CSIR

DIVISION OF WATER ENVIRONMENT
AND FORESTRY TECHNOLOGY

Report to the

WATER RESEARCH COMMISSION

on

THE REMOVAL OF SUSPENDED SOLIDS FROM PULP AND PAPER EFFLUENTS BY EMPLOYING THE COMBINED SEDIMENTATION FLOTATION PROCESS

by

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PRETORIA

EXECUTIVE SUMMARY

In the pulp and paper industry significant concentrations of suspended solids are present in the effluent of these mills. Large volumes of these effluents are then disposed of into the environment where they can lead to widespread environmental damage. Suspended solids in the effluent of pulp and paper mills are comprised of both less dense particles (mainly fibres) and denser particles such as clay.

Modern dissolved air flotation (DAF) cells have been installed at a number of local mills. These achieve improved suspended solids removal, especially of the lighter organic fraction that do not easily settle. They are however, not effective at removing the denser inorganic solids. These solids tend to settle out in the flotation units and this leads to operational and maintenance problems.

The full scale application of conventional settling or clarification as a treatment process ahead of flotation is not economical. In addition, the sedimentation ahead of flotation can lead to anaerobic conditions in the settling tank.

In order to address these concerns, this project investigated, at pilot scale, the use of a compact inclined plate settler integrated ahead of a flotation cell. The advantage of this configuration is the high rate of sedimentation coupled to the shorter solids retention time within the unit.

The most significant conclusions of this study are that high percentages of removal for suspended solids can be obtained with the combined SEDIDAF process; the settling stage of the process contributes most to the overall removal of solids from the effluent; effective suspended solids removal can be obtained with settling in an inclined plate settler at surface loading rates as high as 10.9 m/h; improved suspended solids removal is obtained at lower flotation zone velocities in the DAF stage; the DAF stage does not only remove the organic fraction of the suspended solids but also inorganic particles; and, the settling stage does not only remove the inorganic fraction of the suspended solids, but also organic particles.

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This report is the product of the efforts of many individuals. Gratitude goes to each person involved in the research and preparation of this report.

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Mr E Goosen	:	Nampak Rosslyn

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LIST OF ABBREVIATIONS

COD	:	Chemical oxygen demand
DAF	:	Dissolved air flotation
NIWR	:	National Institute for Water Research
SEDIDAF	:	Combined process of sedimentation and dissolved air flotation
TSS	:	Total suspended solids

CHAPTER 1: INTRODUCTION AND OBJECTIVES OF THE STUDY

1.1 INTRODUCTION

1.1.1 Extent and significance of the problem

In the pulp and paper industry significant concentrations of suspended solids are present in the effluent of these mills. Large volumes of these effluents are then disposed of into the environment where they can lead to widespread environmental damage. Disposal of these effluent into rivers can lead to serious aesthetical problems, whilst the non-biodegradable fibres have a negative influence on the eco-system.

1.1.2 Background

Suspended solids in the effluent of pulp and paper mills are comprised of both less dense particles (mainly fibres) and denser particles such as clay. It is common practice for mills in South Africa to attempt to recover these suspended solids and to re-use the fibres together with raw materials. This is practised internally with the use of so-called "save-alls", or external to the process by means of treatment processes such as clarification, centrifugation and filtration.

These conventional treatment processes are not always effective at removing the fine suspended solids and concentrations of up to 250 mg/ℓ in treated effluents have been measured (WRC Report 106/1/87). If the particles are flocculated prior to sedimentation, anaerobic conditions develop as a result of the organic matter present. As a consequence H_2S forms and this leads to serious odour and corrosion problems.

Sveen Pedersen flotation cells are used worldwide to achieve better suspended solids removal. They are however generally not effective at achieving this.

Modern dissolved air flotation (DAF) cells have been installed at a number of local mills. These achieve improved suspended solids removal, especially of the lighter organic fraction that do not easily settle. They are however, not effective at removing the denser inorganic solids, like clay, that are present in the effluent. These solids tend to settle out in the flotation units and this leads to operational and maintenance problems.

The full scale application of conventional settling or clarification as a treatment process ahead of flotation is not economical. In addition, the sedimentation ahead of flotation will still lead to anaerobic conditions in the settling tank.

In order to address the above concerns, this project investigated, at pilot scale, the use of a compact inclined plate settler integrated ahead of the flotation cell. The advantage of this configuration is the high rate of sedimentation coupled to the shorter solids retention time within the unit. In addition, the flotation resulted in effective aeration of the effluent. Both of these reduced the likelihood of anaerobic conditions developing. A further advantage of this configuration, is that both the organic, less dense fraction and the inorganic dense fraction would be removed from the effluent typical in the pulp and paper industry.

1.2 OBJECTIVES

The objectives of this project were to:

- determine design parameters for the combined process of sedimentation and flotation for the removal of suspended solids from effluents in the pulp and paper industry

- determine the optimum ratio sedimentation to flotation for the effective removal of suspended solids.

CHAPTER 2: SEDIDAF PILOT PLANT AND EXPERIMENTAL DESIGN

2.1 DESCRIPTION OF PILOT PLANT

The pilot plant used in this investigation was the SEDIDAF plant that was designed and manufactured by the Division of Water Technology of the CSIR. The pilot plant consists of the following unit processes combined into an integrated water treatment plant:

- an adjustable baffled, plug-flow flocculation chamber, with in-line mixers for coagulant dosing and pH correction ahead of the flocculation unit
- a countercurrent inclined plate sedimentation unit
- an integrated dissolved air flotation-filtration unit. This unit uses the NIWR nozzles that are designed for the formation of microscopic air bubbles
- a sludge thickening grid at the surface of the flotation cell

The pilot plant is designed for a flow of $1 m^3/h$ and is schematically depicted in Figure 1.

