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Evaluation of coagulant/polymer combinations on VEAS wastewater

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Abstract:

Three coagulant / polymer combinations from two metal salts (M14, M31), two cationic polymers (A25, A27) and one anionic polymer (P6) are evaluated on VEAS wastewater for their flocculating, sedimentating and sludge characterestics. A continous, semi-pilot scale experimental apparatus is used. Cationic polymers do not significantly influence on the overflow rates. Anionic polymers increase the overflow rates by two to five times at dosages 0.3 mg/l and 1 mg/l, respectively. A flocculation period of 3 min between metal salt and cationic polymer, 4 min (and also 7 min) between cationic and anionic polymers, and 2 min between metal salt and anionic polymer are selected best among the tested conditions. The combination of M14, A27 and P6 are considered to give the best overall performance.

4 keywords, Norwegian

1. Avløpsvann
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4. Optimalisering

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1. Wastewater
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SUMMARY

Three coagulant / flocculant combinations are tested on the domestic wastewater collected at VEAS. The chemical combinations are selected from two metal salts (M14 and M31), two cationic polymers (A25 and A27) and one anionic polymer (P6).

A continuous, semi-pilot scale experimental apparatus with in-line chemical dosing is used. The principles of operation of the apparatus is described. The qualitative evaluation of floc blanket overflow rates (Vf) in sedimentation tanks is the primary intention of the apparatus.

Anionic polymers increase Vf by twice at dosages up to 0.3 mg/l, while a five fold increase may be achieved at higher dosages (1 mg/l). The flocculation period of 2 min between a metal salt and anionic polymer addition is found as the optimum for experimental conditions, while a further increase indicate a slight reduction in Vf. When the both metal salts and cationic polymers used as coagulants, an increase of flocculation periods between cationic and anionic polymers from 4 min to 7 min indicated a small increase in Vf.

The addition of cationic polymers after metal salt coagulants do not increase the overflow rates significantly. A mixing period of 3 min between the coagulants resulted in the best Vf values.

Considering the overall performance, the chemical combination of M31 + A27 + P6 is recommended as the best among the three suggested combinations.

PREFACE

VEAS, the largest wastewater treatment plant in Norway, has intended to optimize the coagulation / flocculation stage to a process which is more suitable for the total treatment plant. An advanced biological treatment process will be introduced to the VEAS treatment process to fulfil the nitrogen removal requirements of the State Pollution Control Authority (SFT). For an optimum operation a biological stage requires a higher alkalinity and a higher dissolved phosphate concentrations in the coagulated water, compared to the performance of the current coagulant. The optimization of coagulant / flocculant combination for the whole treatment process is therefore important for an economical and an environmentally safe operation.

Based on a range of jar-tests evaluation of the particle and phosphate removal and alkalinity consumption, three suitable coagulant / flocculant combinations are proposed by Kemira Kemi AB. The Norwegian Institute for Water Research (NIVA) has conducted further experiments to evaluate their performance related to sedimentation characteristics and sludge characteristics on a semi-pilot scale experimental apparatus.

The coagulation experiments were conducted at VEAS using an experimental apparatus developed at SINTEF-NHL.

The authors wish to thank Mr Rune Tangen for assisting in experiments. The technical and administrative staff at VEAS are also thanked for their cooperation.

Oslo, 23. April 1992.

Harsha Ratnaweera, Dr.Ing.

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INTRODUCTION

VEAS as a wastewater treatment plant with a coagulation/precipitation stage prior to the biological treatment stage, is using iron chloride (JKL) as the coagulant. The extremely good particle removals which achieved by JKL were always accompanied with very good phosphate removals and with high consumptions of alkalinity (VEAS, 1990).

A coagulation stage with traditional coagulants as JKL or alum is reported to have optimum pH <6.5. However, the biological treatment stage usually requires higher pH ranges for a better performance. The latter is usually difficult to achieve in practice with low alkalinity wastewaters where the pH is tend to be reduced both by JKL (or alum) and the biological treatment stage itself.

Among the other limiting parameters of a biological stage, the dissolved phosphate concentration may also be of importance. Therefore, the ortho-P concentrations after coagulation with JKL may be a limiting factor.

Therefore, VEAS intend to find new chemicals as coagulants and flocculants which are equally good or better in particle removal compared to JKL, while removing less phosphates and consuming less alkalinity. After a jar-test experimental series with a range of coagulants, Kemira Kemi AB has selected three coagulant / flocculant combinations which may be suitable for the application at VEAS.

Jar-tests are designed for evaluation of certain properties (turbidity removal, pH, alkalinity consumption, influence on chemical composition) based on different coagulant / flocculant combinations and different mixing environments. A reliable evaluation of flocculation and sedimentation characteristic are, however, very difficult to achieve with jar-tests.

As supporting experiments to jar-tests, SINTEF-NHL has developed a semi-pilot scale apparatus (Ødegaard *et al.*, 1992). Many parameters as settling speed, floc blanket overflow rate, sludge volume and sludge characteristics are possible to evaluate using this apparatus and its procedures.

For obvious reasons (scale, mixing conditions etc) the absolute values of overflow rates etc will be difficult to obtain during these experiments. For comparison of different coagulant combinations and various mixing procedures, however, this apparatus gives reliable and reproducible results.

Therefore, it was decided to conduct a series of experiments to compare the flocculation / sedimentation performances of the three given coagulant / flocculant combinations, using the above mentioned apparatus. The influence of flocculation time was also studied. For comparison, several experiments with JKL were also included. This report presents a brief description of the apparatus, conducted experiments and a discussion of results.

2. EXPERIMENTAL APPARATUS AND PROCEDURES

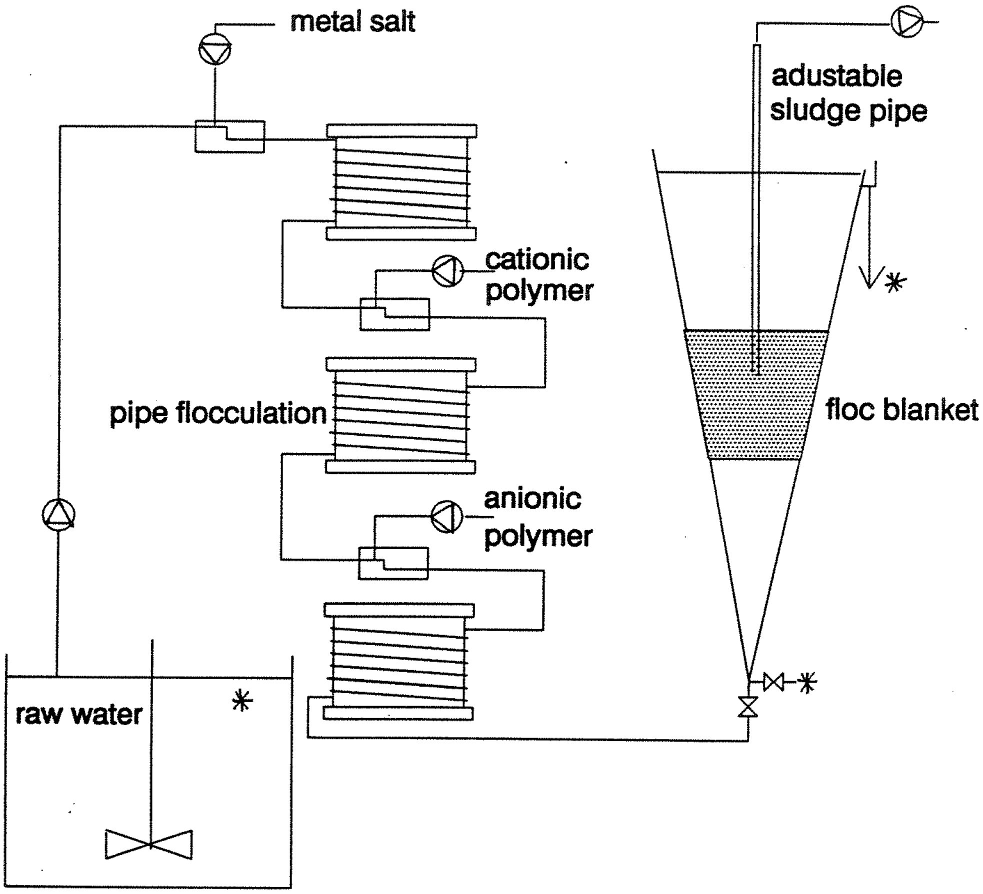

Figure 1. Experimental set-up. (sampling points for chemical analysis)*

Fig. 1 shows the experimental set-up used for the experiments. It is a continuously operating (2 l/min) chemical treatment plant based on in-line mixing of chemicals, pipe flow flocculation and floc blanket sedimentation. The each of the treatment steps are designed in such a way that the actual unit process can easily be controlled.

The wastewater was collected to a 1 m^3 tank equipped with a stirrer. In order to investigate the performance of chemicals on different water types, the raw water was collected at different times of the day (high concentrated: between 1700-1900 hours on the previous day; low concentrated: between 0700-0800 hours on the experimental day). The raw water was pumped to the plant by a peristalitic pump.

The chemicals (coagulants and flocculants) were added to the raw water stream through in-line mixers with a design proposed by Klute (1990) and described in (Ødegaard *et al.*, 1990). In this mixer, wastewater and chemicals are mixed within 0.1-0.3 seconds. Three units of these mixers were installed to the experimental set-up for metal-salt, cationic polymer and anionic polymer addition, where necessary.

Instead of traditional stirring-tanks, the flocculation was carried out in pipe flow flocculators. In the first part, metal salt (and cationic polymer) was added and flocculated for periods between 1-7 min for various experiments. The initial mixing was turbulent, where a 30 sec of G=740 sec^{-1} and 30 sec of 350 sec^{-1} were achieved. Small, dense flocs were created in this microflocculation step. The microfloc containing water was thereafter led through a new in-line mixing unit where the cationic polymers were added (where necessary) and flocculated for 2-6 min. The anionic polymers were added using an another in-line mixing unit. This pipe flow flocculator consisted with different pipes giving G-values of 350, 190 and 70 sec^{-1} during a 38 sec period. The detailed mixing procedures are given in Table 1.

Table 1: Pipe flocculation details

	diameter, mm	length, m	G-value, sec^{-1}	detention	total detention
Metal salt -> anionic polymer	8 10 additional: 16	20 13 10-30-60	740 350 70	30 sec 30 sec 1-3-6 min	1,2,4 & 7 min
Metal salt -> cationic polymer	8 10 16 additional: 16	20 13 10 10-40	740 350 70 70	30 sec 30 sec 1 min 1-4 min	2,3 & 6 min
Cationic polymer -> anionic polymer	16	20-30 40-70	70	2,3, 4 & 7 min	2,3,4 & 7 min
anionic polymer -> inlet to cone	10 12 16	2 1 5	350 190 70	4.7 sec 3.4 sec 30 sec	38 sec

The standard flocculation times were chosen after a row of preliminary tests. The flocculation times proven to be suitable for model wastewaters (Nilsen, 1991) were slightly adjusted, i.e. flocculation after coagulant addition was increased up to 1 min. The additional flocculation times given in table 1 were selected during some experiments where flocculation times were compared.

Coagulants and polymers were dosed in to the in-line mixing units by fine peristalitic pumps (Alitea AB). The chemicals used in this experiment are described in Table 2.

Table 2. Chemicals used in experiments

Name	Description	Type
M14	metal salt	main coagulant
M31	metal salt	main coagulant
JKL	$FeClSO_4$	main coagulant
A25	cationic polymer	suppl. coagulant
A27	cationic polymer	suppl. coagulant
P6	anionic polymer	flocculant

The settling reactor was designed as a cone of about 1 m height and with a cone angle of 8'. The floc suspension after flocculant addition and a 38 sec of pipe flocculation was directed to the settling reactor through its' bottom opening. After 13 min the sludge was pumped out from the sludge blanket at a rate equal to its production. The sludge was always taken from a layer placed between 1-3 cm from the top of sludge blanket. During the first five minutes of this procedure it was possible to establish the necessary sludge pumping speed. The procedure was continued for a further 7 minutes at the same speed.The sludge blanket's position in the reactor were measured at given times.

The raw water supply was stopped after this, and the floc blanket's situation was measured during 30 minutes. The sludge volumes were calculated from these measured values.

The supernatant was collected from the top of the cone at the time of closing the raw water supply and also after settling for 30 minutes. The latter was analysed for turbidity, pH and ortho-P. The turbidity in the first sample was measured. The sludge was collected after settling, and analysed for dry solids content and for settling by centrifugation. A portion from the pumped sludge was also collected and measured the pumping speed.

The raw water was analysed for turbidity, ortho-P, pH and alkalinity. The standard jar-tests with syringe dosing of coagulants were also conducted for comparison the performance of given coagulants with each raw water sample.

To compare the results with the experimental set-up used in these experiments with jar-test results reported previously (Ryrfors, 1992), standard jar-tests were conducted with each water type.

3. RESULTS AND DISCUSSION

3.1. Efficiency of in-line mixing and pipe flocculation

The importance of efficient mixing of coagulants with water to be treated have been investigated by several researchers, and it is established that an efficient mixing enhances the coagulation process (Amirtharajah and O'Melia, 1990). The efficient performance of in-line mixing units in model wastewater was compared in an earlier study, and given in Fig. 2 (Ødegaard *et al.*, 1990).

A remarkable difference is observed between the two methods of initial mixing. A considerable coagulant saving is possible using an in-line mixer.

We have compared the results of jar-tests (with syringe dosing + paddle flocculation + sedimentation) with in-line mixing (with pipe flocculation + floc separation through a floc blanket) in Fig.3.

