

# OPTIMISED PARTICLE SEPARATION IN THE PRIMARY STEP OF WASTEWATER TREATMENT

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## ABSTRACT

Since the pollutants in wastewater to such a large extent are associated with particles, enhanced particle separation in the primary step of wastewater treatment should be aimed at. Space restrictions demand pretreatment options with a small "foot-print". In this paper it is shown that coagulation with metal salts is very efficient but leads to excessive sludge production. It is demonstrated how the use of cationic polymers may reduce the sludge production considerably without ruining the SS-removal efficiency and also how improved flocculation, either chemically, by the addition of flocculants or physically, by improvement of settling tank design, may lead to better particle separation as well as smaller "foot-print" of the plant. As an alternative to primary settling, primary filtration in coarse, floating filters is discussed as well.

## KEYWORDS

Wastewater; primary treatment; coagulation; polymers; sludge production; coarse media filtration

## INTRODUCTION

Wastewater treatment is to a very large extent a matter of particle separation. This is a result of the fact that most of the pollutants in wastewater exist on particulate or colloidal form or are transformed to this form in the course of the treatment process. This has led to the wastewater treatment strategy of removing particulate and colloidal matter in the primary step and thereafter deal with soluble compounds that need to be transformed to colloidal and particulate matter (e.g. bacteria) before they are separated (Ødegaard, 1992). Traditionally particle separation in the primary step is carried out by settling. This paper will concentrate on how direct particle separation in the primary step may be enhanced and how this may be achieved at a smaller plant "foot print". The basis for this discussion must be the characteristics of raw wastewater that to a large extent is determined by the processes that take place in the wastewater during its flow through the sewer network.

## WASTEWATER CHARACTERISTICS AND ITS INFLUENCE ON TREATMENT

Already in the fifties there were studies carried out in order to fractionate the organic contaminants in wastewater in different size fractions and demonstrate the difference in biodegradability of these fractions (Balmat, 1957; Heukelekian and Balmat, 1959; Richert and Hunter, 1971; Munch et al, 1980). Generally it was found in these studies that about 25 % of the COD was on a soluble form (defined as compounds/

particles with size  $< 0,08 \mu\text{m}$ ). 15 % of the organic matter was found to be appearing as colloidal ( $0,08-1,0 \mu\text{m}$ ), about 25 % as supracolloidal ( $1-100\mu\text{m}$ ) and about 35 % as settleable ( $> 100 \mu\text{m}$ ) particles.

Based on a thorough study of particle size distributions in the primary effluents of some US plants, Levine et al (1985) concluded that organic contaminants in municipal wastewater could effectively be classified as being either greater than or smaller than  $0,1 \mu\text{m}$ . It was found that 63-70 % of the TOC was associated with particles  $> 0,1 \mu\text{m}$ . Recently Neis and Thiem (1996) carried out size distribution analysis in primary effluents in some German plants. They found that among particles  $> 0,1\mu\text{m}$ , 25-30 % was  $< 1 \mu\text{m}$ , 70-85 %  $< 8 \mu\text{m}$ , 85-95 %  $< 32 \mu\text{m}$  and 100 %  $< 100\mu\text{m}$ . From 48 to 69 % of the COD was found to be associated with particles  $> 0,1 \mu\text{m}$  while from 7 to 18 % was associated with particles  $> 8 \mu\text{m}$  in primary effluents. When evaluating data from Scandinavian plants, Ødegaard (1992) reported that the filtered fraction ( $1 \mu\text{m}$  filter) in raw water samples was typically 20-30 % of the total COD, 30-40 % of tot P and 75-85 % of tot N. With respect to other contaminants, like organic and inorganic micropollutants, it is quite clear that heavy metals as well as PCB's and PAH's are strongly associated with particles (Ødegaard, 1987).