It is possible to adjust the number of inclined plates in use in the sedimentation unit, and thereby adjust the settling velocity. By using different settings in the flotation unit, the reaction zone and flotation zone velocities can be altered. The quantity of air used in the flotation process is varied by adjusting the flow rate of the recycle stream or by adjusting the pressure in the saturator.

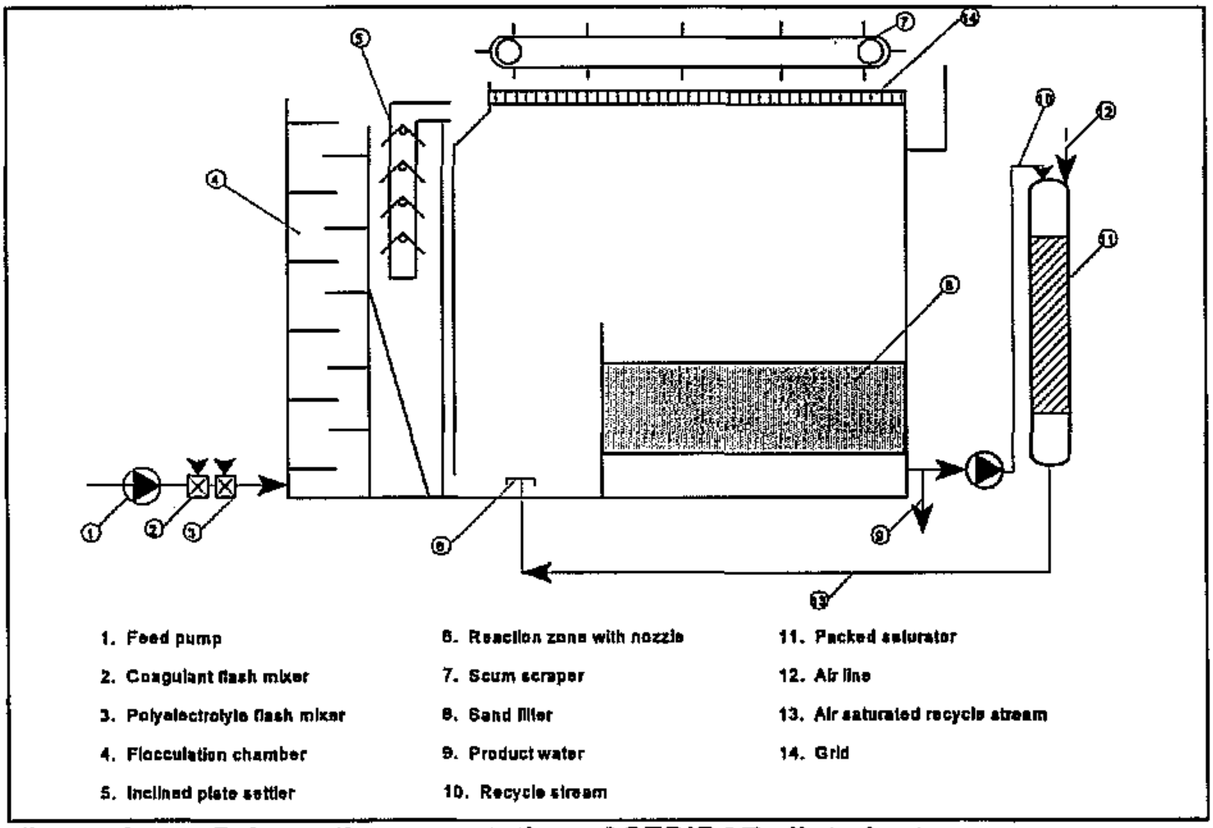

Figure 1: Schematic presentation of SEDIDAF pilot plant

2.2 EXPERIMENTAL DESIGN

The effects of the following parameters on the suspended solids removal efficiency were evaluated:

- Settling velocity

  The settling velocity is defined as the flow rate (in m^3/h) to the settler divided by the surface area (in m^2) of the settler

- Reaction zone velocity

  Reaction zone velocity is defined as the flow rate (in m^3/h) to the reaction zone of the DAF unit divided by the area (in m^2) of the reaction zone

- Flotation zone velocity

  The flotation zone velocity is defined as the flow rate (in m^3/h) to the flotation

The flotation zone velocity is defined as the flow rate (in m^3/h) to the flotation zone divided by the flotation zone surface area (in m^2). The flow rate used is the sum of the feed flow rate and the recycle flow rate

- Air quantity (as the saturator pressure remained constant this was varied by means of the recycle ratio)
  The air quantity is the amount of dissolved air introduced into the reaction zone by means of the air saturated recycle stream

The effect of each parameter was evaluated at a high value and a low value. This lead to a two level factorial experimental design with 2^4(16) experiments. The values used for the different parameters were; settling velocity 3.4 and 10.9 m/h, reaction zone velocity 40 and 80 m/h, flotation zone velocity 5 and 10 m/h and recycle ratio 20% and 40%. Table 1 presents the experimental design that was used for this investigation.