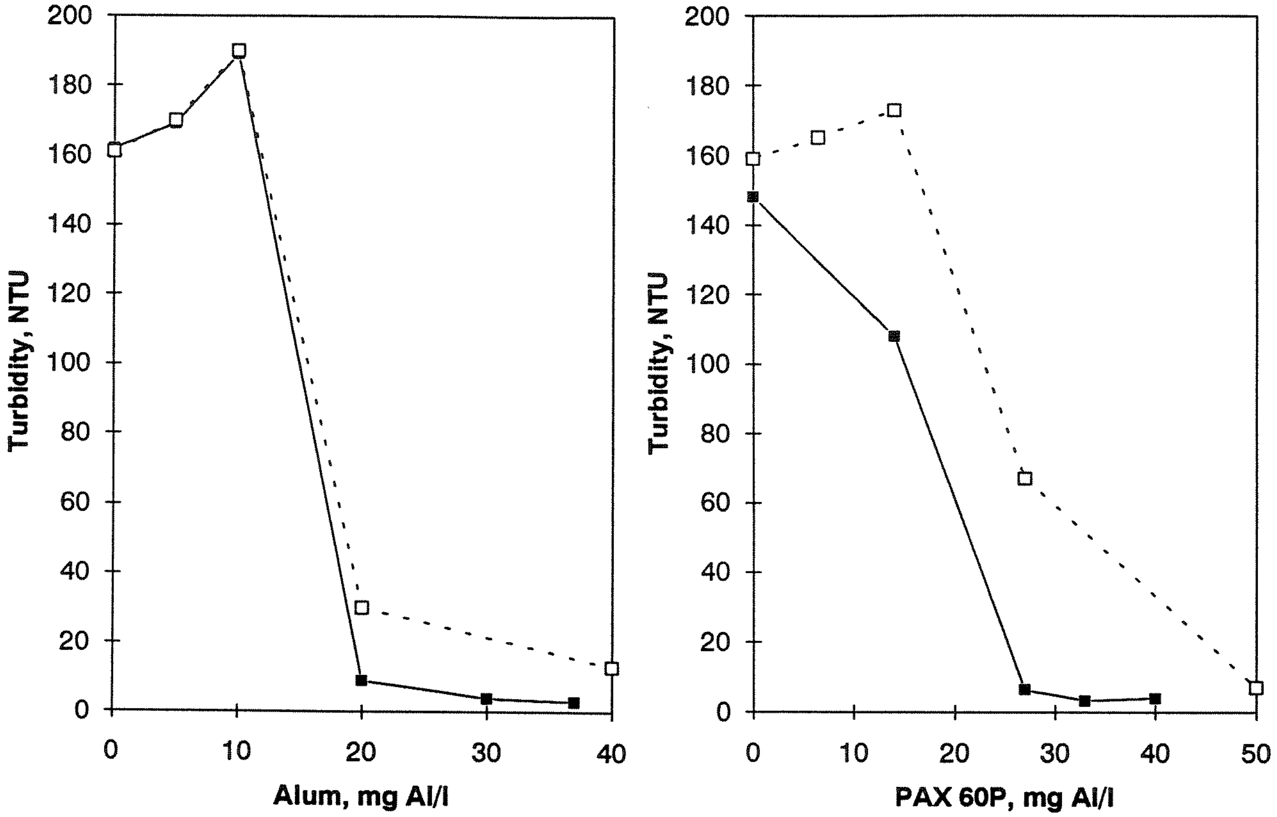

Figure 2. A comparison between syringe dosing (dotted lines) and in-line mixing (solid lines) of coagulants. Jar-tests with model wastewater (Ødegaard et al.*, 1990)*

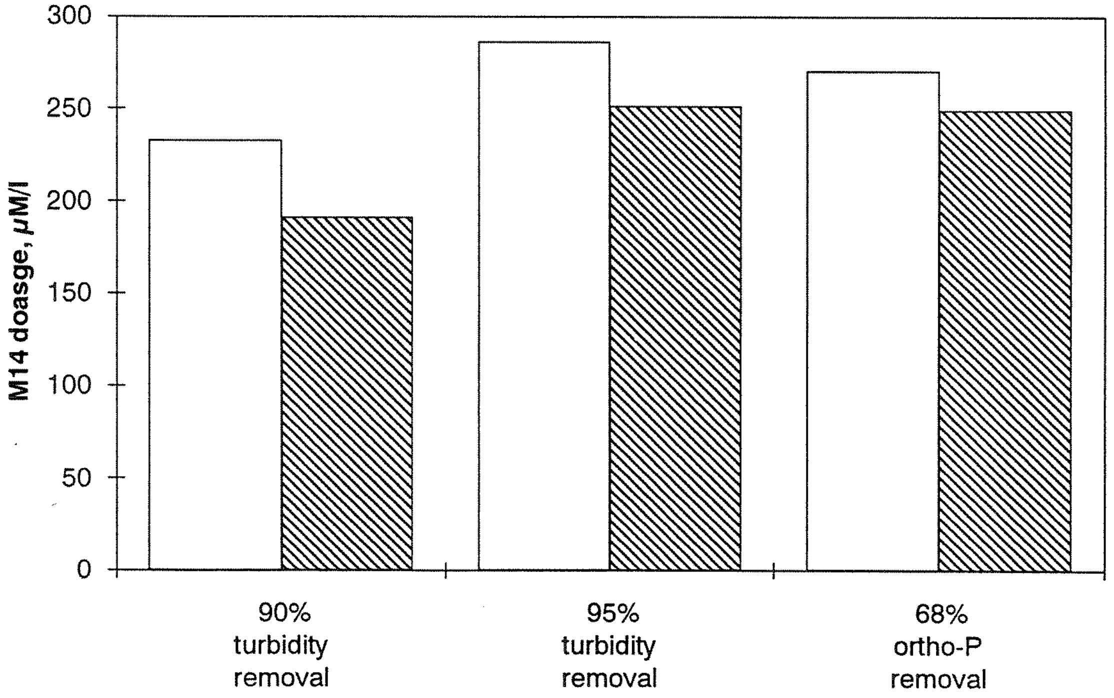

Figure 3. Syringe dosing , paddle flocculation and sedimentation (clear bars) compared with in-line mixing, pipe-flocculation and floc-blanket sludge separation (shaded bars). On VEAS wastewater 17.2.92.

The better performance of coagulants with the presence of in-line mixers are shown in Fig. 3. The differences, however, are smaller than to those of Fig. 2. It is assumed that the floc separation method used in the experiments with in-line mixers might have been not equally efficient as in sedimentation in jar-tests (Fig.2), especially due to the low retention time (10 min). It was observed a number of fine flocs remaining in the supernatant, and these were probably dissolved during sampling, resulting in higher turbidities.

Anionic polymers aid flocculation and the floc separation seemed to be much effective with these. Results from an experiment with anionic polymer is given in Fig. 4. The in-line mixing/pipe flocculation experiments were conducted with 0.2 mg/l anionic polymer (P6), and microflocs were not observed in the supernatant. Therefore, the difference between syringe dosing/jar tests and in-line mixing/pipe flocculation/sedimentation cone is possible to compare with the results given in solid lines in Fig. 4. The results of experiments with in-line mixing without anionic polymer is given in parentheses in Fig. 4. The differences between syringe dosing and in-line mixing is considerably higher.

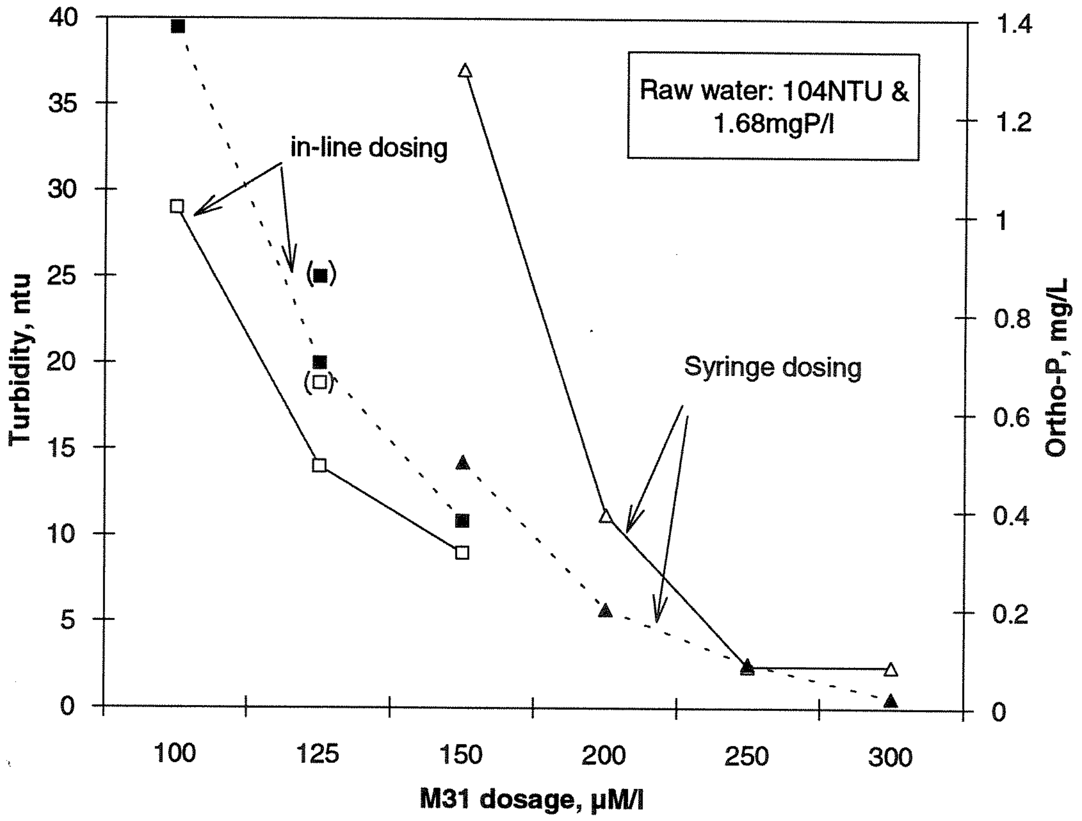

Figure 4. Syringe dosing (with paddle flocculation and sedimentation) compared with in-line mixing (with pipe-flocculation and floc-blanket sludge separation). On VEAS wastewater 25.2.92. Solid lines: turbidity removal, dotted lines: phosphate removal.

The experimental results presented above (Figs. 2-4) and the results of similar experiments presented in Appendix indicate that a considerable savings on coagulants can be achieved simply by improving mixing procedures.

3.2. Floc blanket overflow rate

On entering the sedimentation cone, a floc blanket establishes itself at a height in the reactor characteristic for the settling velocity of flocs in the particular suspension. This is resulted by the balance between the upstream flow force and the gravity force of flocs.

The sludge accumulation in the reactor will cause the floc blanket to move slowly upwards after some time caused by the space needed by the sludge that is produced. This phenomenon is significant at the first few minutes where a rapid increase of floc building occurs, and becomes less significant when the sludge production rate becomes constant. If the floc blanket overflow rate is registered versus time for a defined time, a floc blanket overflow curve characteristic for the given suspension can be established and compared with other similar curves made under same circumstances.

This method only gives a qualitative picture of the settling rate to be expected with different coagulants and dosages. The change of the floc blanket overflow rate (Vf) is becoming less significant with the time of operation. Fig. 5 illustrates the change of Vf with the time of operation. The very first data points for each curve (left end) are related to the 'establishing' floc blanket while the latter points (right end) are related to the established floc blanket. The large changes in the establishing Vf are caused by the intensification of flocculation within the floc blanket and thereby increasing the sludge production speed. However, after a few minutes of operation, the flocculation process within the sludge blanket and the sludge production speed become constant. The slight change observed in Vf is then related only to the sludge production. From this moment, if the sludge is removed at the same speed of production, Vf should stay constant and should be characteristic to the overflow rate.

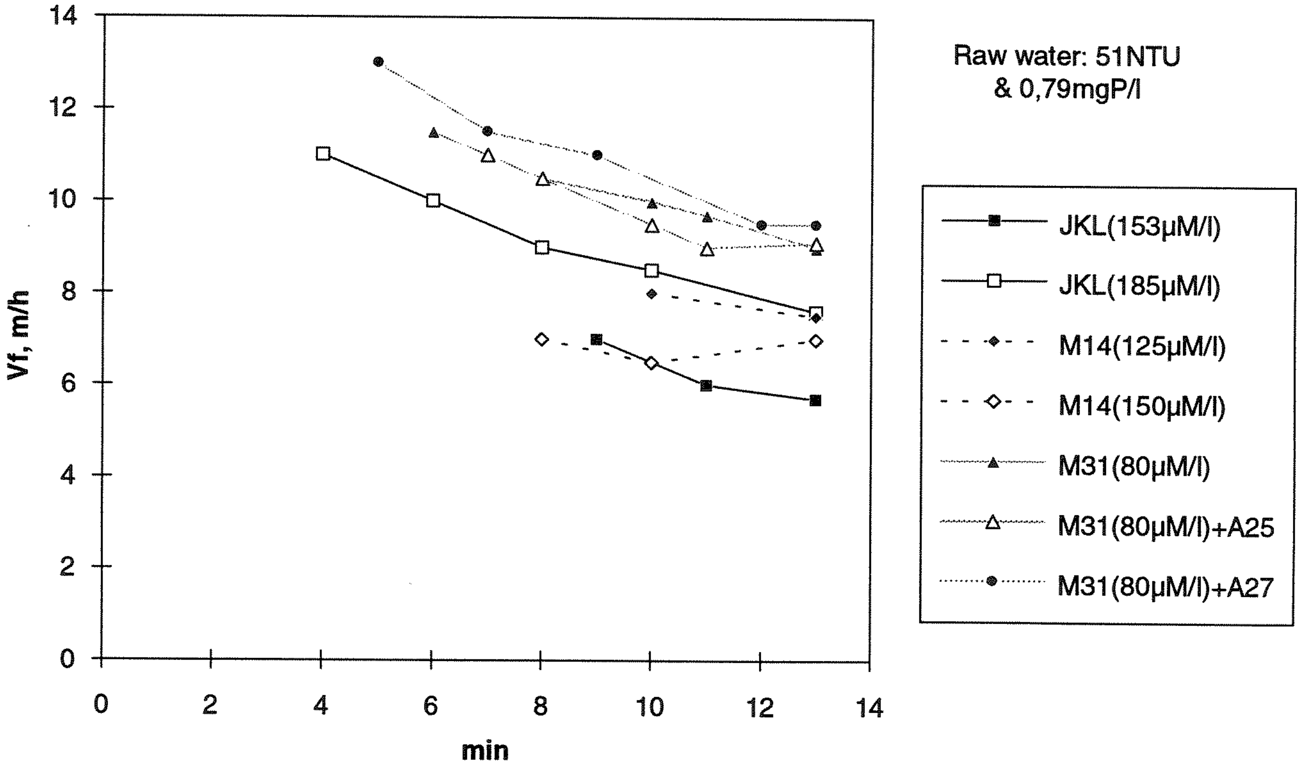

Figure 5. Floc blanket overflow rate versus time of operation. No sludge removal. VEAS wastewater from 3.3.92.

This method was used in the experiments reported here. After a series of experiments, it was established that an initial operation period of 13 min was suitable, and the sludge pumping was started after that.

One can also note the difference in the beginning time of each curve in Fig. 5, this will be discussed later (chapter 3.7).

3.3. Influence of anionic polymers

Figs. 6 and 7 present results of coagulation experiments (M14) with different anionic polymer (P6) additions.

The addition of anionic polymers seemed to result higher floc blanket overflow rates. Vf was increased from 2.4-2.7 m/h to 3.8-5.3 m/h at P6 dosages of 0.3 mg/l. The influence on sludge volume was, however, not significant.