An important conclusion from these investigations, is that the smaller organic fractions biodegrade more rapidly than the larger fractions. Even if this should be pretty obvious from a microbiological point of view, it is not taken much into consideration in the planning and design of wastewater treatment plants. This means that not only will the load of organic matter on bioprocesses be reduced by enhanced primary treatment, but the rate at which the bioprocess will perform, will be increased as well.

### **Transformations of wastewater composition in the sewer network.**

One of the main reasons for the large differences with respect to how organic matter (as well other pollutants) appear in the wastewater that is to be treated, is the fact that biological and physical/chemical processes are taking place in the sewer network before the wastewater is reaching the treatment plant. Only lately, have we become interested in the sewer network processes and this has resulted in the organising of conferences on the topic (Hvitved-Jacobsen et al, 1995). The interest has primarily been driven by the fact that researchers dealing with biological nitrogen and phosphorous removal have been concerned about the fate of the organic acids of the wastewater. There are several processes taking place in the sewer network, depending on the prevailing conditions, such as aerobic/anaerobic, laminar/turbulent, oxidising/reducing etc and on the composition of individual discharges to the sewer such as amount and type of industrial discharge, sewer corrosion, inclination of sewers, the extent of sewage pumping and so on.

One can characterise two extreme situations that to a large extent may explain transformations of organic matter in sewers. Typical for the first situation is that the landscape is flat and consequently the sewers are laid with a low inclination. Sewage pumping is necessary and the sewer pipe is filled most of the time. Anaerobic conditions prevail in the wastewater and in the biofilm that will establish itself on the wall of the sewer. Particulate organic matter will be captured/adsorbed in the biofilm and hydrolysed biologically. The end result will be that the amount of soluble, easily biodegradable organic matter (organic acids) is increased while the amount of particulate/colloidal, heavily biodegradable organic matter is decreased.

Typical for the other situation is that the landscape is hilly, the sewers are laid with a steep inclination and the wastewater flows fast in sewers that function as channels. Oxygen is driven into the wastewater because of turbulence. Aerobic conditions prevail in the wastewater and in the biofilm that will establish itself on the wall of the sewer. The end result will be decreased amounts of soluble, easily biodegradable organic matter (organic acids) and increased amounts of particulate/-colloidal, heavily biodegradable organic matter in the form of biomass. More will be gained by enhanced particle separation in this situation than in the one described above.

### **The possibilities for improvement of the efficiencies of the primary treatment step**

Traditionally primary settling has been used for particle separation in the first step of wastewater treatment. With the overflow rates normally used (around 2 m/h) and the densities of typical wastewater particles, it can be calculated from Stokes law that particles down to about 30-50  $\mu\text{m}$  will be settled out. This means in practice that around 50 % of the suspended solids and 30 % of the organic matter is removed by primary settling. If particles down to around 0,1  $\mu\text{m}$  could be removed, considerable improvement would be gained.

More and more the "foot print" of the wastewater treatment plant is a factor that has to be taken into consideration. Compared to what is achieved in terms of treatment, the primary settling tanks are too spacious and more compact, "area-efficient" separation units are being looked for.

In order to improve the particle separation- and area efficiency, there are three possible ways to go, none of which excludes the others :

1. To pretreat the wastewater before settling in order to increase particle size and/or particle density
2. To improve the design of the settling tank so that better efficiency can be achieved at a smaller space
3. To use another more efficient particle separation method

#### IMPROVED EFFICIENCY BY PRETREATMENT BASED ON COAGULATION

The most well-known and commonly used method of pretreatment in order to enhance particle separation in primary treatment, is the addition of coagulants. In primary coagulation (sometimes also referred to as primary precipitation) a coagulant is added to the raw wastewater resulting in destabilisation of colloids. The small aggregates of primary destabilised particles are flocculated and separated by settling (most common), flotation or filtration. The coagulant is normally based on aluminium or iron resulting in precipitation of phosphate as well as coagulation of colloids. In fact, where primary precipitation plants are frequently used, as in Norway, the primary treatment goal has been phosphate elimination. In Norway the conditions in the sewer network can frequently be described by the situation where aerobic conditions prevail, for which primary coagulation is very favourable, since a major part of the organic matter appears in the form of particles/colloids. This is demonstrated in Table 1 where the average treatment result from Norwegian primary precipitation plants, taken from two different investigations of larger and smaller plants respectively (Ødegaard, 1992 and Ødegaard and Skråvseth, 1995) are given.