Table 1: Experimental design

Experiment no	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)
1	3.4	40	5	20
2	10.9	40	5	20
3	3.4	80	5	20
4	10.9	80	5	20
5	3.4	40	10	20
6	10.9	40	10	20
7	3.4	80	10	20
8	10.9	80	10	20
9	3.4	40	5	40

Experiment no	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)
10	10.9	40	5	40
11	3.4	80	5	40
12	10.9	80	5	40
13	3.4	40	10	40
14	10.9	40	10	40
15	3.4	80	10	40
16	10.9	80	10	40

CHAPTER 3: METHODOLOGY

3.1 EXPERIMENTAL SETUP

This investigation was conducted at the premises of Nampak Paper in Rosslyn, Pretoria. The feed to the SEDIDAF was taken from a large effluent collection tank prior to it entering the municipal sewer. The effluent was pumped to the pilot plant and the flow rate was kept constant at $1 m^3/h$ by means of a valve and feed flowmeter.

For each experimental run, the plant was set in operation and allowed to reach steady state. Jar flocculation tests were performed on a sample of the raw water to determine the optimum chemical dose for the conditions at the time of the experiment. A cationic polyelectrolyte (LT22) was then dosed at this rate on the pilot plant. The necessary adjustments to the various parameters were made to the plant at the commencement of each experimental run. It was previously determined that approximately 1 hour is required for the plant to reach steady state.

Samples of the effluent were taken at the following points on the pilot plant:

- raw effluent (feed to the plant)
- after settling
- after flotation

3.2 ANALYSES AND DATA INTERPRETATION

The following analyses were performed on each of the samples; pH, suspended solids (TSS), chemical oxygen demand (COD) and ash content. The analyses were conducted according to the standard methods (APHA *et al*, 1985).

As the effluent quality varied dramatically, the results for each of the experimental runs was recalculated to reflect the percentage removed in an attempt to make the comparison of the data possible. The following formula was used:

$$\% \, removal = \frac{Ci - Ca}{Ci} x\, 100$$

where: Ci = concentration in feed

Ca = concentration after treatment stage

CHAPTER 4: RESULTS

The percentage removal of the various constituents is presented in this section. The actual analytical results on which the removals were calculated are given in Appendix A.

4.1 SUSPENDED SOLIDS REMOVAL

The removal obtained in the different sections of the pilot plant as measured by suspended solids is presented in Table 2. This data is graphically presented in Figures 2 to 5.

Table 2: Suspended solids removal

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	Suspended solids removal (%)
Raw After settling After DAF	10.9	40	5	20	15 69
Raw After settling After DAF	3.4	40	5	20	87 61
Raw After settling After DAF	10.9	40	5	40	8 88
Raw After settling After DAF	3.4	40	5	40	73 85
Raw After settling After DAF	10.9	40	10	20	22 62

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	Suspended solids removal (%)
Raw After settling After DAF	3.4	40	10	20	0 82
Raw After settling After DAF	10.9	40	10	40	48 91
Raw After settling After DAF	3.4	40	10	40	12 91
Raw After settling After DAF	10.9	80	5	20	34 78
Raw After settling After DAF	3.4	80	5	20	31 83
Raw After settling After DAF	10.9	80	5	40	81 88
Raw After settling After DAF	3.4	80	5	40	86 89
Raw After settling After DAF	10.9	80	10	20	72 92
Raw After settling After DAF	3.4	80	10	20	83 88
Raw After settling After DAF	10.9	80	10	40	70 87
Raw After settling After DAF	3.4	80	10	40	76 83

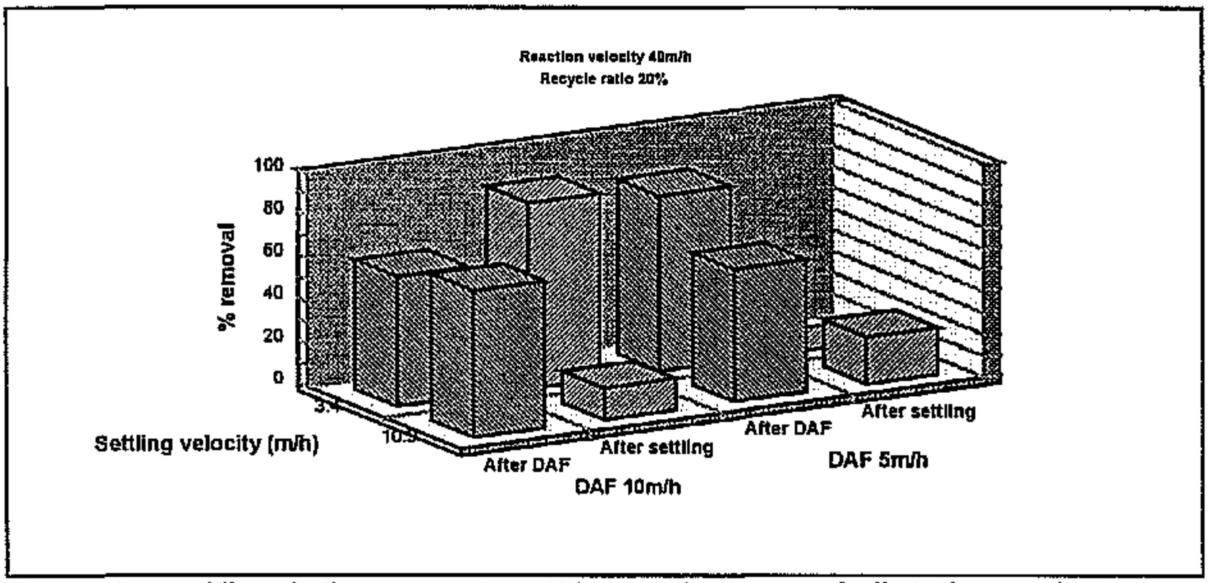

Figure 2: The influence of settling velocity and flotation velocity on suspended solids removal at a reaction zone velocity of 40 m/h and a recycle ratio of 20%.