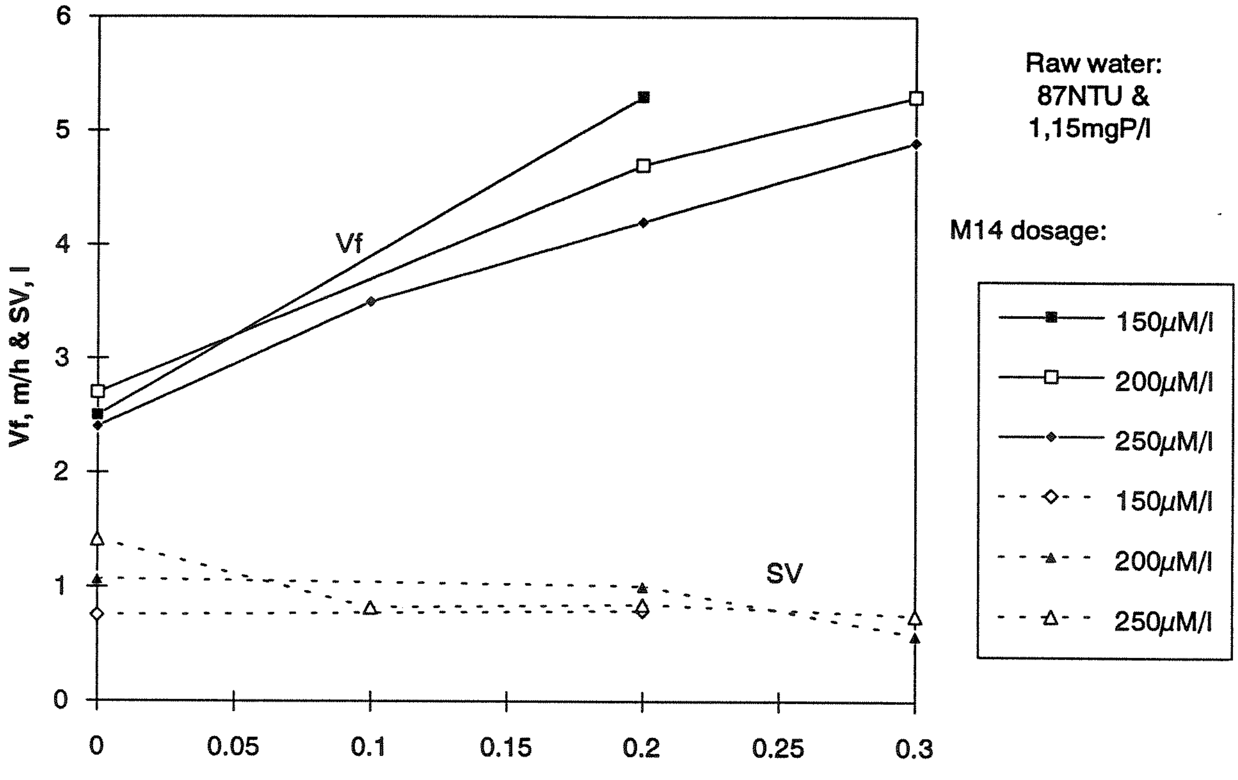

Figure 6. Vf (solid lines) and sludge volume (dashed lines) versus anionic polymer P6 dosage on VEAS wastewater (concentrated) from 17.2.92. 1 min mixing between coagulant and polymer addition.

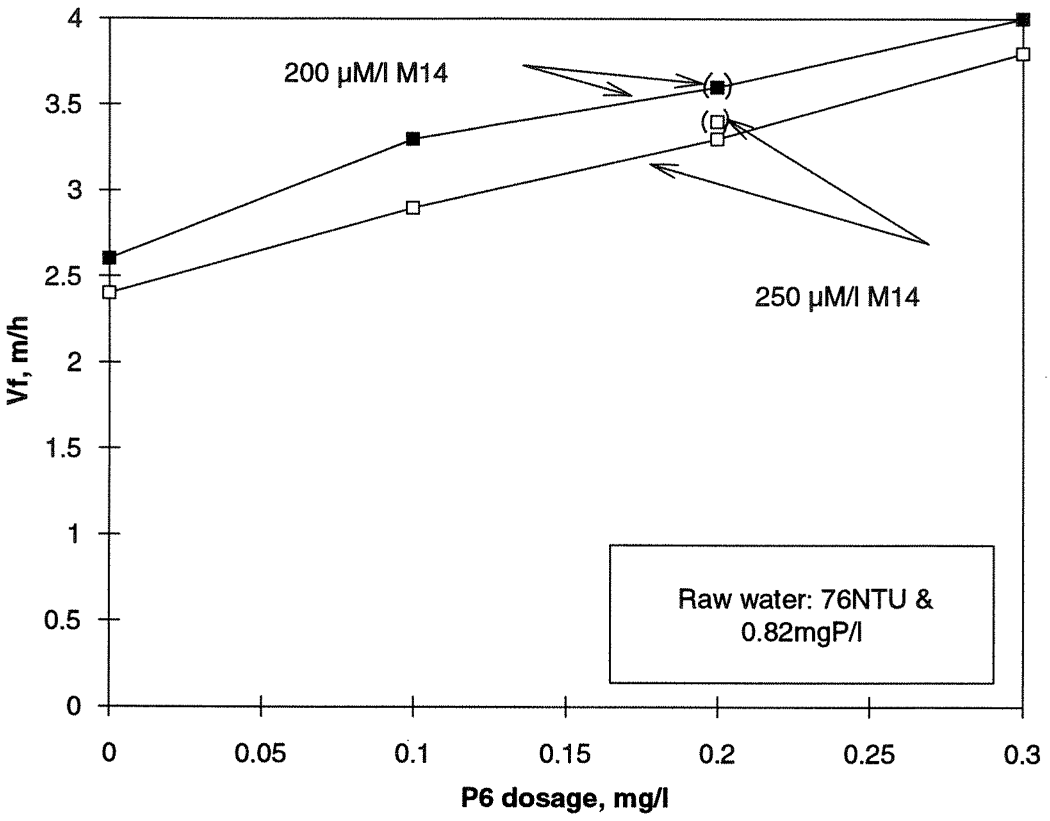

Figure 7. Vf versus anionic polymer (P6) dosage on VEAS wastewater from 17.2.92. Solid lines: 1 min mixing- ; points within parentheses: 7 min mixing between coagulant and polymer.

At higher anionic polymer dosages, the Vf is reported to be increasing to very high values as 12.6 m/h (Ødegaard *et al.*, 1992). Fig. 8 illustrates such a situation with 1 mg/l anionic polymer (Praestol 2540 BC) both with JKL and PAX 61 P.

It is concluded that very high overflow rates could be achieved by using high dosages of anionic coagulants and would be applicable in practice, if the polymer costs are comparable. An efficient control of coagulant and anionic polymer dosing must be achieved in this situation, since a slight dosing failure may cause the restablization of a soft wastewater suspension.

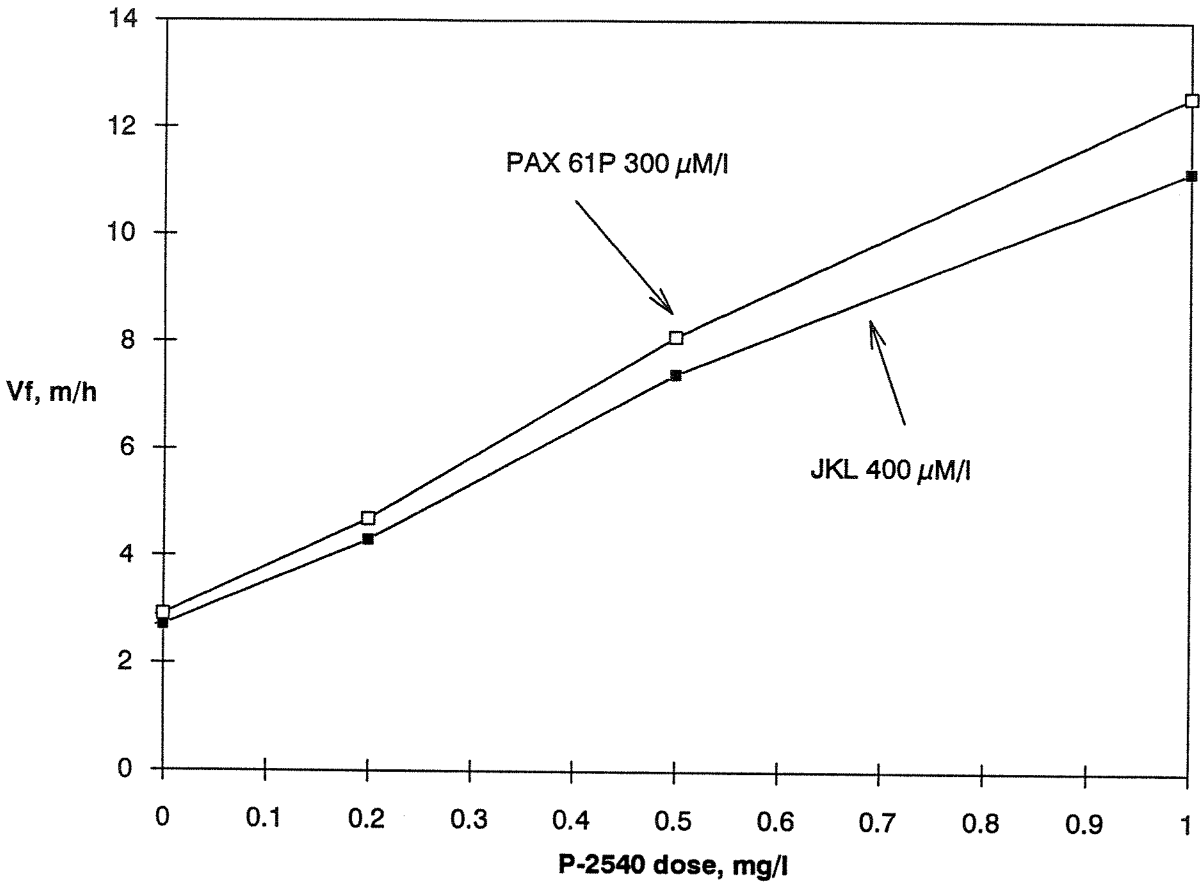

Figure 8. Vf versus anionic polymer (Praestol 2540 BC) dosage on VEAS wastewater from 5.3.92. (Ødegaard et al., 1992).

3.4. Efficiency of M14 and M31 as coagulants

Figure 9 presents the results with M14 (200 μM/l) and M31 (150 & 200 μM/l), with 0.2 mg/l anionic polymer (P6).

At the same dosage (200 μM/l) both coagulants resulted turbidities <5 NTU. The phosphate removal was poorer with M14. These observations agree with the jar-test results (Ryrfors,1992). Vf is higher with M31 (6 m/h) compared to M14 (5.3 m/h), while the sludge volumes seems to be the same.

A M31 dosage of 150 μM/l resulted a turbidity of 12 NTU and a Vf of 4.8 m/h, while at the same dosage M14 did not coagulate at all.

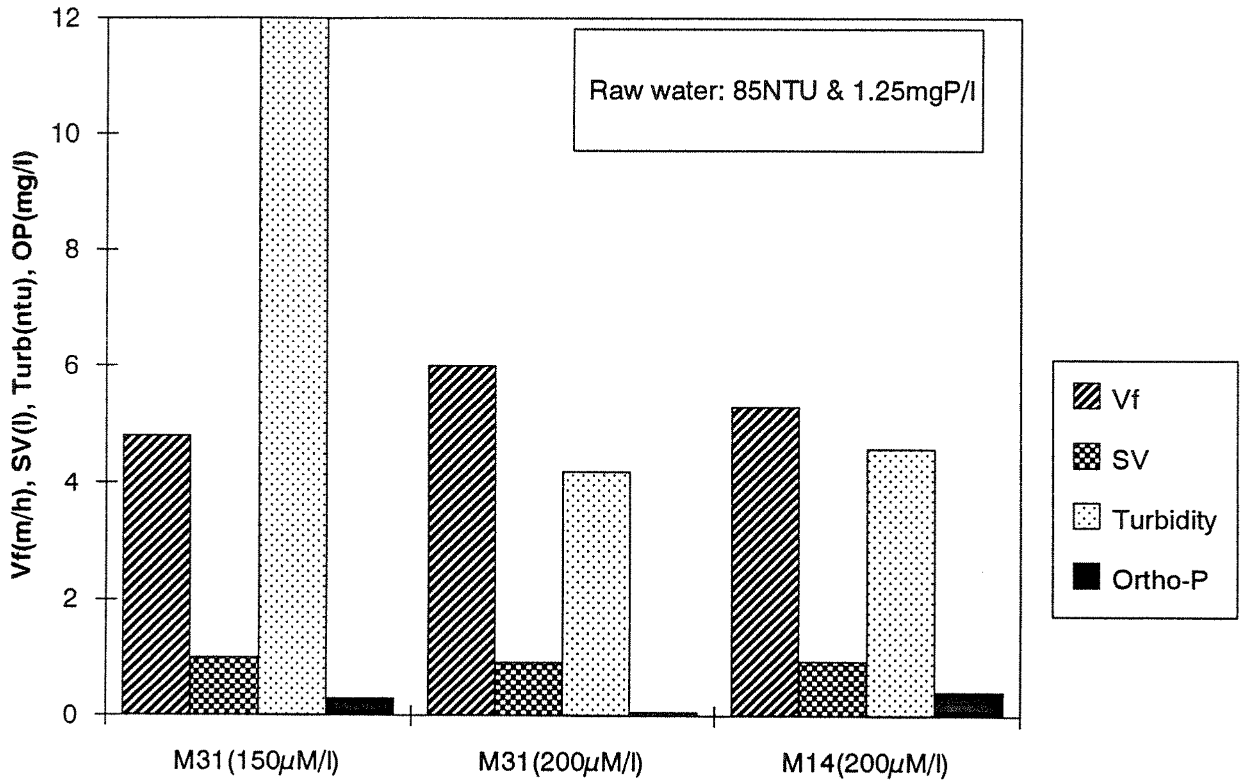

Figure 9. Coagulation with M14 and M31 on VEAS wastewater from 18.3.92. 7 min mixing time.

3.5. Efficiency of cationic polymers A25 & A27

In Fig.9, it was illustrated the efficient phosphate removal with M31, even to levels which may probably affect the biological stage. The cationic polymers are reported to be efficient in particle removal without consuming any alkalinity and resulting very low sludge volumes. However, they do not remove soluble phosphates from the municipal wastewater (Fettig *et al.*, 1989). Therefore, Kemira's suggestion to combine low dosages of M31 with cationic polymers seems logical, in order to achieve the goals of VEAS. Figs. 10 and 11 present results with such combinations.

The floc blanket overflow rate seemed to be slightly increasing with the cationic polymer dosage. A27 seemed to perform slightly better than with A25 at a dosage of 0.2 mg/l. The influence on the sludge volume is significant at larger M31 dosages (Fig. 10) and insignificant at lower dosages (Fig. 11).