Table 1. Average treatment results in 23 larger (>2.000 pe)(Ødegaard, 1992) and 35 smaller (<2.000 pe) (Ødegaard and Skråvseth, 1995) primary precipitation plants in Norway

Parameter	Average inlet concentration		Average outlet concentration		Average treatment efficiency	
	Large plants	Small plants	Large plants	Small plants	Large plants	Small plants
SS (mg/l)	233 $\pm$ 171	226 $\pm$ 150	17,3 $\pm$ 10,0	22,3 $\pm$ 16,6	92,0	90,1
COD (mg/l)	505 $\pm$ 243	494 $\pm$ 90	108 $\pm$ 40	121 $\pm$ 72	78,6	75,5
Tot P (mg/l)	5,40 $\pm$ 3,01	5,33 $\pm$ 2,26	0,28 $\pm$ 0,14	0,50 $\pm$ 0,46	94,8	90,6

It is demonstrated that very good efficiencies in SS-removal can be obtained even at small plants with large variations in flow, demonstrating the operational stability of the process. These good SS-removal results in a reduction of the COD-load on proceeding processes with more than 75 %. And when a metal salt is used as the coagulant (as in this case) excellent phosphate removal is obtained as well.

## Minimising sludge production

The downside of traditional chemical primary coagulation is the considerably increased sludge production as compared to primary settling only, partly as a result of improved SS-removal but partly also due to precipitated material. The sludge produced during chemical coagulation consists basically of the suspended solids removed and the coagulated/precipitated matter, as described below (Ødegaard, 1994):

$$SP = SS_{in} - SS_{out} + K_{prec.} * D$$

where SP = sludge production (g SS/m<sup>3</sup>)  
SS<sub>in</sub>, SS<sub>out</sub> = suspended solids concentration in influent and effluent respectively (g SS/m<sup>3</sup>)  
K<sub>prec.</sub> = sludge production coefficient (g SS/g Me), typically 4-5 for Fe and 6-7 for Al  
D = dosage of metal coagulant (g Me/m<sup>3</sup>)

If the primary goal is optimised particle removal (low SS<sub>out</sub>), one can reduce sludge production only by reducing K or D or both. The level of the dosage in primary precipitation plants in practice, is very much determined by the need for phosphate removal since this, to a large extent, is governed by the pH of coagulation. Plant operators have experienced that the best phosphate removal takes place at pH around 6 and they add enough of the acid metal coagulant to get down to this pH. This results in overdosing and a considerable precipitation of metal hydroxide, i.e. excessive sludge production.

If, on the other hand, phosphate removal is not the important issue, but rather particle removal, one could lower the dosage without ruining coagulation efficiency by replacing part of the metal cation with an organic polymeric cation. The cation will not result in precipitation and would only add very little extra sludge production caused by coagulation. This effect is demonstrated in Figure 1 showing that reducing the Al-dosage and replacing this with cationic polymer could considerably lower sludge production.

Fig. 1. Example of reduced sludge production as a consequence of replacement of some of the metal cation dose with a polymer cation dose in order to reach a given SS-concentration in effluent. Coagulant Pax XL-60. Polymer: Fennofix 40 (Ødegaard and Karlsson, 1994).

Such low-metal dose coagulation, not intended for phosphate removal, has especially been used in the US under the name of "Chemically enhanced primary treatment" (CEPT)(Morrissey and Harleman, 1992).

The least sludge production would be obtained by coagulation with polymeric cation alone. In principle the K<sub>prec.</sub>-value would then be close to zero. Experience have shown, however, that it is difficult, with polymer alone, to obtain as good particle removal as with the use of metal coagulant. A comparison is shown in Figure 2 where jar-test results from various dosing situations are compared.

