time between backwashes as shown in Figure 17. The cleaning of the PBC screens occurs on an *ad hoc* basis approximately once a month. The process takes ~2 hours per PBC during which the flow to the other two PBC's is generally reduced.

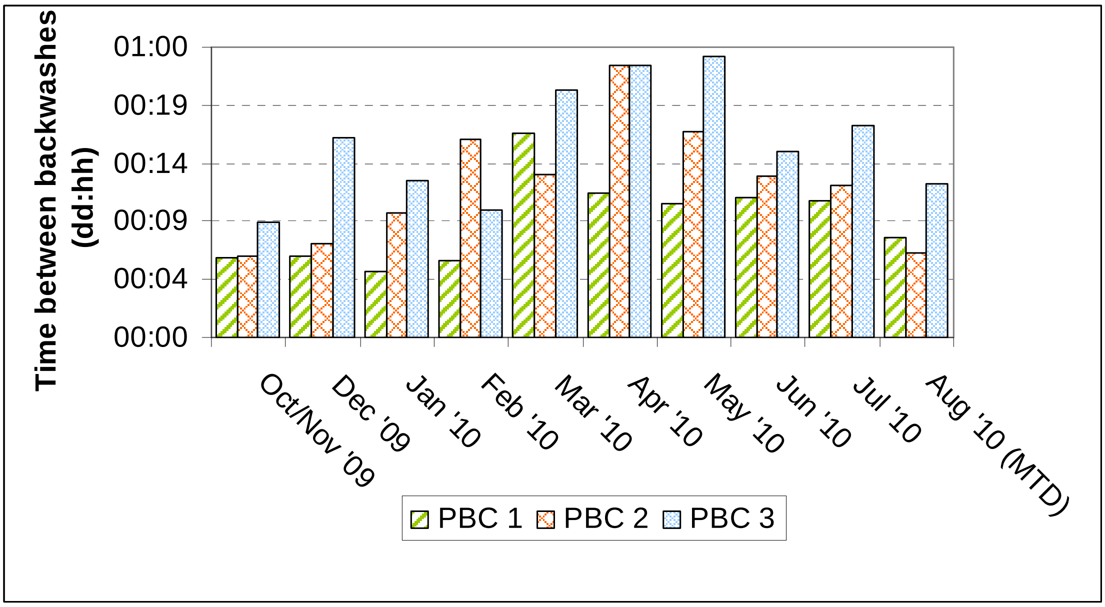



**Figure 16: Monthly average time between backwashes for PBC's**

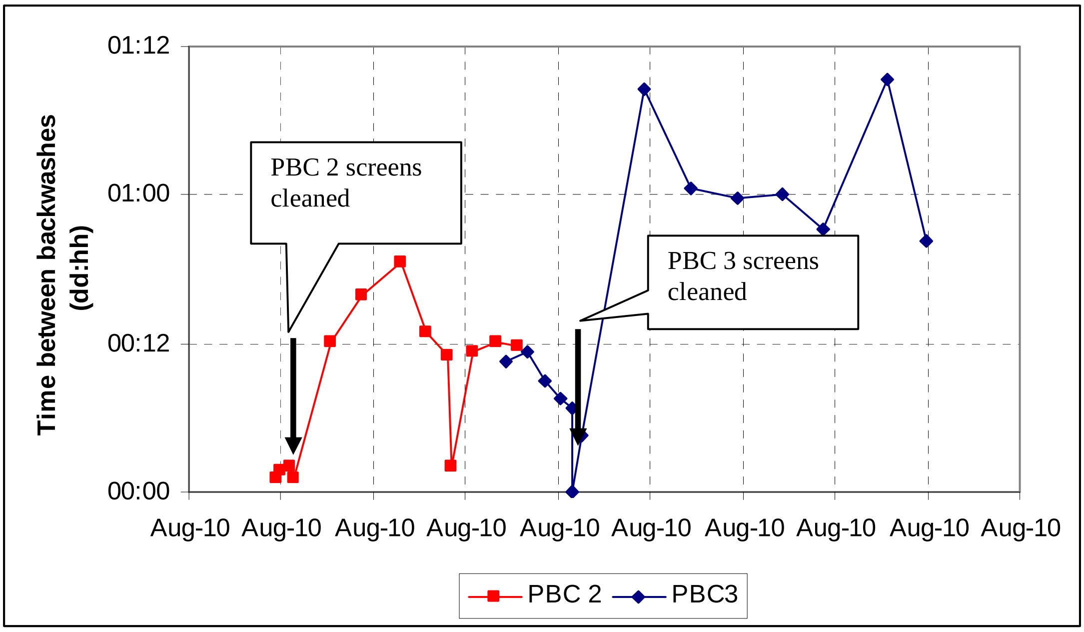



**Figure 17: Effect of cleaning screens on time between backwashes**

# 6 Conclusions

The three piloting campaigns formed a basis for the design and operation of the industrial scale PBC's. During commissioning key learnings and improvements were made, *viz.* the effect of fine media leading to media blinding, moving the sludge removal point to the tip of the cone to effect better solids removal, effect of flocculent concentration on TSS results and reduction in flocculent dosage to prevent the build up of sticky solids on the PBC cone.

A marked improvement in PBC performance, in terms of percentage PLS required by SX, was seen in March 2010. This improvement was a result of cleaning the cones and internals of all three PBC's and reducing the flocculent make-up strength from 0.3% to 0.2% which reduced the flocculent dosage to the PBC's from 2 g/m$^3$ to 1 g/m$^3$. An increase in the period between backwashes was also seen from March onwards, with monthly averages ranging from 11 to 23 hours. The average TSS of the PLS supplied to SX from the PBC's is 16 g/m$^3$ or 2.7 NTU. The feed to PBC's over this period ranged from 36 to 68 g TSS/m$^3$. The solids removal efficiency based on turbidity measurements is 95%.

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