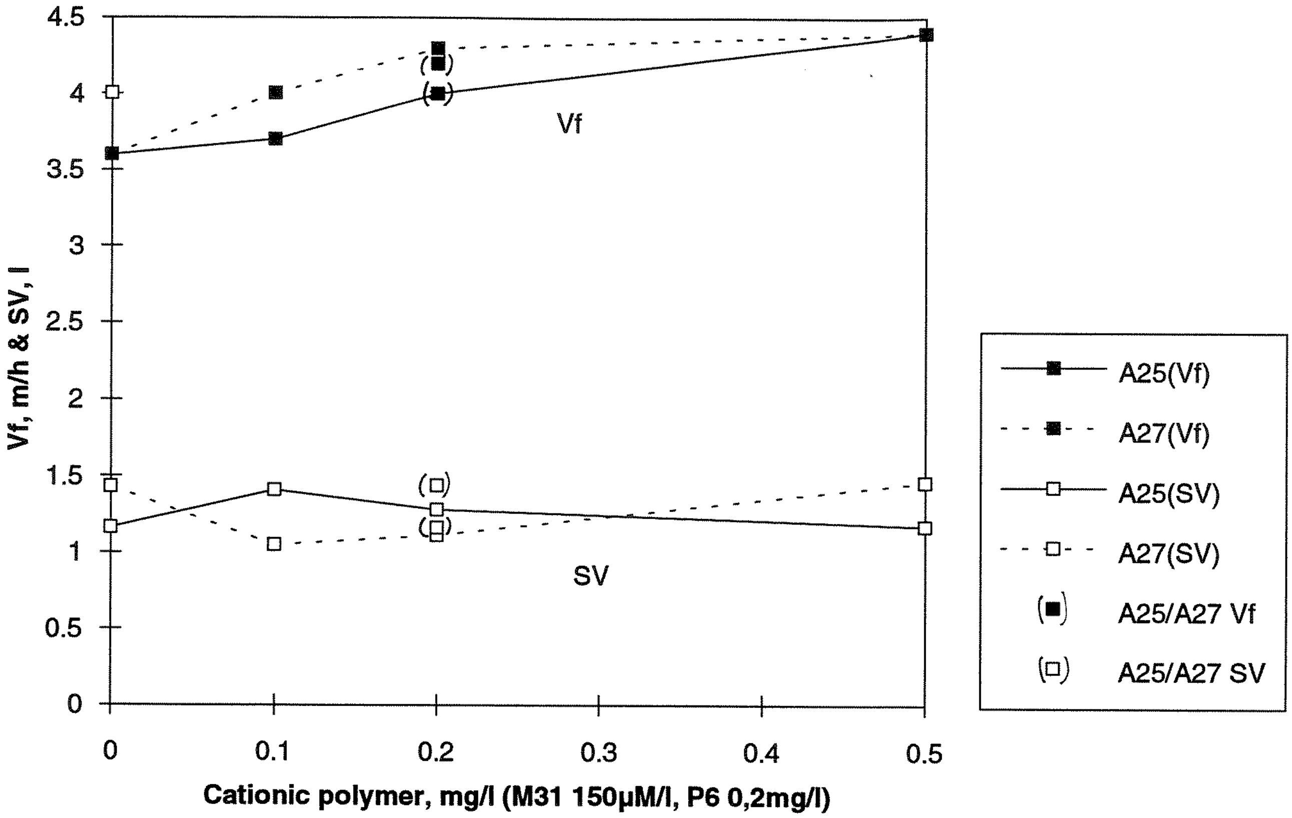

Figure 10. Coagulation with M31 and cationic polymers. VEAS wastewater from 19.2.92. (lines:3 min and 4 min flocculation between M31 -cationic polymer and cationic polymer-anionic polymer, points within parentheses: 2 and 2 min flocculation)

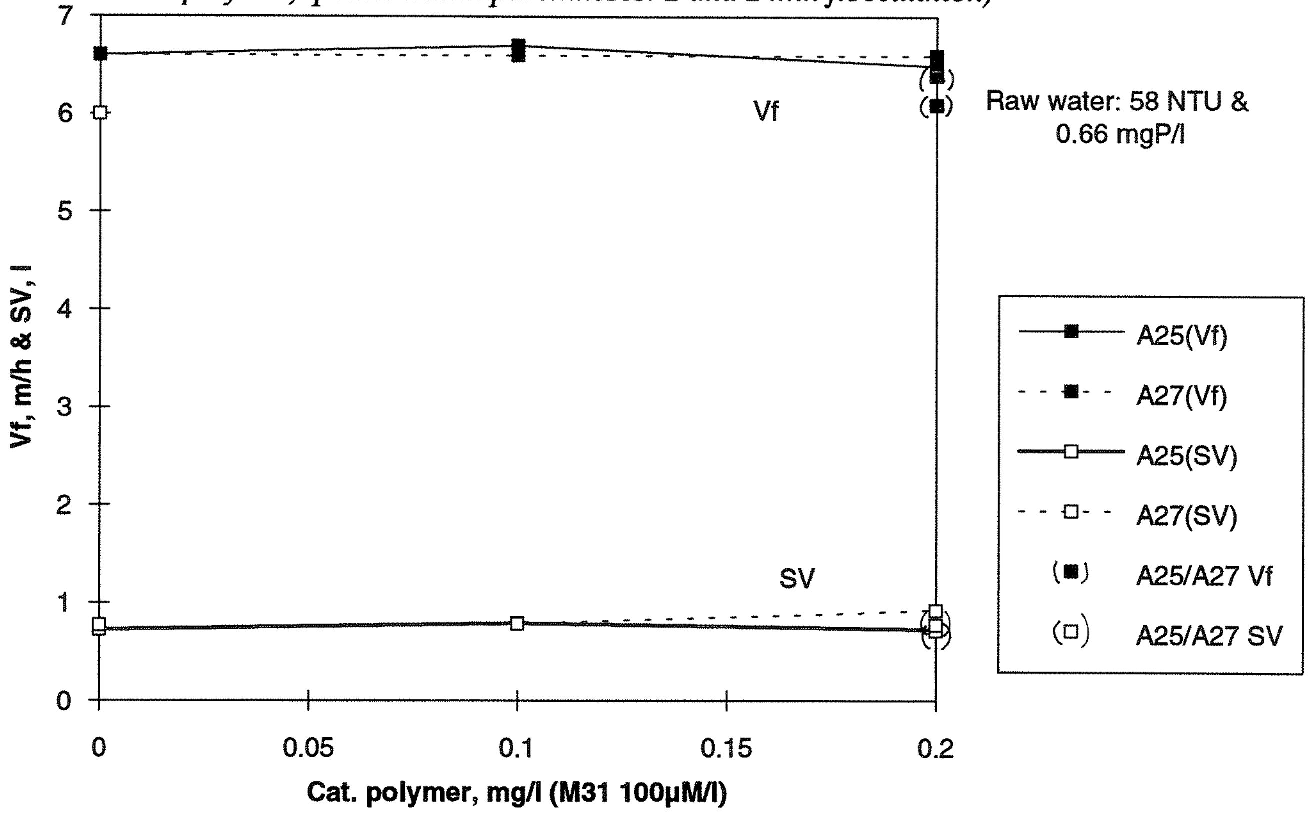

Figure 11. Coagulation with M31 and cationic polymers. VEAS wastewater from 24.2.92. (lines:3 min and 4 min flocculation between M31 -cationic polymer and cationic polymer-anionic polymer, points within parentheses: 2 and 2 min flocculation)

3.6. Influence of mixing period

An efficient mixing of chemicals with raw water is important for particle destablization process, while a good flocculation period is important in floc characteristics.The selection of mixing and flocculation times often influence the chemical costs and the area needs of a chemical treatment plant. During our experiments, the mixing of coagulants with raw water was achieved through an in-line mixer together with a turbulent pipe flocculation of 740 G^{-1} (30 sec) and 340 G^{-1} (30 sec) and were selected as standard parameters. To investigate the influence of additional flocculation periods, a series of experiments were conducted. Fig. 12 presents results with M14.

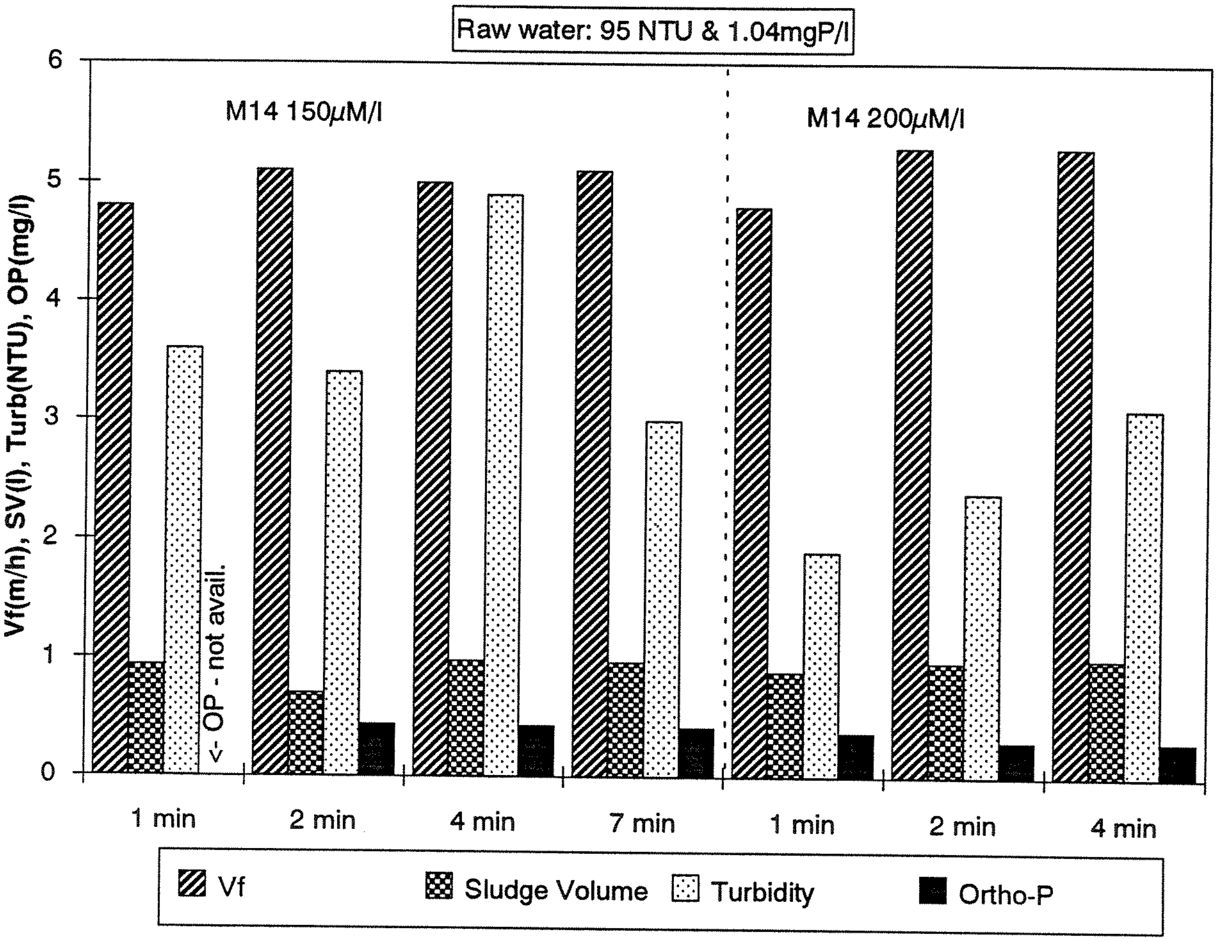

Figure 12. Influence of flocculation period. Coagulation by M14 with two dosages.VEAS wastewater from 3.3.92.

No dramatic influence on floc blanket overflow rates was observed with flocculation period increased up to 7 min. However, slightly higher overflow rates were observed at 2 min of flocculation. The sludge volume was also slightly lower. The ortho-P results seemed to be not affected, while the turbidity results seemed to be difficult to correlate with the flocculation time.

With M31 a triple dosing system was used, and therefore the flocculation times between metal salt-cationic polymer and cationic polymer-anionic polymer were necessary to change. Fig. 13 illustrates the results with M31.

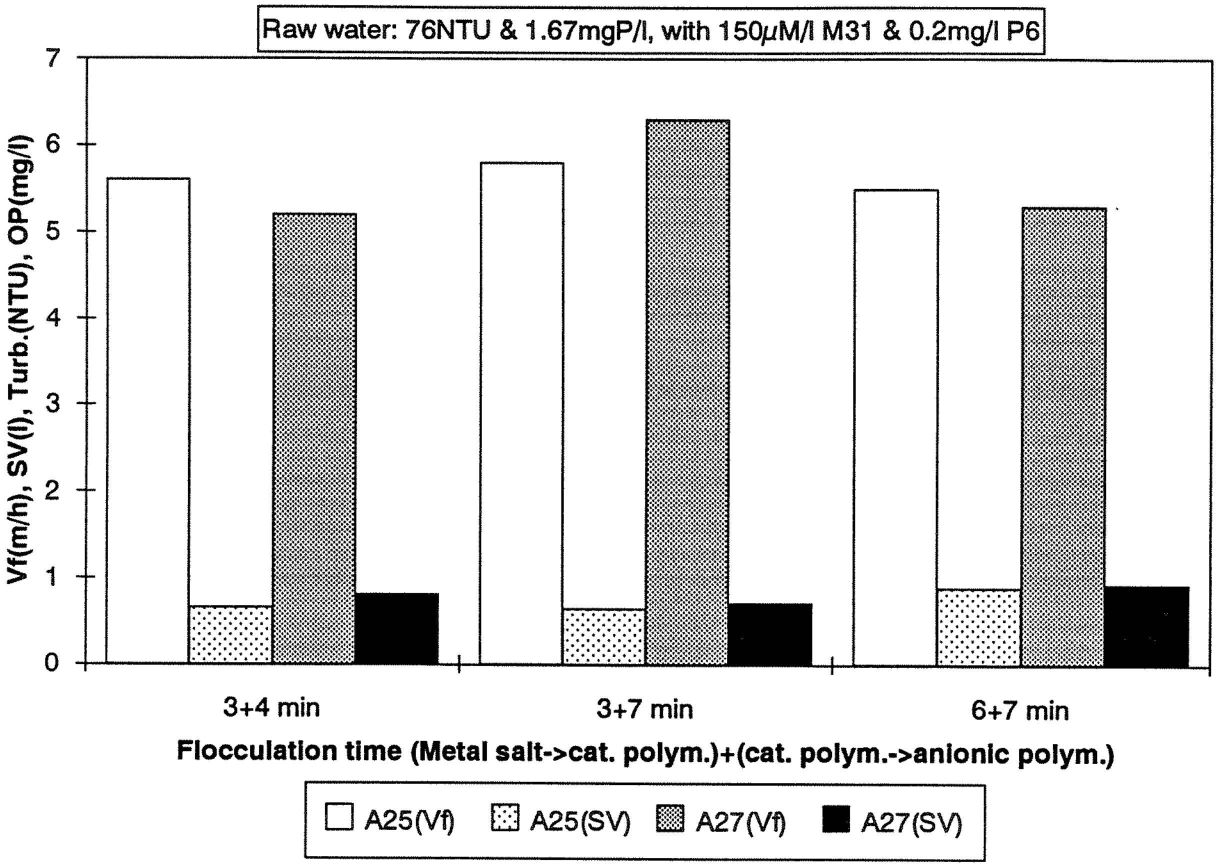

Figure 13. Influence of flocculation times during the coagulation with M31, cationic polymers and anionic polymers.VEAS wastewater from 26.2.92

Three situations are illustrated in Fig. 13. The first two are with 3 min flocculation time between the metal salt and the cationic polymer. The third experiment was conducted with 6 min flocculation. A 3 min of flocculation seemed to be satisfactory between the metal salt and the cationic coagulant.