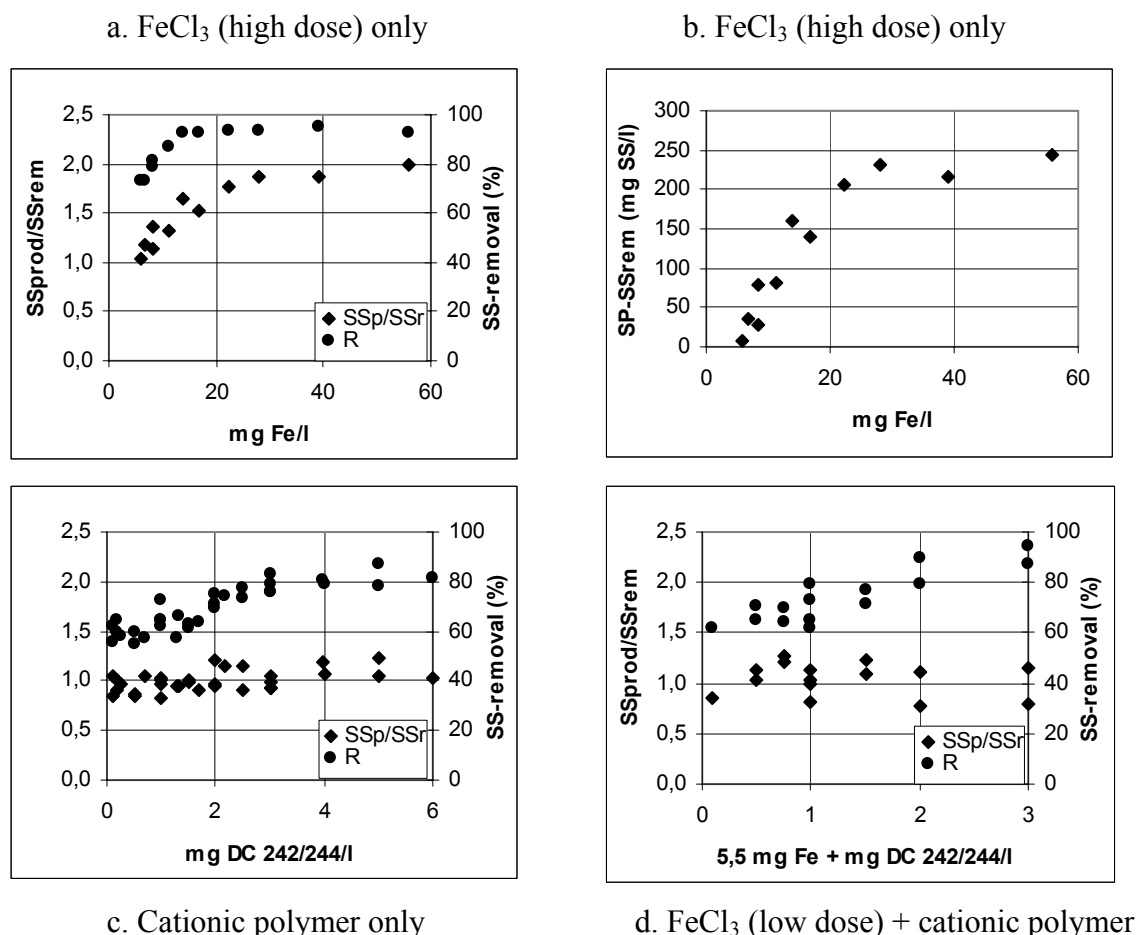


Fig. 2. Comparison of primary particle separation at different dosage scenarios

In Figure 2 a, c and d the ratios between the amount of SS produced (sludge production) and the amount of SS removed ( $SS_{in} - SS_{out}$ ) as well as removal efficiency  $(1 - SS_{out}/SS_{in})100$  are given versus dosage of coagulant. In Figure 2a only FeCl<sub>3</sub> was used as coagulant. The ratio of sludge production relative to the amount of SS that is removed, increases with the iron dosage from 1 to about 2 since matter is precipitated. The SS-removal efficiency increases with dosage to its maximum at dosages over around 15 mg Fe/l. Figure 2b shows that the difference between the amount of sludge produced and the amount removed, increases with dosage, demonstrating the amount of sludge production caused by precipitation. It is interesting to note that the curve crosses the x-axis at around 5 mg Fe/l under which no precipitation seems to occur.