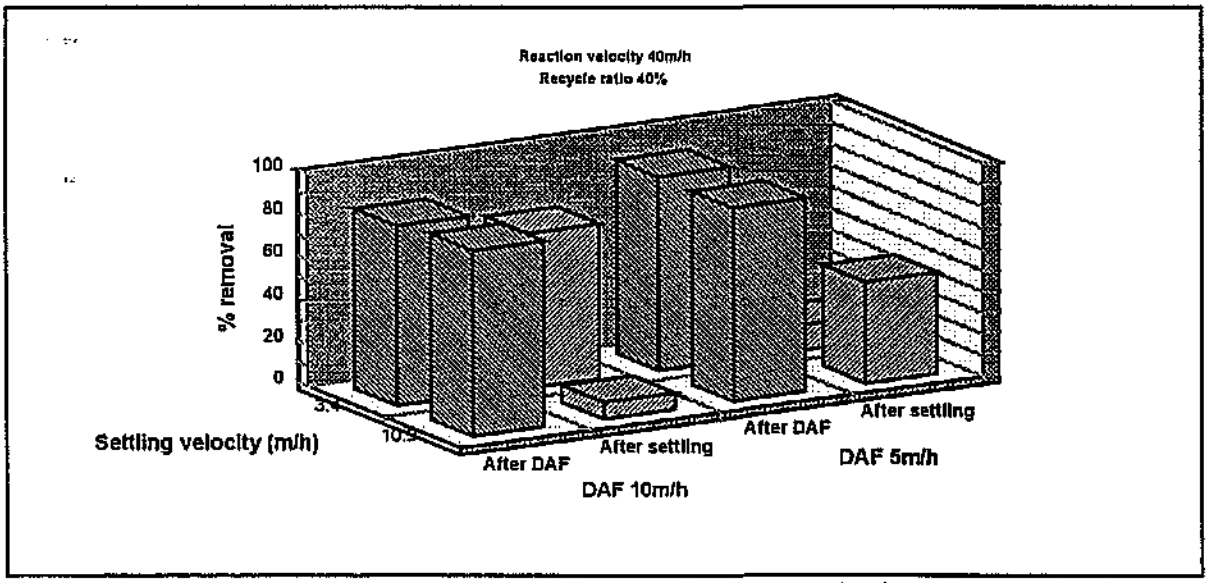

Figure 3: The influence of settling velocity and flotation velocity on suspended solids removal at a reaction zone velocity of 40 m/h and a recycle ratio of 40%.

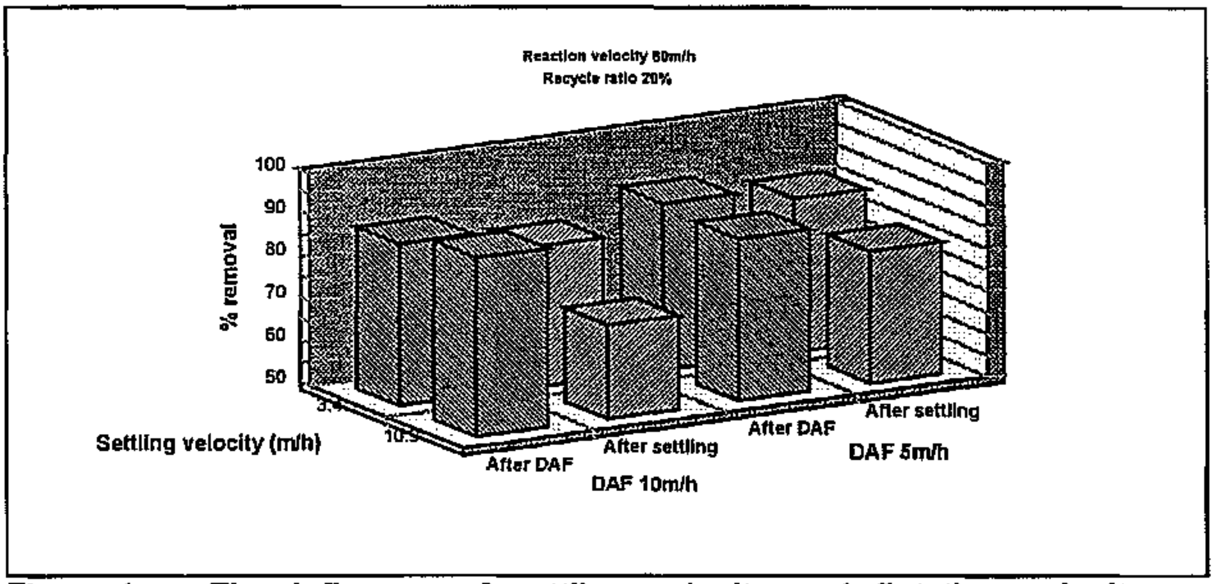

Figure 4: The influence of settling velocity and flotation velocity on suspended solids removal at a reaction zone velocity of 80 m/h and a recycle ratio of 20%.