In the same experiment, the flocculation times between cationic and anionic polymers were selected as 4 and 7 min. When the flocculation period is increased from 4 min to 7 min, slightly higher overflow rates were observed.

These conclusions agree with the general understanding of coagulation practice. Both the metal salt and the cationic polymer act as destabilizing agents, and the mixing time between them should influence only on the particle destabilizing. The flocculation time prior to anionic coagulant addition may be important since only a suspension with effectively destabilized particles will result in good flocs with anionic coagulants.

3.7. Floc blanket appearance

It was observed a large difference between the times needed to establish the floc blanket (FB) in the sedimentation cone. During the experiments without anionic polymer addition 12-14 min were usually needed to establish the floc blanket. We have studied this with different coagulants with an anionic polymer dosage of 0.2 mg/l. Fig. 14 presents the floc blanket appearance times, also with JKL for comparison.

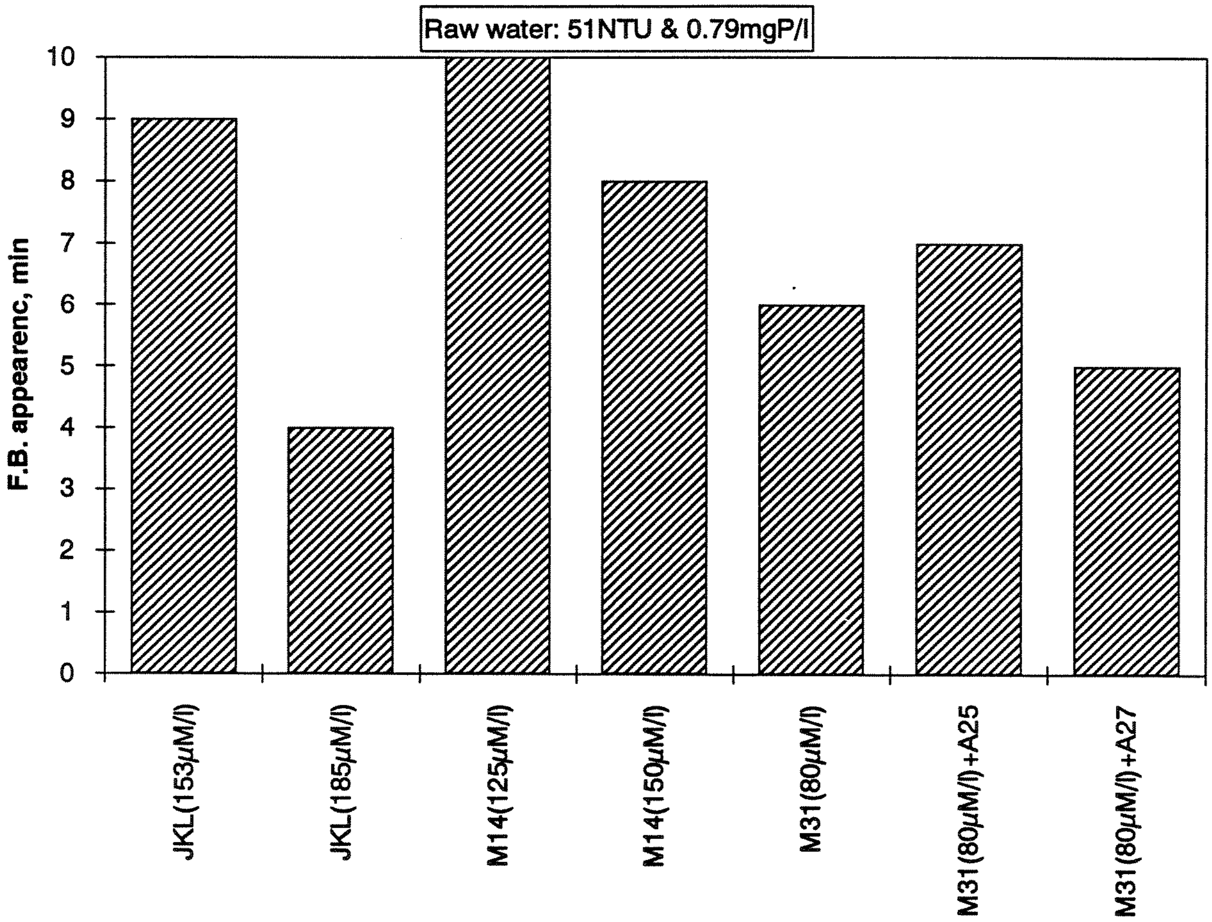

Figure 14. Floc blanket appearance time. VEAS wastewater on 3.3.92.

With the increase of coagulant dosage, the FB seemed to be established earlier. This phenomenon is related to the better floc building capacity by anionic polymers at optimum dosages and overdosages of coagulants.

A slow floc blanket building is resulted by a slowly flocculating suspension. This may also affect the sedimentation process, but this was not investigated further in this research.

3.8. Overall performance

A series of experiments were conducted with selected parameters using the same wastewater batch in order to compare the performances. Figs. 15 & 16 present the results for concentrated and less concentrated wastewater, respectively.

The floc blanket overflow rates are usually higher with M31 and cationic polymers, while the combination M31 / A27 gave the best results. The sludge volumes were comparable with other coagulants. A good turbidity removal was also observed with M31 and A27, while the ortho-P was less efficiently removed compared to JKL or M14.

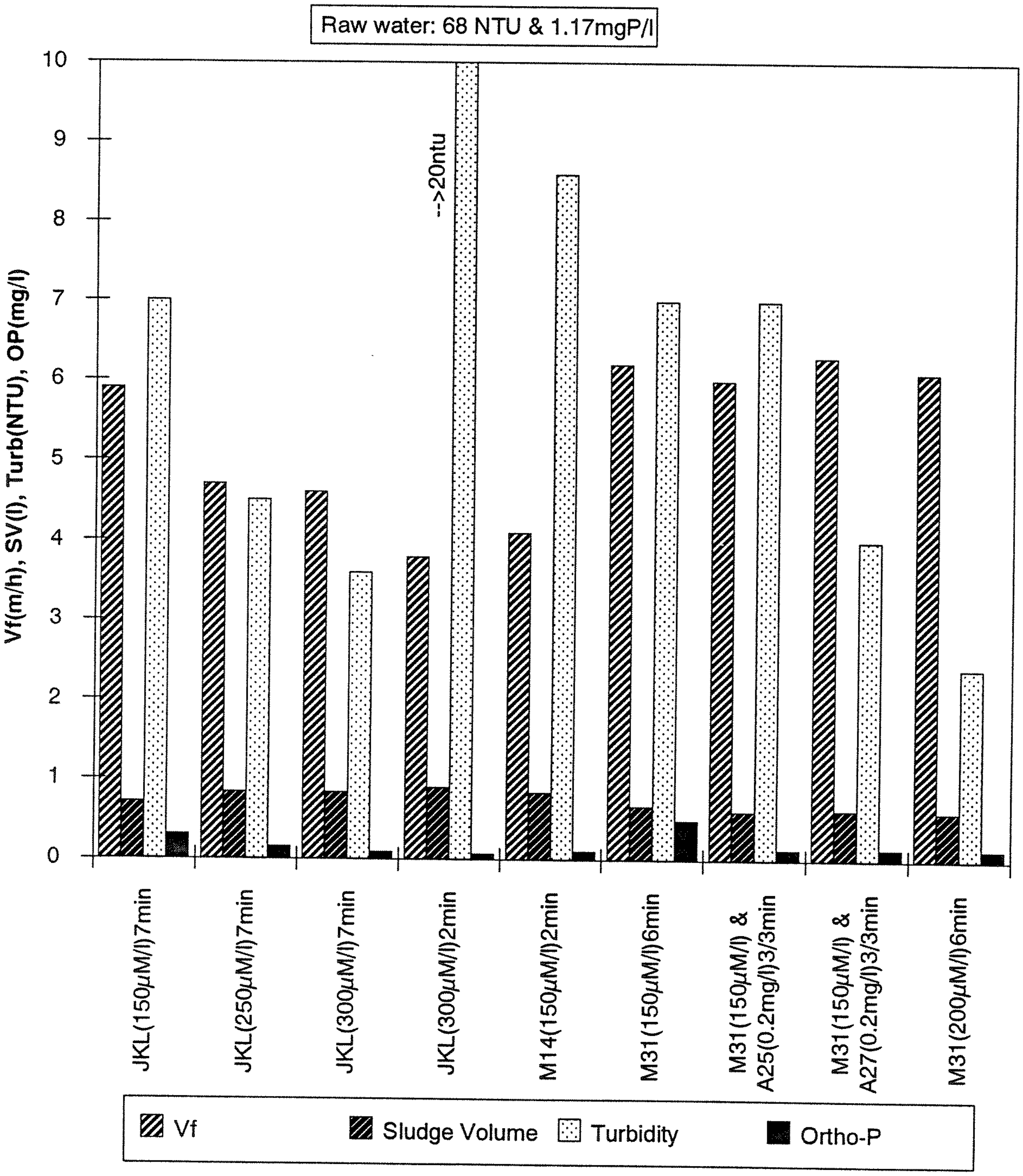

Figure 15. Comparison of coagulation performances with different coagulants on VEAS wastewater (concentrated) from 4.3.92.

An analysis of all Vf values measured versus coagulant dosage does not indicate any direct relationship between them. The Vf observed to be slightly decreasing with he coagulant dosage due to the increasing sludge productions in the floc blanket. However, at certain low coagulant dosages (resulting poor turbidity removals) Vf was higher compared to the Vf measured at slightly higher dosages. The poor floc quality and low sludge production at these dosages have resulted a poor flock blanket, which resulted for high apparent Vf values.

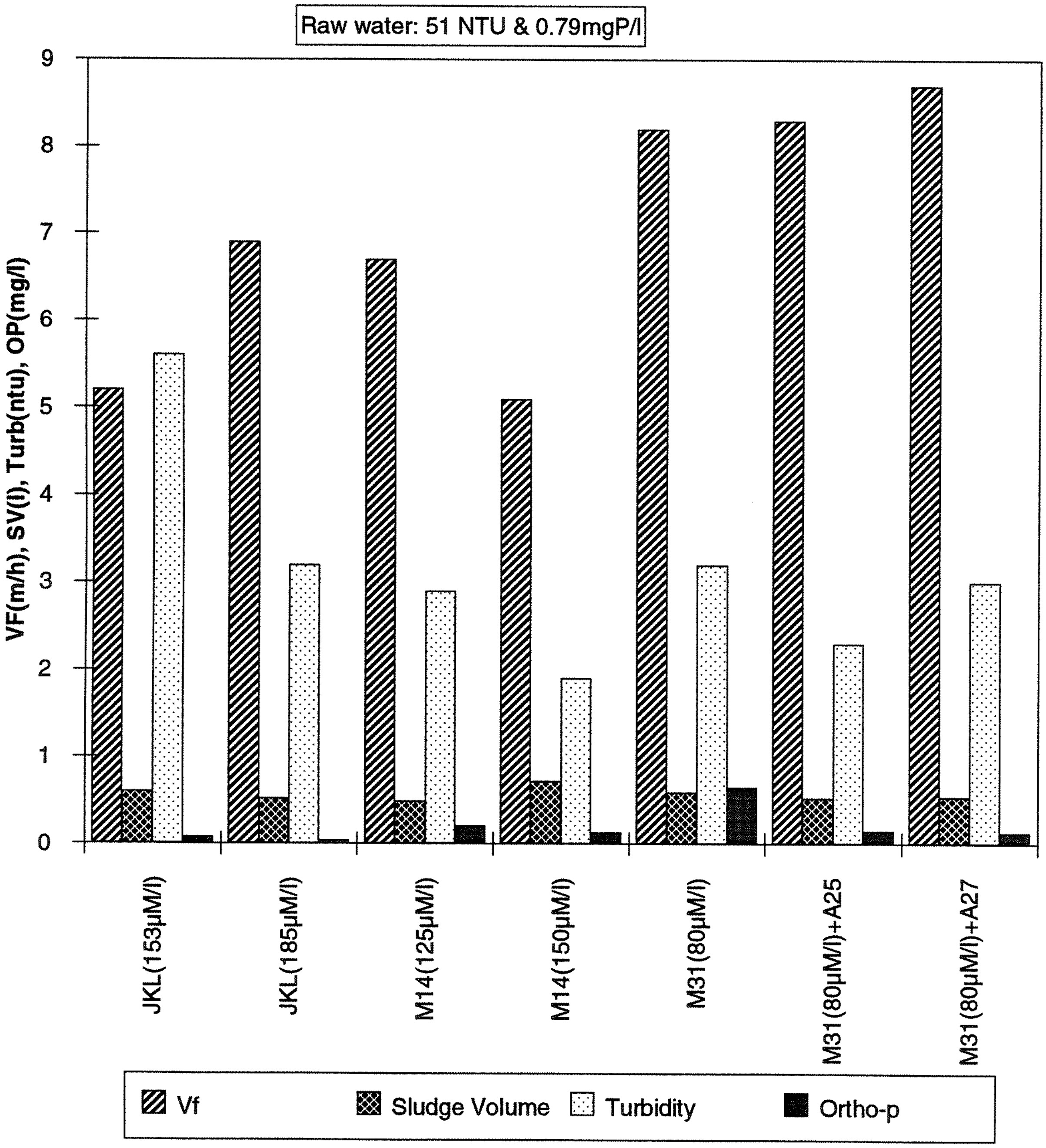

Figure 16. Comparison of coagulation performances with different coagulants on VEAS wastewater from 3.3.92. Flocculation times: 7 min (or 3+4 min when cationic polymers used).

3.9 Other

During the turbidity measurements, it was observed that some small flocs were remaining in the sample. These small flocs were also sedimentated after few more minutes, and therefore, the turbidity was measured both on the samples collected immediately after closing the inlet and also after 30 min. The results from most of the experiments are plotted in Fig. 17 as ortho-P versus turbidity.