In Figure 2c the results from the use of a low molecular weight, strongly cationic polymer, as the only coagulant, are shown. Two different polymers were tested (Sepco DC 242 and Sepco DC 244). They showed little difference in performance, so the results from the use of both are included in the same figure. Now the sludge production is demonstrated to be close to equal to the amount of SS removed independent upon coagulant dosage. This means that close to nothing is precipitated. The SS-removal efficiency increases with dosage but reaches a maximum of about 80 % at dosages over 4 mg/l.

High SS-removal efficiency, combined with low sludge production can, however, be obtained when combining a low dosage of metal coagulant with a relatively low dosage of cationic polymer, as demonstrated in Figure 2d. From this figure it seems that the low iron dosage does not result in precipitation but rather in enhancement of the coagulation of particles.

There have been objections to the use of synthetic, polymeric cations because of the possibility of monomer formation. Therefore, we are undertaking research into the area of using natural, cationic biopolymers, such as chitosan. Some results are shown in Figure 3, where varying dosages of the chitosan biopolymer Profloc 240 was added to a wastewater at two different aluminium-dosages.

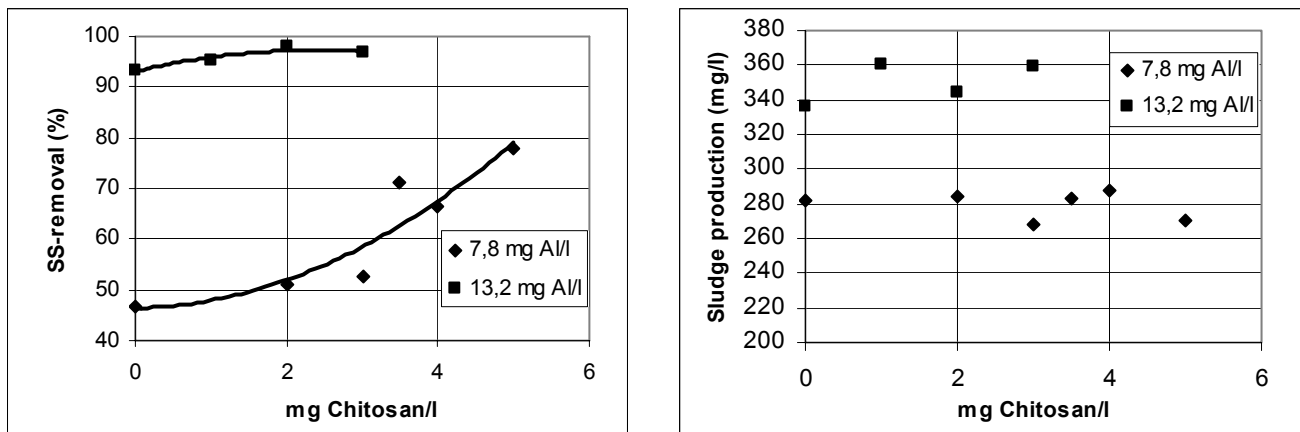


Fig. 3. Example on the use of the biopolymer chitosan (here Profloc 240) as replacement for metal cation

The lower dose - 7,8 mg Al/l - represented an under-dose situation while the higher dose - 13,2 mg Al/l - represented a sufficient-dose situation for good SS-removal. The best SS-removal and the highest sludge production were achieved at the higher Al-dosage. It is demonstrated that the addition of chitosan improved the SS-removal at the lower Al-dosage from 50 % to 80 % without increasing the sludge production.