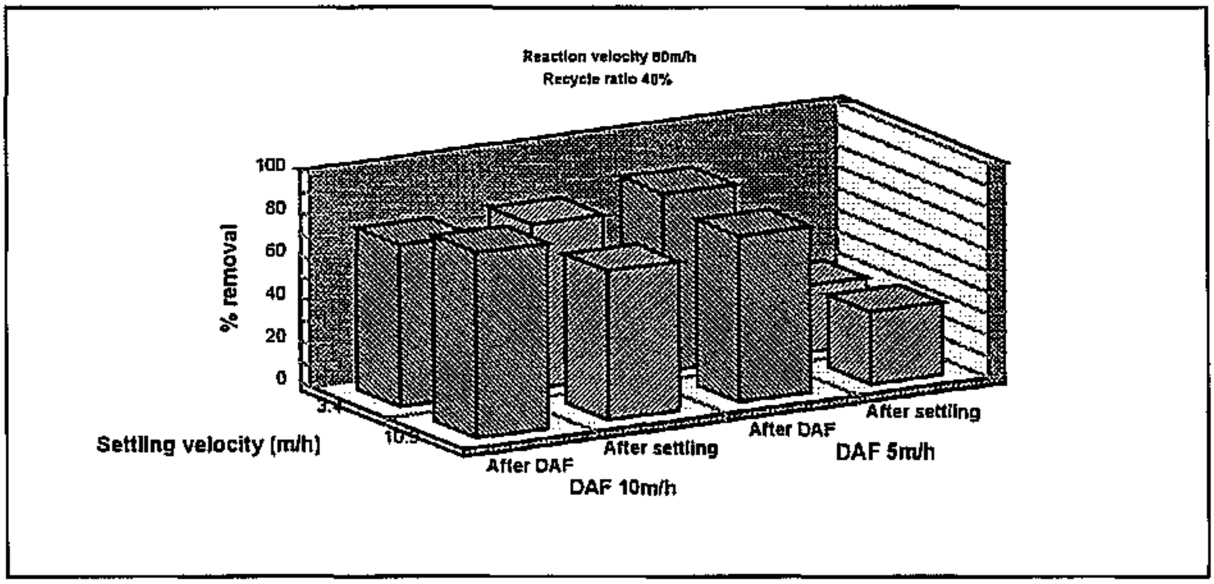

Figure 5: The influence of settling velocity and flotation velocity on suspended solids removal at a reaction zone velocity of 80 m/h and a recycle ratio of 40%.

4.2 CHEMICAL OXYGEN DEMAND REMOVAL

The removal obtained in the different sections of the pilot plant as measured by the COD is presented in Table 3.

Table 3: Chemical oxygen demand removal

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	COD removal (%)
Raw					
After settling	10.9	40	5	20	10
After DAF					19
Raw					
After settling	3.4	40	5	20	30
After DAF					28
Raw					
After settling	10.9	40	5	40	0
After DAF					7
Raw					
After settling	3.4	40	5	40	20
After DAF					29
Raw					
After settling	10.9	40	10	20	20
After DAF					20
Raw					
After settling	3.4	40	10	20	10
After DAF					25
Raw					
After settling	10.9	40	10	40	30
After DAF					31
Raw					
After settling	3.4	40	10	40	18
After DAF					24

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	COD removal (%)
Raw After settling After DAF	10.9	80	5	20	13 22
Raw After settling After DAF	3.4	80	5	20	18 25
Raw After settling After DAF	10.9	80	5	40	16 13
Raw After settling After DAF	3.4	80	5	40	17 16
Raw After settling After DAF	10.9	80	10	20	13 15
Raw After settling After DAF	3.4	80	10	20	16 15
Raw After settling After DAF	10.9	80	10	40	19 16
Raw After settling After DAF	3.4	80	10	40	13 10

4.3 ASH CONTENT REMOVAL

The removal obtained in the different sections of the pilot plant as measured by ash content is presented in Table 4.This data is graphically presented in Figures 6, 7 and 8.

Table 4: Ash content removal

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	Ash content removal (%)
Raw After settling After DAF	10.9	40	5	20	
Raw After settling After DAF	3.4	40	5	20	
Raw After settling After DAF	10.9	40	5	40	0 0
Raw After settling After DAF	3.4	40	5	40	
Raw After settling After DAF	10.9	40	10	20	
Raw After settling After DAF	3.4	40	10	20	0 85
Raw After settling After DAF	10.9	40	10	40	51 65
Raw After settling After DAF	3.4	40	10	40	14 92
Raw After settling After DAF	10.9	80	5	20	37 87
Raw After settling After DAF	3.4	80	5	20	38 92
Raw After settling After DAF	10.9	80	5	40	97 97

Sample position	Settling velocity (m/h)	Reaction zone velocity (m/h)	Flotation zone velocity (m/h)	Recycle ratio (%)	Ash content removal (%)
Raw After settling After DAF	3.4	80	5	40	93 79
Raw After settling After DAF	10.9	80	10	20	72 91
Raw After settling After DAF	3.4	80	10	20	94 94
Raw After settling After DAF	10.9	80	10	40	68 85
Raw After settling After DAF	3.4	80	10	40	77 74