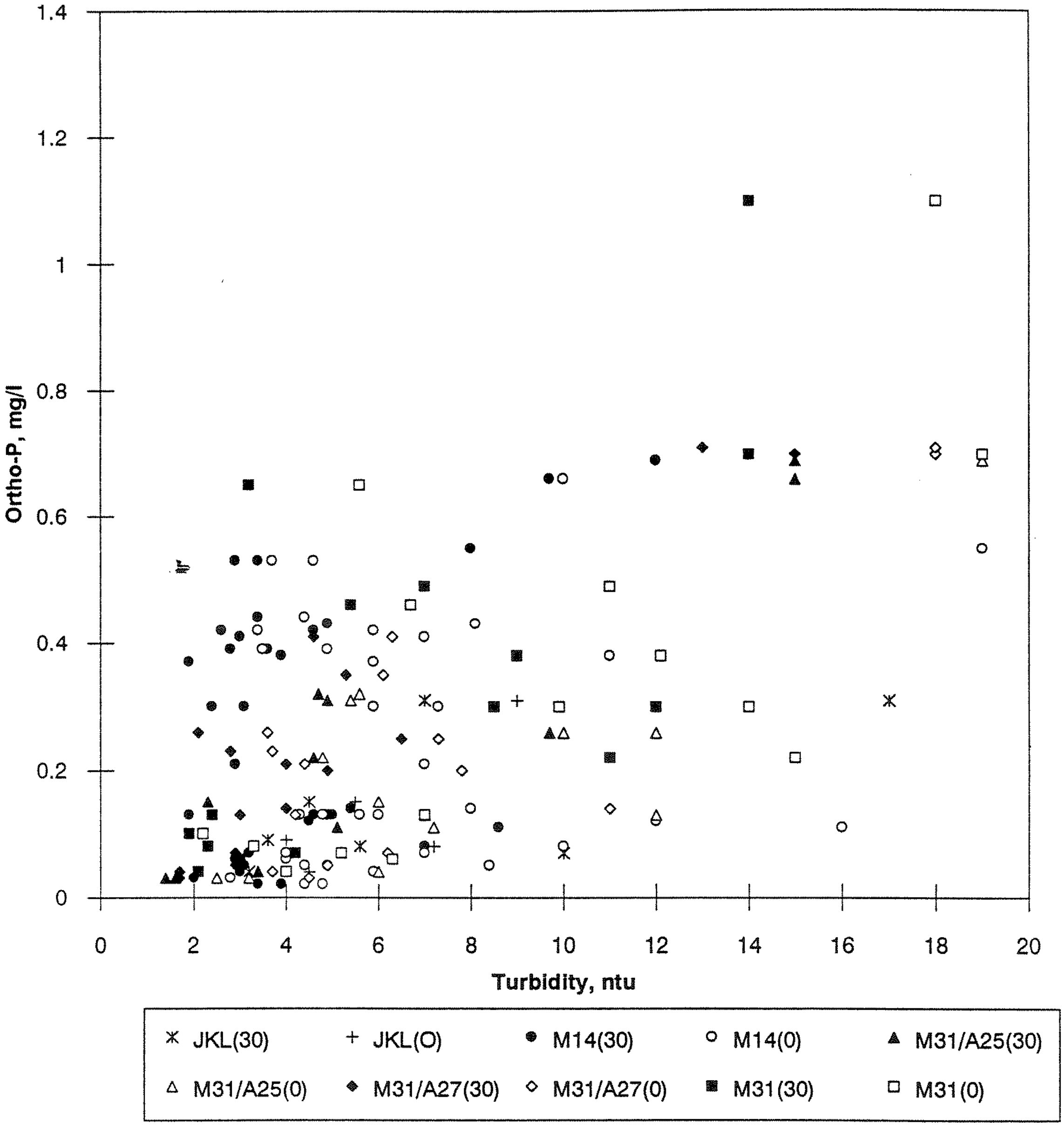

Figure 17. Ortho-P versus turbidity. The difference between 30 min additional sedimentation.

The open markers (and '+' for JKL) seemed to be situated mostly between 3 to 8 ntu, while the closed markers (and 'x' for JKL) between 2 and 5. In the experimental apparatus sedimentation time was limited to 10 min (at 2 l/min of V=20 l). Usually, much higher sedimentation periods are used in practice, and therefore one may find better turbidity results than the values given in Fig. 17. However, if 2-3 ntu is a satisfactory effluent quality, one may be able to select coagulant / polymer combinations resulting 0.01-0.60 mg/l ortho-P.

The dry solids content in sludge was varied between 0.48% to 1.24% during the experiments. This parameter was observed to be more dependent on the coagulant dosage and the water type, rather than on the coagulant/flocculant combination or mixing procedures. A centrifugation of 1 min at 1000 rpm has resulted in a sludge volume reduction by 74% to 88%.

4. Conclusions

The anionic polymer P6 increases floc blanket overflow rate (Vf) from 1.7-2.7 m/h to 3.5-5.2 m/h, almost directly proportional to the dosage (0-0.3 mg/l). It was demonstrated that the floc blanket overflow rate can be increased by five times at high polymer dosages (e.g. at 1 mg/l of Praestol 2540).

The sludge volume decreases with the increasing anionic polymer dosage. The influence of anionic polymer on the sludge volume is, however, much less than on the floc blanket overflow rate. The floc blanket establishes faster resulted by better structured flocs with increasing P6 dosages.

A 2 min flocculation period between the metal salt and anionic polymer addition seems to be optimum for the apparatus and for the experimental conditions. Longer flocculation periods may result in lower overflow rates.

Cationic polymers A25 and A27 at 0.1-0.3 mg/l dosages do not influence the floc blanket overflow rates as anionic polymers. The turbidity removal may, however, increase with the cationic polymer dosage.

The overflow rates with A 27 are slightly higher than with A 25. The floc blanket appears earlier and the sludge volumes are lower with A27 compare to the results with A 25.

When the cationic polymer is added after 3 min, the best floc blanket overflow rates may be achieved. The increase of this period to 6 min have not positively influenced on Vf. An increase of the flocculation time between the cationic polymer and anionic polymer increases the overflow rate.

Among the three given chemical combinations, the combination M31+A27+P6 is concluded to be the best for VEAS wastewater, considering the overall performances.

5. Literature

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Appendix

Appendix

Date	12.Feb	12.Feb	12.Feb	12.Feb								
Water collected:	12.Feb	12.Feb	12.Feb	12.Feb								
Coagulant	M14	M14	M14	M14								
Dose, µmole/l	325	250	300	350								
Cationic polym.												
Dose, mg/l												
Anionic polym. (P6)												
Dose, mg/l	0	0.1	0.1	0.1								
Pipe floc.												
coag-cat.												
cat-anion.	1min	1min	1min	1min								
anion-cone	38 sec	38 sec	38 sec	38 sec								
Turb(raw), NTU	77	77	77	77								
Ortho-P(raw), mg/l	1.1	1.1	1.1	1.1								
pH(raw)	7.2	7.2	7.2	7.2								
Alkalinity, mmole/l	2.46	2.46	2.46	2.46								
Turb.(0), NTU	4.4	10	8.4	4.8								
Turb.(30),NTU	3.4	7	4.9	3.9								
Ortho-P, mg/l	0.02	0.08	0.05	0.02								
pH			7									
Centrif., %												
Dry Solids, %	0.96	0.8	0.84	1.04								
Floc Bl. level, m/h												
after 3min												
4min												
5min												
6min												
7min												
8min												
9min												
10min												
11min												
12min												
Sl. pumping, ml/min												
Settling(30min), ml/l												
Fl. bl. (Vf)-not corrected for sl. pumping;m/h												
Vf(0)	*2.7*	*5*	*3.5*	*3.7*								
Vf(5)	*4.2*	*9*	*6*	*5*								
Vf(10)	*5.9*	*11.5*	*8.1*	*8.5*								
Vf(20)	*8.2*	*12.1*	*10.2*	*10.5*								
Vf(30)	*9.1*	*13.8*	*7.3*	*12*								
Vf-corrected:m/h												
Vf(0)	2.7	5	3.5	3.7								
Vf(5)	4.2	9	6	5								
Vf(10)	5.9	11.5	8.1	8.5								
Vf(20)	8.2	12.1	10.2	10.5								
Vf(30)	9.1	13.8	7.3	12								
SV(0),l	12.00	5.05	8.73	7.73								
SV(30min),l	2.08	1.09	2.83	1.38								
Jar-test												
Coagulant	M14	M14	M14	M14	M14							
Dose, µmol/l	150	200	250	300	350							
turbidit, NTU	20	8	4.9	3.1	2.9							
pH	7.3	7.3	7.2	7.3	7.2							
Ortho-P, mg/l	0.46	0.29	0.19	0.1	0.06							
************												

Date	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	
Water collected:	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	
Coagulant	M14	M14	M14	M14	M14	M14	M14	M14	M14	M14	M14	
Dose, µmole/l	200	250	175	200	200	200	200	250	250	250	250	
Cationic polym.												
Dose, mg/l												
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0	0	0.1	0.2	0.3	0	0.1	0.2	0.3	
Pipe floc.												
coag-cat. }												
cat-anion. }	7min	7min	1min	1min	1min	1min	1min	1min	1min	1min	1min	
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	
Turb(raw), NTU	76	76	76	76	76	76	76	76	76	76	76	
Ortho-P(raw), mg/l	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	
pH(raw)	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	
Alkalinity, mmole/l	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	
Turb.(0), NTU	4	2.8	12	8	5.6	6	4.8	7	4.4	5.9	4	
Turb.(30),NTU	2.9	2	4.5	5.4	4.9	5	4.6	3.2	3.1	3	3.2	
Ortho-P, mg/l	0.06	0.03	0.12	0.14	0.13	0.13	0.13	0.07	0.05	0.04	0.07	
pH	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	
Centrif., %												
Dry Solids, %	0.64	0.72	0.6	0.56	0.56	0.64	0.72	0.6	0.56	0.52	0.56	
Floc Bl. level, m/h												
after 3min												
4min												
5min												
6min												
7min												
8min												
9min												
10min												
11min												
12min												
Sl. pumping, ml/min	450	450	300	400	360	300	400	650	600	600	500	
Settling(30min), ml/l	60	90	90	20	70	70	100	120	90	60	70	
Fl. bl. (Vf)-not corrected for sl. pumping,m/h												
Vf(0)	*4.7*	*4.4*	*3.3*	*3.3*	*4*	*4.2*	*5*	*3.5*	*4.2*	*4.8*	*5*	
Vf(5)	*8.2*	*8.2*	*6.4*	*7*	*8*	*6*	*9.5*	*7*	*7*	*7.5*	*11.8*	
Vf(10)	*11*	*11*	*8.2*	*9*	*10*	*8*	*11*	*9.5*	*9*	*10*	*13*	
Vf(20)	*13.4*	*12.4*	*10.5*	*11.5*	*12.4*	*10.5*	*13*	*12*	*10*	*12.4*	*17.2*	
Vf(30)	*15*	*14.5*	*12.1*	*13*	*14.1*	*11*	*16.2*	*13.8*	*11.8*	*13.8*	*19.5*	
Vf-corrected:m/h												
Vf(0)	3.6	3.4	2.8	2.6	3.3	3.6	4	2.4	2.9	3.3	3.8	
Vf(5)	6.4	6.4	5.4	5.6	6.6	5.1	7.6	4.7	4.9	5.8	8.3	
Vf(10)	8.5	8.5	7	7.2	8.2	6.8	8.8	6.4	6.3	7.8	9.1	
Vf(20)	10.4	9.6	8.9	9.2	10.2	8.9	10.4	8.1	7	9.6	12	
Vf(30)	11.6	11.2	10.3	10.4	11.6	9.4	13	9.3	8.3	10.7	13.7	
SV(0),l	5.5	6.03	9.29	9.29	6.96	6.47	4.98	8.5	6.47	5.29	4.98	
SV(30min),l	0.96	1.01	1.32	1.19	1.05	1.53	0.85	1.09	1.37	1.09	0.65	
SV(p), l	1.02	1.09	1.37	1.2	1.1	1.59	0.93	1.21	1.51	1.18	0.7	
Jar-test												
Coagulant	M14	M14	M14	M14	M14	M14						
Dose, µmol/l	75	100	150	200	250	300						
Turbidity, NTU	28	14.2	5.2	4.2	3.2	4						
pH	7.3	7.2	7.3	7.3	7.4	7.3						
Ortho-P, mg/l	0.58	0.47	0.28	0.15	0.07	0.03						

Appendix

Date	18.Feb	18.Feb	18.Feb	18.Feb	18.Feb	18.Feb	18.Feb	18.Feb	18.Feb			
Water collected:	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb	17.Feb			
Coagulant	M14	M14	M14	M14	M14	M14	M14	M14	M14			
Dose, μmole/l	150	150	200	200	200	250	250	250	250			
Cationic polym.												
Dose, mg/l												
Anionic polym. (P6)												
Dose, mg/l	0	0.2	0	0.2	0.3	0	0.1	0.2	0.3			
Pipe floc.												
coag-cat.												
cat-anion.	7min	7min	7min	7min	7min	7min	7min	7min	7min			
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec			
Turb(raw), NTU	87	87	87	87	87	87	87	87	87			
Ortho-P(raw), mg/l	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15			
pH(raw)	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4			
Alkalinity, mmole/l	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59			
Turb.(0), NTU	26	10	19	4.6	3.7	11	4.9	3.5	3.4			
Turb.(30),NTU	12	9.7	8	3.4	2.9	3.9	3.6	2.8	2.6			
Ortho-P, mg/l	0.69	0.66	0.55	0.53	0.53	0.38	0.39	0.39	0.42			
pH	7.5	7.5	7.5	7.5	7.5	7.4	7.4	7.5	7.4			
Centrif., %												
Dry Solids, %	0.92	0.88	0.56	0.84	0.72	0.52	0.56	0.68	0.64			
Floc Bl. level, m/h												
after 3min												
4min												
5min												
6min												
7min												
8min												
9min												
10min												
11min												
12min												
Sl. pumping, ml/min	340	250	350	250	340	500	600	500	500			
Settling(30min), ml/l	150	150	140	120	130	80	110	140	150			
Fl. bl. (Vf)-not corrected for sl. pumping;m/h												
Vf(0)	*3*	*6*	*3.3*	*5.4*	*6.4*	*3.2*	*5*	*5.6*	*6.5*			
Vf(5)		*12.4*		*10*	*13.4*	*6.2*	*10.5*	*11*	*12*			
Vf(10)	*13*	*15.3*	*13*	*12*		*8.2*	*12.4*	*12.7*				
Vf(20)		*17.2*		*12.1*		*10.2*	*15.3*	*15.3*				
Vf(30)	*18.3*	*18.3*	*14.5*	*15.3*	*23.2*	*12*	*18.3*	*18.3*	*20.8*			
Vf-corrected:m/h												
Vf(0)	2.5	5.3	2.7	4.7	5.3	2.4	3.5	4.2	4.9			
Vf(5)	0	10.9	0	8.8	11.1	4.7	7.9	8.3	9.9			
Vf(10)	10.8	13.4	10.7	10.5	0	6.2	9.3	9.5	0			
Vf(20)	0	15.1	0	10.6	0	7.7	11.5	11.5	0			
Vf(30)	15.2	16	12	13.4	19.3	9	13.7	13.7	17.2			
SV(0),l	10.71	3.79	9.29	4.44	3.44	9.73	4.98	4.2	3.36			
SV(30min),l	0.71	0.71	1.01	0.93	0.5	1.34	0.71	0.71	0.59			
SV(p), l	0.75	0.79	1.07	1.01	0.58	1.41	0.82	0.85	0.75			
Jar-test												
Coagulant	M14	M14	M14	M14	M14	M14						
Dose, μmol/l	100	150	200	250	300	350						
Turbidity, NTU	47	38	14.7	5.1	3.6	3.7						
pH	7.4	7.4	7.3	7.3	7.3	7.2						
Ortho-P, mg/l	0.9	0.76	0.56	0.43	0.29	0.21						