#### IMPROVED DESIGN AND OPERATION OF THE SETTLING TANK

The key factor to improvement of the efficiency of the settling tank (improved separation result at a smaller "foot-print") is improved flocculation. In conventional primary settling, flocculation is not taken into consideration at all, while in primary precipitation, flocculation is considered important, either being enhanced by mixing (orthokinetic flocculation) or by flocculant addition (chemical flocculation).

#### The increase of hydraulic loading by the use of polymeric flocculants

Traditionally, settling tanks for primary wastewater treatment have been designed for an overflow rate of 2-2,5 m/h. The traditional primary precipitation plants have been designed with a surface load of 1-1,5 m/h, somewhat higher than typical for separation of activated sludge in secondary treatment plants (0,8-1,0 m/h). The acceptable overflow rate is given by the floc settling velocity which is primarily dependent upon floc size and density both of which may be influenced by the addition of a flocculant, normally in the form of an synthetic, organic, anionic polymer. This is demonstrated in Figure 4 (Ødegaard et al, 1992) that is taken from an experiment where the floc settling velocity was determined in a small scale floc blanket reactor at two chemical dosage situations. These included iron chloride (JKL) followed by anionic polymer (Praestol 2540) and prepolymerised aluminium chloride (PAX 60) followed by anionic polymer. Without the anionic flocculant, the settling velocity was in the order of 2-2,5 m/h, well in accordance with what is experienced as maximum acceptable overflow rates in practice. It is demonstrated, however, that the floc settling velocity could be considerably improved by increasing dosages of the anionic flocculant without ruining effluent particle concentration.

#### The significance of orthokinetic flocculation

The key factors in orthokinetic flocculation are the turbulent velocity gradient ( $G, \text{sec}^{-1}$ ), the mean residence time ( $T, \text{min}$ ), the residence time distribution (characterised by the mixing efficiency) and the floc volume fraction ( $\Phi$ ) (Ødegaard, 1979). In order not to increase the "foot-print" of the plant, one would like to avoid considerable detention time. By the use of pipe flocculators (Grohmann, 1985) very controlled G-values and efficient flocculation may be obtained. Increasing the floc volume fraction by establishing floc blankets, through which the suspension has to flow, is another very efficient way of improving flocculation.

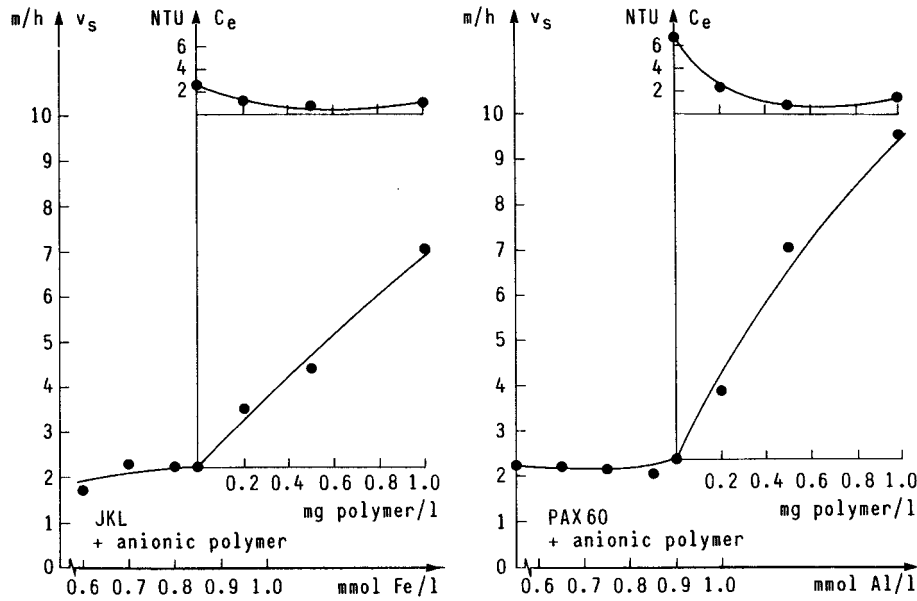


Fig. 4 Influence of anionic polymer addition on chemical floc settling rate (Ødegaard et al, 1992)