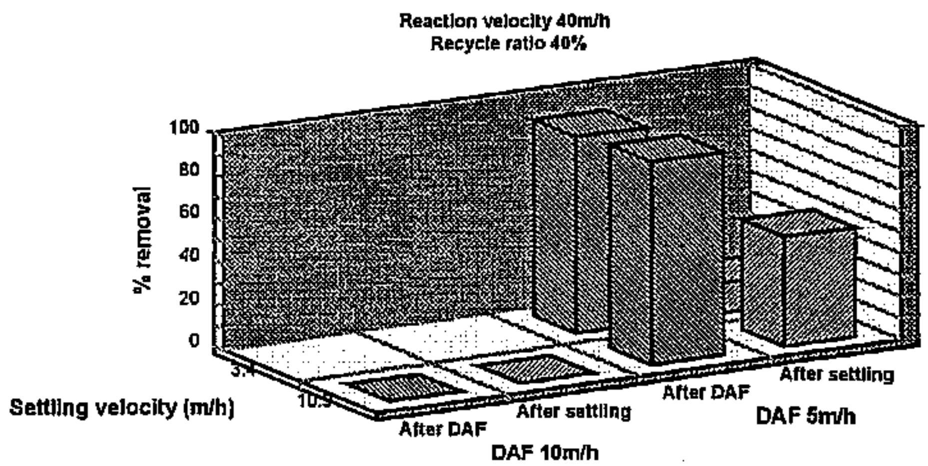

Figure 6: The influence of settling velocity and flotation velocity on ash content removal at a reaction zone velocity of 40 m/h and a recycle ratio of 40%.

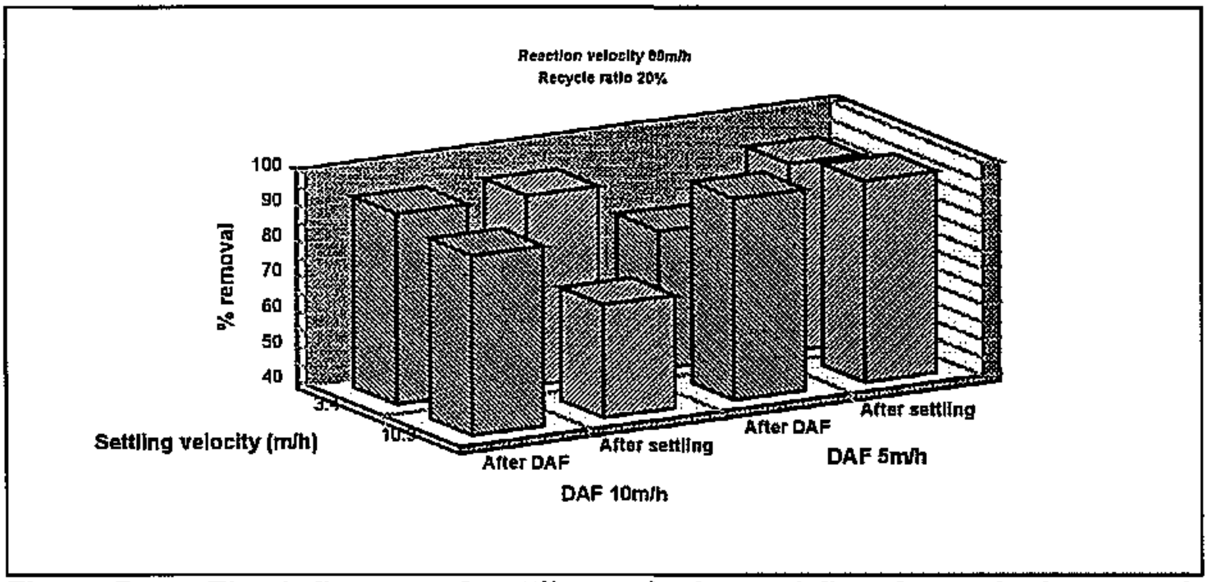

Figure 7: The influence of settling velocity and flotation velocity on ash content removal at a reaction zone velocity of 80 m/h and a recycle ratio of 20%.

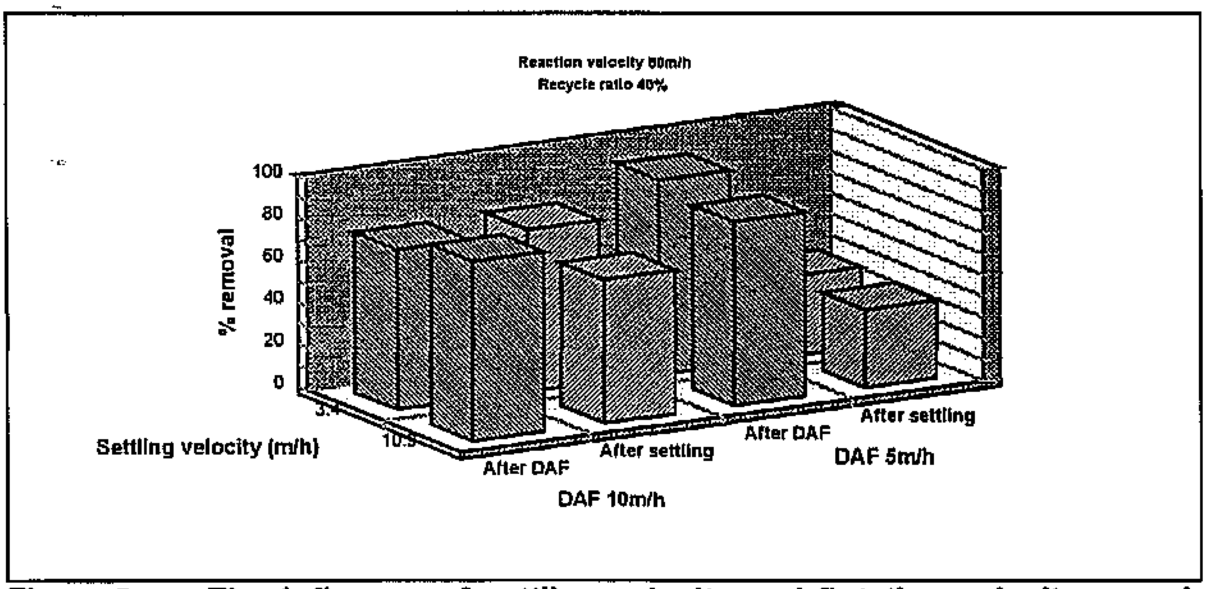

Figure 8: The influence of settling velocity and flotation velocity on ash content removal at a reaction zone velocity of 80 m/h and a recycle ratio of 40%.