Appendix

Date	19.Feb	19.Feb	19.Feb									
Water collected:	18.Feb	18.Feb	18.Feb									
Coagulant	M31	M31	M14									
Dose, µmole/l	150	200	200									
Cationic polym.												
Dose, mg/l												
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2									
Pipe floc.												
coag-cat. }												
cat-anion. }	3min	3min										
anion-cone	4min	4min	7min									
Turb(raw), NTU	85	85	85									
Ortho-P(raw), mg/l	1.25	1.25	1.25									
pH(raw)	7.6	7.6	7.6									
Alkalinity, mmole/l	2.78	2.78	2.78									
Turb.(0), NTU	14	5.2	5.9									
Turb.(30),NTU	12	4.2	4.6									
Ortho-P, mg/l	0.3	0.07	0.42									
pH	7.6	7.5	7.6									
Centrif., %												
Dry Solids, %	0.52	0.72	1.04									
Floc Bl. level, m/h												
after 3min												
4min												
5min												
6min												
7min												
8min												
9min												
10min												
11min												
12min												
Sl. pumping, ml/min	260	220	240									
Settling(30min), ml/l	120	250	200									
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*5.5*	*6.7*	*5.3*									
Vf(5)	*10*	*12*	*11*									
Vf(10)	*12*	*13.8*	*13*									
Vf(20)	*14.5*	*15.3*	*15.3*									
Vf(30)	*15.3*	*17.2*	*16.2*									
Vf-corrected:m/h												
Vf(0)	4.8	6	5.3									
Vf(5)	8.7	10.7	11									
Vf(10)	10.4	12.3	13									
Vf(20)	12.6	13.6	15.3									
Vf(30)	13.3	15.3	16.2									
SV(0), l	4.32	3.21	4.56									
SV(30min),l	0.93	0.78	0.85									
SV(p), l	1.01	0.94	0.96									
Jar-test												
Coagulant	M31	M31	M31	M31	M31	M31						
Dose, µmol/l	100	150	200	250	300	350						
Turbidity, NTU	47	41	35	10.1	4.1	2.5						
pH	7.3	7.5	7.3	7.3	7.3	7.3						
Ortho-P, mg/l	0.99	0.68	0.53	0.13	0.05	0.04						

Appendix

Date	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb	20.Feb
Water collected:	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb	19.Feb
Coagulant	M31	M31	M31	M31	M31	M31	M31	M31	M31	M31	M31	M31
Dose, µmole/l	200	150	150	150	150	150	150	150	150	150	150	150
Cationic polym.		A25	A27		A25	A25	A25	A25	A27	A27	A27	A27
Dose, mg/l	0	0.2	0.2	0	0	0.1	0.2	0.5	0	0.1	0.2	0.5
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pipe floc.												
coag-cat.	3min	2min	2min	2min	3min	3min	3min	3min	3min	3min	3min	3min
cat-anion.	4min	2min	2min	2min	4min	4min	4min	4min	4min	4min	4min	4min
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec
Turb(raw), NTU	97	97	97	97	97	97	97	97	97	97	97	97
Ortho-P(raw), mg/l	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
pH(raw)	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Alkalinity, mmole/l	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37
Turb.(0), NTU	3.3	7.2	6.2	15	9.9	12	10	4.8	9.9	7.3	7.8	3.7
Turb.(30),NTU	2.3	5.1	2.9	11	8.5	10	9.7	4.6	8.5	6.5	4.9	2.8
Ortho-P, mg/l	0.08	0.11	0.07	0.22	0.3	0.26	0.26	0.22	0.3	0.25	0.2	0.23
pH	7.2	7.1	7.1	7.1	7.3	7.2	7	7.3	7.3	7.2	7.3	7.3
Centrif., %	78	84	82	88	84	84	80	88	84	82	80	78
Dry Solids, %	1.24	0.88	0.82	0.78	0.8	0.8	1.04	1.12	0.8	0.84	0.8	0.92
Floc Bl. level, m/h												
after 3min	10				7.5			9	7.5	8	8.5	9
4min		(7)	(7)				7					
5min	8					7.5		7				
6min		6	6							6.7	7	
7min					6			6.7	6			6.7
8min							6.3				6	
9min	6.5					5.5		6.3				
10min					5.5				5.5	5.3		6.3
11min		5	5.3	6			5.3				5.3	
12min												5.5
Sl. pumping, ml/min	450	300	310	280	400	350	400	350	400	380	285	250
Settling(30min), ml/l	200	150	150	100	130	110	160	140	150	150	140	150
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*5.3*	*4.7*	*5*	*4.7*	*4.5*	*4.5*	*5*	*5.3*	*4.5*	*4.9*	*5*	*5*
Vf(5)	*9.5*	*7*		*8.2*	*7.5*	*8*	*9.3*	*8.2*	*7.5*	*10*	*8.2*	*7.5*
Vf(10)	*11.5*	*8.4*	*11*	*10*	*9.3*	*9.5*	*11*	*9.5*	*9.3*	*12*	*10.5*	*9.3*
Vf(20)	*13.4*	*10*		*12.4*	*9.5*	*12*	*13*	*11.7*	*9.5*	*13.8*	*13*	*10.5*
Vf(30)	*14.5*	*12.2*	*14.2*	*13.8*	*12.4*	*13*	*14.5*	*12*	*12.4*	*15.3*	*14.5*	*12*
Vf-corrected:m/h												
Vf(0)	4.1	4	4.2	4	3.6	3.7	4	4.4	3.6	4	4.3	4.4
Vf(5)	7.4	6	0	7.1	6	6.6	7.4	6.8	6	8.1	7	6.6
Vf(10)	8.9	7.1	9.3	8.6	7.4	7.8	8.8	7.8	7.4	9.7	9	8.1
Vf(20)	10.4	8.5	0	10.7	7.6	9.9	10.4	9.7	7.6	11.2	11.1	9.2
Vf(30)	11.2	10.4	12	11.9	9.9	10.7	11.6	9.9	9.9	12.4	12.4	10.5
SV(0), l	4.56	5.46	4.98	5.46	5.83	5.83	4.98	4.56	5.83	5.13	4.98	4.98
SV(30min),l	1.01	1.31	1.04	1.09	1.27	1.19	1.01	1.34	1.27	0.93	1.01	1.34
SV(p), l	1.25	1.44	1.16	1.16	1.41	1.28	1.17	1.51	1.43	1.05	1.11	1.46
Jar-test												
Coagulant	M31	M31	M31	M31	M31	M31						
Dose, µmol/l	100	150	200	250	300	350						
Turbidity, NTU	51	41	48	4.8	2.6	1.9						
pH	7.1	7.1	7.1	7	7	6.9						
Ortho-P, mg/l	1.25	0.78	0.86	0.04	0	0						

Date	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb		
Water collected:	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb	24.Feb		
Coagulant	M31	M31	M31	M31	M31	M31	M31	M31	M31	M31		
Dose, μmole/l	150	100	100	100	100	100	100	100	100	100		
Cationic polym.			A25	A27	A25	A25	A25	A27	A27	A27		
Dose, mg/l	0	0	0.2	0.2	0	0.1	0.2	0	0.1	0.2		
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
Pipe floc.												
coag-cat.	2min	2min	2min	2min	3min	3min	3min	3min	3min	3min		
cat-anion.	2min	2min	2min	2min	4min	4min	4min	4min	4min	4min		
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec		
Turb(raw), NTU	58	58	58	58	58	58	58	58	58	58		
Ortho-P(raw), mg/l	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66		
pH(raw)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5		
Alkalinity, mmole/l	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05		
Turb.(0), NTU	2.2	6.3	6	4.9	4	3.2	2.5	4	4.5	3.7		
Turb.(30),NTU	1.9	3	3.4	2.9	2.1	1.4	1.6	2.1	1.7	1.7		
Ortho-P, mg/l	0.1	0.06	0.04	0.05	0.04	0.03	0.03	0.04	0.03	0.04		
pH	7.5	7.6	7.6	7.5	7.6	7.6	7.6	7.6	7.6	7.6		
Centrif., %	84	86	82	82	80	82	82	80	84	82		
Dry Solids, %	0.6	0.68	0.76	0.72	0.72	0.64	0.64	0.72	0.8	0.8		
Floc Bl. level, m/h												
after 3min	10											
4min		10	10	10		11	11					
5min			9		12			12	11	11		
6min	9				11			11				
7min		9	8.5	8			9.5		9.5	9		
8min	8	8.5				10						
9min									8.5			
10min		7.3		7		9				8		
11min	7.5		7.5		8.5		9	8.5				
12min												
Sl. pumping, ml/min	220	220	180	180	200	260	180	200	250	250		
Settling(30min), ml/l	100	100	120	120	120	90	150	120	180	160		
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*6*	*6.7*	*7*	*6.7*	*7.3*	*7.7*	*7.2*	*7.3*	*7.5*	*7.5*		
Vf(5)	*10*	*13*	*13*	*12.4*	*13.8*	*13*	*13.2*	*13.8*	*13.8*	*12.1*		
Vf(10)	*12*	*14.5*	*15.3*	*13.8*	*15.3*	*14.9*	*17.2*	*15.3*	*16.2*	*14.1*		
Vf(20)	*14.5*	*16.2*	*17.2*	*15.3*	*17.2*	*16.2*	*18.3*	*17.2*	*17.2*	*15.8*		
Vf(30)	*16.2*	*18.3*	*19.5*	*18.3*	*19.5*	*18.3*	*19.5*	*19.5*	*19.5*	*17.2*		
Vf-corrected:m/h												
Vf(0)	5.3	6	6.4	6.1	6.6	6.7	6.5	6.6	6.6	6.6		
Vf(5)	8.9	11.6	11.8	11.3	12.4	11.3	12	12.4	12.1	10.6		
Vf(10)	10.7	12.9	13.9	12.6	13.8	13	15.7	13.8	14.2	12.3		
Vf(20)	12.9	14.4	15.7	13.9	15.5	14.1	16.7	15.5	15.1	13.8		
Vf(30)	14.4	16.3	17.7	16.7	17.6	15.9	17.7	17.6	17.1	15.1		
SV(0), l	3.79	3.21	3.01	3.21	2.82	2.61	2.89	2.82	2.71	2.71		
SV(30min),l	0.85	0.71	0.65	0.71	0.65	0.71	0.65	0.65	0.65	0.78		
SV(p), l	0.91	0.77	0.71	0.77	0.72	0.79	0.72	0.72	0.78	0.92		
Jar-test												
Coagulant	M31	M31	M31	M31	M31	M31						
Dose, μmol/l	75	100	150	200	250	300						
Turbidity, NTU	18	7.2	3.1	2.4	2.1	2.1						
pH	7.4	7.4	7.4	7.3	7.2	7.2						
Ortho-P, mg/l	0.23	0.11	0.04	0.03	0.02	0.01						

Date	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb			
Water collected:	25.Feb	25.Feb	25.Feb	25.Feb	25.Feb	25.Feb	25.Feb	25.Feb	25.Feb			
Coagulant	M31	M31	M31	M31	M31	M31	M31	M31	M31			
Dose, µmole/l	125	125	125	125	125	125	100	125	150			
Cationic polym.	A25	A25	A25	A27	A27	A27						
Dose, mg/l	0	0.2	0.5	0	0.2	0.5	0	0	0			
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2			
Pipe floc.												
coag-cat.	3min	3min	3min	3min	3min	3min	3min	3min	3min			
cat-anion.	4min	4min	4min	4min	4min	4min	4min	4min	4min			
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec			
Turb(raw), NTU	104	104	104	104	104	104	104	104	104			
Ortho-P(raw), mg/l	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68			
pH(raw)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)			
Alkalinity, mmole/l	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42			
Turb.(0), NTU	19	19	21	19	18	18	37	31	12.1			
Turb.(30),NTU	14	15	15	14	15	13	29	25	9			
Ortho-P, mg/l	0.7	0.69	0.66	0.7	0.7	0.71	1.35	0.66	0.38			
pH	7.4	7.4	7.4	7.4	7.4	7.4	7.3	7.4	7.4			
Centrif., %	94	86	86	94	84	88	84	88	78			
Dry Solids, %	0.88	0.96	0.96	0.88	1.04	1.04	1.08	0.68	0.92			
Floc Bl. level, m/h												
after 3min									(9)			
4min	(9.5)		(8)	(9.5)	(9)	(10)						
5min		(8)							9			
6min	9			9					7.5			
7min			8.5		8.5	9						
8min	8	8		8					7			
9min		7	7.5		7	7.5						
10min	6.7			6.7								
11min		6.7			6.5	7	(7)		6.3			
12min							7	(?)				
Sl. pumping, ml/min	200	300	300	200	300	300	300	290	310			
Settling(30min), ml/l	90	80	80	90	80	80	60	70	90			
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*5.7*	*5.8*	*6*	*5.7*	*6*	*5.8*	*7.5*	*1.9*	*6.2*			
Vf(5)	*11.5*	*11.7*	*13.4*	*11.5*	*13*	*12*	*12.4*	*16.2*	*10.1*			
Vf(10)	*12.7*	*14.5*	*15.8*	*12.7*	*15.3*	*13*	*14.5*	*18*	*13.6*			
Vf(20)	*17.2*	*18.3*	*19.5*	*17.2*	*18.3*	*16.2*	*18.3*	*21.2*	*14.5*			
Vf(30)	*20.8*	*20.8*	*22*	*20.8*	*19.5*	*19.5*	*20.8*	*23.8*	*18.3*			
Vf-corrected:m/h												
Vf(0)	5.1	4.9	5.1	5.1	5.1	4.9	6.38	1.62	5.2			
Vf(5)	10.4	9.9	11.4	10.4	11.1	10.2	10.54	13.85	8.5			
Vf(10)	11.4	12.3	13.4	11.4	13	11.1	12.33	15.39	11.5			
Vf(20)	15.5	15.6	16.6	15.5	15.6	13.8	15.56	18.13	12.3			
Vf(30)	18.7	17.7	18.7	18.7	16.6	16.6	17.68	20.35	15.5			
SV(0), l	4.09	3.99	3.79	4.09	3.79	3.99	2.71	21.26	3.61			
SV(30min),l	0.59	0.59	0.54	0.59	0.65	0.65	0.59	0.48	0.71			
SV(p), l	0.62	0.63	0.58	0.62	0.7	0.7	0.64	0.49	0.78			
Jar-test												
Coagulant	M31	M31	M31	M31								
Dose, µmol/l	150	200	250	300								
Turbidity, NTU	37	11.2	2.4	2.4								
pH	7.1	7.2	7.2	7.2								
Ortho-P, mg/l	0.5	0.2	0.09	0.02								