CHAPTER 5: DISCUSSION

5.1 SUSPENDED SOLIDS

The suspended solids concentration of the effluent showed considerable variation. The highest concentration measured was 3 372 mg/ℓ and the lowest concentration measured was 942 mg/ℓ. This large variation in suspended solids concentration made it difficult to compare results obtained during different experimental conditions. The calculation of percentage removal was used in an attempt to be able to compare the results from the different experiments. This large variation in suspended solids concentration was not only experienced during different experiments, but also during the execution of individual experiments.

The highest overall (ie. after DAF) suspended solids removal obtained was 92% and the lowest was 62%. The DAF stage of the treatment process contributed between 3 and 82% of the suspended solids removal. The average suspended solids removal for the settling stage was 50% and the average suspended solids removal for the DAF stage was 36%. The value for the DAF is however, skewed by a few high values. For eight of the sixteen experiments the DAF stage contributed to no more than 20% of the overall suspended solids removal. The highest suspended solids removal by the settling stage was 87% and for eight of the sixteen experiments the settling stage accounted for more than 70% of the overall suspended solids removal.

Whilst not conclusively shown with the results obtained, Figures 2 to 5 present evidence that there is a slight decrease in the overall suspended solids removal at the higher flotation velocity of 10 m/h. The effect of settling velocity is not clear, as for some of the experiments, higher removal is obtained after settling at the higher settling velocity of 10.9 m/h, but for other experiments better suspended solids removal is obtained at the lower settling velocity of 3.4 m/h.

Unfortunately no clear pattern emerges as to under which conditions the higher settling velocity is feasible.

At the reaction zone velocity of 40 m/h, improved suspended solids removal is obtained with a larger air quantity (ie. recycle ratio). This effect is more evident at the higher flotation zone velocity of 10 m/h. At a higher reaction zone velocity (80 m/h) a decrease in suspended solids removal is observed at larger air quantities. This may indicate that the additional recycle stream that enters the reaction zone together with the high velocity in this zone, leads to excessive turbulence and the subsequent decrease in performance.

5.2 CHEMICAL OXYGEN DEMAND

The COD of the effluent showed similar variation as that of the suspended solids. The maximum COD concentration measured was 11 240 mg/ℓ and the minimum COD concentration measured was 5 790 mg/ℓ. The COD concentration was closely related to the suspended solids concentration, in that high concentrations of suspended solids also resulted in high concentrations of CODs.

The combined sedimentation dissolved air flotation (SEDIDAF) process was not effective at reducing the COD of the effluent. The highest overall COD removal obtained was 31% and the lowest was 7%. The average overall COD removal was 20%.

The settling stage of the process contributed the most to the overall COD reduction, with the DAF stage on average only resulting in an additional 4% removal of COD. These results indicate that once the particulate fraction of the COD is removed, the remaining soluble fraction passes through the treatment process. The soluble COD fraction of this effluent is high and the SEDIDAF process as used during this study was not suitable for reducing the COD by any significant amount.

5.3 ASH CONTENT

The ash content of the effluent was determined as a measure to quantify the inorganic fraction of the suspended solids. The ash content expressed as a percentage of the suspended solids was consistent at a value between 10 and 12%. There was one occasion when the ash content comprised 29% of the suspended solids in the effluent.

The ash percentage of the suspended solids did not change to any significant degree after the different stages of the process. The percentage remained around 10% after settling as well as after DAF. On three occasions the percentage after DAF was considerably reduced and this is contrary to what was expected. It was expected that the DAF would remove the less dense fraction of the suspended solids. This is usually the organic fraction of the suspended solids. If this fraction is preferentially removed by the DAF stage the ash percentage of the suspended solids would then increase in the effluent after the DAF stage. This was not observed in the experimental results.

Similar results were obtained on the effluent after the settling stage. The percentage ash of the suspended solids remained constant. It is usually expected that the settling removes the denser, inorganic fraction of the suspended solids. This would lead to an expected decrease in the ash percentage of the suspended solids, which was not observed in the experimental data.

From Figures 5, 6 and 7 it appears that increased removal of the ash fraction is obtained at the higher settling velocity of 10.9 m/h. A decrease in the removal of the ash fraction of the suspended solids is observed at the higher flotation zone velocity of 10 m/h. The difference in the removal at the two flotation zone velocities (5 and 10 m/h) is however small and not always consistent. There was one occasion when improved removal was observed at the higher flotation velocity.

An increase in the reaction zone velocity from 40 to 80 m/h did not result in a significantly poorer removal of the ash fraction in the effluent. However, when increased air quantities (ie. recycle ratio) were used a decrease in the removal was observed at the higher reaction zone velocity. It was suspected that the same mechanism as described in the suspended solids section, namely increased turbulence, resulted in this decrease in removal efficiency.