Appendix

Date	27.Feb	27.Feb	27.Feb	27.Feb	27.Feb	27.Feb	27.Feb	27.Feb	27.Feb			
Water collected:	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb	26.Feb			
Coagulant	M31	M31	M31	M31	M31	M31	M31	M31	M31			
Dose, μmole/l	125	150	150	150	150	150	150	150	150			
Cationic polym.		A25	A27	A25	A25	A25	A27	A27	A27			
Dose, mg/l	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2			
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2			
Pipe floc.												
coag-cat.	3min	3min	3min	3min	3min	6min	3min	3min	6min			
cat-anion.	4min	4min	4min	4min	7min	7min	7min	7min	7min			
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec			
Turb(raw), NTU	76	76	76	76	76	76	76	76	76			
Ortho-P(raw), mg/l	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67			
pH(raw)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)			
Alkalinity, mmole/l	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33	2.33			
Turb.(0), NTU	18	6.7	6.7	5.7	5.6	5.4	6.3	4.4	6.1			
Turb.(30),NTU	14	5.4	5.4	4.6	4.7	4.9	4.6	4	5.3			
Ortho-P, mg/l	1.1	0.46	0.46		0.32	0.31	0.41	0.21	0.35			
pH	7.3	7.4	7.4	7.4	7.4	7.5	7.4	7.4	7.4			
Centrif., %	82	82	82	76	78	82	80		78			
Dry Solids, %	0.92	0.88	0.88	0.92	0.92	0.8	0.92	0.92	0.92			
Floc Bl. level, m/h												
after 3min	(-8)	(-10)	(-10)		(-10)		(-10)	11	(-9)			
4min		9.5	9.5	10	11	9.5	10		9			
5min	10				9.5			10				
6min		8.5	8.5			8.5	9		8.5			
7min	8				8.5			9				
8min		7.7	7.7	7.2			8.5		7.3			
9min					7.3	7		7.8				
10min	7.5	7.3	7.3				7.5					
11min				6.6	7	6.9		7.5	6.3			
12min		6.5	6.5									
Sl. pumping, ml/min	300	340	340	240	240	260	340	240	240			
Settling(30min), ml/l	90	140	140	160	170	140	140	150	140			
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*5.7*	*6.5*	*6.5*	*6.4*	*6.6*	*6.3*	*6.3*	*7.2*	*6*			
Vf(5)	*12.4*	*11.2*	*11.2*	*12.7*	*13*	*10*		*13.4*	*10*			
Vf(10)	*14.5*	*13.4*	*13.4*	*15*	*15.3*	*12*	*13*	*15*	*12*			
Vf(20)	*17.2*	*14.9*	*14.9*	*16.8*	*17.2*	*14.1*	*15.3*	*16.2*	*14.1*			
Vf(30)	*19.5*	*16.7*	*16.7*	*19.3*	*19.5*	*15.8*	*16.7*	*18.3*	*15.3*			
Vf-corrected:m/h												
Vf(0)	4.8	5.4	5.4	5.6	5.8	5.5	5.2	6.3	5.3			
Vf(5)	10.5	9.3	9.3	11.2	11.4	8.7	0	11.8	8.8			
Vf(10)	12.3	11.1	11.1	13.2	13.5	10.4	10.8	13.2	10.6			
Vf(20)	14.6	12.4	12.4	14.8	15.1	12.3	12.7	14.3	12.4			
Vf(30)	16.6	13.9	13.9	17	17.2	13.7	13.9	16.1	13.5			
SV(0), l	4.09	3.36	3.36	3.43	3.28	3.52	3.52	2.88	3.79			
SV(30min),l	0.65	0.82	0.82	0.66	0.65	0.89	0.82	0.71	0.93			
SV(p), l	0.7	0.96	0.96	0.75	0.75	1	0.95	0.82	1.03			
Jar-test												
Coagulant	M31	M31	M31	M31								
Dose, μmol/l	150	200	250	300								
Turbidity, NTU	31	7.5	2.7	1.8								
pH	6.7	6.8	6.8	6.8								
Ortho-P, mg/l	0.43	0.13	0.04	0.03								

Date	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar				
Water collected:	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar				
Coagulant	JKL	JKL	M14	M14	M31	M31	M31	JKL				
Dose, µmole/l	153	185	125	150	80	80	80	92				
Cationic polym.						A25	A27					
Dose, mg/l					0	0.2	0.2					
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Pipe floc.												
coag-cat.	7min	7min	7min	7min	3min	3min	3min	7min				
cat-anion.					4min	4min	4min					
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec				
Turb(raw), NTU	51	51	51	51	51	51	51	51				
Ortho-P(raw), mg/l	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79				
pH(raw)	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3				
Alkalinity, mmole/l	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98				
Turb.(0), NTU	7.2	4.5	7	4.3	5.6	6	4.2	22				
Turb.(30),NTU	5.6	3.2	2.9	1.9	3.2	2.3	3	17				
Ortho-P, mg/l	0.08	0.04	0.21	0.13	0.65	0.15	0.13	0.31				
pH	7.2	7.1	7.5	7.5	7.4	7.4	7.4	7.5				
Centrif., %	82	80	76	74	84	82	82					
Dry Solids, %	1.04	0.88	0.84	0.72	0.8	0.96	0.88					
Floc Bl. level, m/h												
after 3min		'(11)					(-12)					
4min		11										
5min					(-11)	(-12)	13					
6min		10			11.5							
7min				'(7)		11	11.5					
8min	'(7)	9		7	10.5	10.5						
9min	7		'(8)				11					
10min		8.5	8	6.5	10	9.5						
11min	6				9.7	9						
12min							9.5					
Sl. pumping, ml/min	190	190	220	220	170	170	170					
Settling(30min), ml/l	70	90	90	90	140	160	170					
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*5.7*	*7.6*	*7.5*	*5.7*	*9*	*9.1*	*9.5*					
Vf(5)	*17*	*14.9*	*16.2*	*10.7*	*18.3*	*17.8*	*18.3*					
Vf(10)	*16.7*	*17.2*	*19.5*	*13*	*20.8*	*20.8*	*22*					
Vf(20)	*20.1*		*23.8*	*16.2*	*22*	*23.8*	*24*					
Vf(30)	*20.9*	*23.8*	*25*	*18.9*	*22.5*	*24.5*	*24.5*					
Vf-corrected:m/h												
Vf(0)	5.2	6.9	6.7	5.1	8.2	8.3	8.7					
Vf(5)	11.8	13.5	14.4	9.5	16.7	16.3	16.7					
Vf(10)	15.1	15.6	17.4	11.6	19	19	20.1					
Vf(20)	18.2	0	21.2	14.4	20.1	21.8	22					
Vf(30)	18.9	21.5	22.3	16.8	20.6	22.4	22.4					
SV(0), l	4.09	2.66	2.71	4.09	2.06	2.03	1.9					
SV(30min),l	0.58	0.48	0.45	0.68	0.52	0.46	0.46					
SV(p), l	0.6	0.52	0.49	0.72	0.59	0.53	0.54					
Jar-test												
Coagulant	M31	M31	M31	M31								
Dose, µmol/l	75	100	150	200								
Turbidity, NTU	33	15.2	3.7	3								
pH	7.4	'(7)	7.2	7.2								
Ortho-P, mg/l	0.29	0.17	0.05	0.03								

Date	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar				
Water collected:	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar	3.Mar				
Coagulant	M14	M14	M14	M14	M14	M14	M14	M14				
Dose, µmole/l	100	150	150	150	150	200	200	200				
Cationic polym.												
Dose, mg/l												
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
Pipe floc.												
coag-cat.												
cat-anion.	1min	1min	2min	4min	7min	1min	2min	4min				
anion-cone	38sec	38sec	38sec	38sec	38sec	38sec	38sec	38sec				
Turb(raw), NTU	95	95	95	95	95	95	95	95				
Ortho-P(raw), mg/l	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04				
pH(raw)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5				
Alkalinity, mmole/l	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69				
Turb.(0), NTU		6.6	4.4	8.1	7	5.9	7.3	5.9				
Turb.(30),NTU	22	3.6	3.4	4.9	3	1.9	2.4	3.1				
Ortho-P, mg/l	0.55		0.44	0.43	0.41	0.37	0.3	0.3				
pH	7.7	7.4	7.6	7.5		7.6	7.5	7.6				
Centrif., %		76	74	80	82	12	76					
Dry Solids, %		0.88	0.88	0.76	0.56	0.76	0.76	0.72				
Floc Bl. level, m/h												
after 3min			'(12)				'(8)					
4min						'(8)	8					
5min		'(7)				7.5						
6min			6.5			6.6	7.5					
7min	'(4)	8		7				7				
8min		6.7	6.6		8	6	6.7					
9min				6								
10min		6.5	6.2			5.3	6	6.7				
11min	'(3,5)			5.5	7							
12min		5.7										
Sl. pumping, ml/min		180	145	200	220	150	140	170				
Settling(30min), ml/l		110	90	95	100	120	95	95				
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)		*5.3*	*5.5*	*5.5*	*5.8*	*5.2*	*5.7*	*5.8*				
Vf(5)		*10.5*	*12.4*	*10*	*10.1*	*11*	*10.5*	*10.6*				
Vf(10)		*12*	*14.9*	*12.1*	*12.7*	*12.4*	*12.4*	*12.2*				
Vf(20)		*14.5*	*17.8*	*13.8*	*13.8*	*14.9*	*14.1*	*13.9*				
Vf(30)		*15.8*	*18.9*	*15.3*	*15.5*	*16.2*	*15.3*	*15*				
Vf-corrected:m/h												
Vf(0)		4.8	5.1	5	5.1	4.8	5.3	5.3				
Vf(5)		9.6	11.5	9	9	10.2	9.8	9.7				
Vf(10)		10.9	13.8	11.5	11.3	11.5	11.5	11.2				
Vf(20)		13.2	16.5	12.4	12.3	13.8	13.1	12.7				
Vf(30)		14.4	17.5	13.8	13.8	15	14.2	13.7				
SV(0), l		4.56	4.32	4.32	3.99	4.69	4.09	3.99				
SV(30min),l		0.89	0.68	0.93	0.91	0.85	0.93	0.95				
SV(p), l		0.94	0.7	0.98	0.97	0.89	0.97	1				
Jar-test												
Coagulant	M14	M14	M14	M14	M14							
Dose, µmol/l	100	150	200	250	300							
Turbidity, NTU	37	7.7	3.8	3	3.5							
pH	7.3	7.4	7.4	7.4	7.4							
Ortho-P, mg/l	0.61	0.35	0.24	0.13	0.07							

Appendix

Date	5.Mar	5.Mar	5.Mar	5.Mar	5.Mar	5.Mar	5.Mar	5.Mar	5.Mar			
Water collected:	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar	4.Mar			
Coagulant	JKL	JKL	JKL	JKL	M14	M31	M31	M31	M31			
Dose, µmole/l	150	250	300	300	150	150	150	150	200			
Cationic polym.							A25	A27				
Dose, mg/l							0.2	0.2				
Anionic polym. (P6)												
Dose, mg/l	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2			
Pipe floc.												
coag-cat.	7min	7min	7min	2min	2min	3min	3min	3min	3min			
cat-anion.						3min	3min	3min	3min			
anion-cone												
Turb(raw), NTU	68	68	68	68	68	68	68	68	68			
Ortho-P(raw), mg/l	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17			
pH(raw)	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2			
Alkalinity, mmole/l	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29			
Turb.(0), NTU	9	5.5	4	24	16	11	12	11	7			
Turb.(30),NTU	7	4.5	3.6	20	8.6	7	7	4	2.4			
Ortho-P, mg/l	0.31	0.15	0.09	0.07	0.11	0.49	0.13	0.14	0.13			
pH	7.14	6.6	6.6	6.5	6.5	7	7	7	7			
Centrif., %	70	72	78	82	82	84	80	84				
Dry Solids, %	0.76	0.76	0.72	0.48	0.48	0.56		0.64				
Floc Bl. level, m/h												
after 3min			'(12)									
4min			8.6									
5min		(10)		'(6)								
6min		8	7.5									
7min	'(8)			5.5		10						
8min	7.6		6.7		5.7							
9min		7.1		5.1		7.2						
10min	7		6									
11min		6.4		5	5	7						
12min	6.3											
Sl. pumping, ml/min	120	200	280	320	160	130	160	160	170			
Settling(30min), ml/l	90	100	110	90	80	80	100	100	110			
Fl. bl. (Vf)-not corrected for sl. pumping; m/h												
Vf(0)	*6.3*	*5.2*	*5.3*	*4.5*	*4.5*	*6.6*	*6.5*	*6.9*	*6.7*			
Vf(5)	*12.1*	*10.2*	*10.2*	*11*	*11*	*14.9*	*12.4*	*15.3*	*12*			
Vf(10)	*13.8*	*12.2*	*12.4*	*13*	*13.2*	*15.8*	*14.1*	*16.2*	*13.8*			
Vf(20)	*17.2*	*15.4*	*15.8*	*14.5*	*14.8*	*18.3*	*18.3*	*19.1*	*18.3*			
Vf(30)	*18.9*	*16.9*	*17.2*	*16.2*	*16.7*	*19.5*	*20.8*	*20.2*	*21.5*			
Vf-corrected:m/h												
Vf(0)	5.9	4.7	4.6	3.8	4.1	6.2	6	6.3	6.1			
Vf(5)	11.4	9.2	8.8	9.2	10.1	13.9	11.4	14	11			
Vf(10)	13	11	10.7	10.9	12.1	14.8	13	14.9	12.6			
Vf(20)	16.2	13.9	13.6	12.2	13.6	17.1	16.8	17.5	16.7			
Vf(30)	17.8	15.2	14.8	13.6	15.4	18.2	19.1	18.5	19.7			
SV(0), l	3.52	4.7	4.56	5.83	5.83	3.28	3.36	3.07	3.21			
SV(30min),l	0.68	0.8	0.78	0.85	0.82	0.65	0.58	0.59	0.56			
SV(p), l	0.71	0.84	0.84	0.9	0.84	0.67	0.61	0.63	0.6			
Jar-test												
Coagulant	M14	M14	M14	JKL	JKL	JKL						
Dose, µmol/l	150	200	250	250	350	450						
Turbidity, NTU	18.9	3.8	3.2	35	5.5	2.9						
pH	7.1	7.3	7.1	6.8	6.6	6.4						
Ortho-P, mg/l	0.51	0.26	0.21	0.4	0.07	0.02						

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