CHAPTER 6: CONCLUSIONS

The following conclusions can be made from this study:

- high percentages of removal for suspended solids in the pulp and paper effluent can be obtained with the combined SEDIDAF process, but as the initial suspended solids concentrations are high significant concentrations of suspended solids are still present in the effluent after treatment.

- the settling stage of the process contributes most to the overall removal of solids from the effluent.

- the DAF stage of the process has a less significant influence in the overall removal of suspended solids from the effluent.

- effective suspended solids removal can be obtained with settling in an inclined plate settler at surface loading rates as high as 10.9 m/h.

- better suspended solids removal is obtained at lower flotation zone velocities in the DAF stage. In this study only two velocities were used and it is possible that better removal may be obtained at flotation velocities lower than the 5 m/h used in the study.

- improved suspended solids removal is obtained at a reaction zone velocity of 40 m/h and higher recycle ratios.

- the COD of the pulp and paper effluent is not removed to any great extent by the combined SEDIDAF process. The settling stage has the greater influence in removing the COD with the DAF stage making only a minor contribution.

- the DAF stage does not only remove the organic fraction of the suspended solids, but also the inorganic particles.

- the settling stage does not only remove the inorganic fraction of the suspended solids, but also the organic particles.

- the overall performance of the combined SEDIDAF process is primarily due to the performance of the settling stage, with the DAF stage only having a minor contribution.

- the combined SEDIDAF process is applicable in the pulp and paper industry, but will only result in an incremental improvement in solids removal over conventional settling.

CHAPTER 7: RECOMMENDATIONS FOR FURTHER RESEARCH

The following further research is required:

- the solids removal performance of settling only and DAF only should be established.

- a cost benefit analysis for the combined SEDIDAF process should be undertaken.

REFERENCES

APHA, AWWA, WPCF (1985), *Standard Methods for the Examination of Water and Wastewater.* 16th Edition.

WRC Report No. 106/1/87 (1987), *Investigations into Water Management and Effluent Treatment in the processing of Pulp and Paper.* Report to the Water Research Commission by the Pollution Research Group, Department of Chemical Engineering, University of Natal.

APPENDIX A

ANALYTICAL RESULTS

Table A1: Analytical results of experiments

Exp no.	Position	Settling velocity	Reaction velocity	Flotation velocity	Recycle ratio %	pH	TSS g/l	Ash content g/l	Ash content %	COD g/l
1	Raw After settling After DAF	10.9	40	10	20	4.48 4.62 4.49	1.814 1.542 0.570			10050 9030 8180
2	Raw After settling After DAF	3.4	40	10	20	4.05 4.24 4.10	3.372 0.428 1.326			11240 7840 8100
3	Raw After settling After DAF	10.9	40	10	40	4.60 4.29 4.60	0.942 0.870 0.110	0.010 0.088 0.111	1 10 101	6560 7760 6070
4	Raw After settling After DAF	3.4	40	10	40	4.45 4.54 4.63	1.768 0.480 0.260			7760 6220 5500
5	Raw After settling After DAF	10.9	40	5	20	4.03 4.10 4.22	2.772 2.164 1.062			10690 8520 8580
6	Raw After settling After DAF	3.4	40	5	20	4.01 4.08 4.37	2.434 2.886 0.430	0.255 0.303 0.038	10 10 9	10600 9520 7920
7	Raw After settling After DAF	10.9	40	5	40	4.83 4.89 5.01	2.844 1.482 0.256	0.290 0.143 0.015	10 10 6	10750 7560 7420
8	Raw After settling After DAF	3.4	40	5	40	4.84 4.86 4.98	1.960 1.734 0.180	0.214 0.184 0.017	11 11 9	8850 7290 6690
9	Raw After settling After DAF	10.9	80	5	40	5.00 5.01 5.01	1.964 1.290 0.428	0.198 0.125 0.026	10 10 6	8400 7290 6570

Exp no.	Position	Settling velocity	Reaction velocity	Flotation velocity	Recycle ratio %	pH	TSS g/l	Ash content g/l	Ash content %	COD g/l
10	Raw	3.4	80	5	40	4.89	2.330	0.250	11	8740
	After settling					4.91	1.616	0.154	10	7180
	After DAF					4.93	0.392	0.021	5	6540
11	Raw	10.9	80	5	20	4.97	1.478	0.198	13	6760
	After settling					5.08	0.278	0.006	2	5680
	After DAF					4.99	0.170	0.005	3	5870
12	Raw	3.4	80	5	20	5.10	1.656	0.229	14	6780
	After settling					5.08	0.224	0.017	8	5640
	After DAF					5.07	0.178	0.048	27	5670
13	Raw	10.9	80	10	20	5.18	1.628	0.193	12	6850
	After settling					5.21	0.460	0.054	12	5950
	After DAF					5.21	0.130	0.018	14	5830
14	Raw	3.4	80	10	20	5.19	1.602	0.471	29	6980
	After settling					5.22	0.280	0.028	10	5880
	After DAF					5.18	0.200	0.029	15	5930
15	Raw	10.9	80	10	40	5.20	1.278	0.142	11	6770
	After settling					5.23	0.380	0.046	12	5470
	After DAF					5.23	0.170	0.022	13	5670
16	Raw	3.4	80	10	40	5.25	0.950	0.119	13	5790
	After settling					5.29	0.228	0.027	12	5010
	After DAF					5.26	0.164	0.028	17	5230