In order to demonstrate the significance of orthokinetic flocculation also in primary settling, some laboratory experiments were carried out. Raw wastewater with SS-concentration around 350 mg SS/l, was fed continuously to flocculation/settling jars. It was arranged so that the feed to the jars could be passed through a pipe flocculator (70 seconds at  $G=70 \text{ sec}^{-1}$ ) before it entered the jars. Here flocculation by slow stirring ( $G=10-20 \text{ sec}^{-1}$ ) for various durations could be carried out before the suspension were let to settle for 15 min or 30 min respectively. This same procedure was carried out for four different situations with respect to coagulant dosing: no dosing; dosing of 4 mg/l a cationic polymer (Sepco 242); dosing of a low dose of ferri-chloride (0,1 mmol Fe/l) plus a 4 mg/l dosage of the cationic polymer and finally a high ferri-chloride dosage (0,7 mmol Fe/l). The idea behind the experiment, was to demonstrate that orthokinetic flocculation plays an important role for particle removal even in primary treatment.

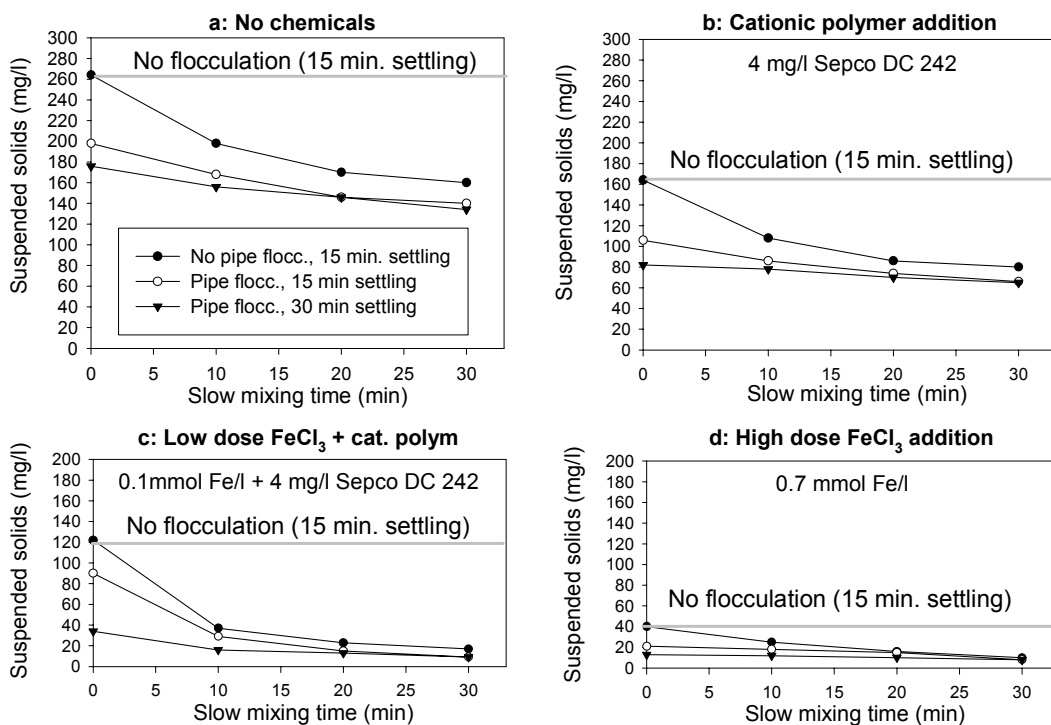


Fig. 5 Demonstrations of the importance of orthokinetic flocculation even in primary treatment.

Figure 5a shows that even without chemical addition of any sort, flocculation through the pipe improves the separation of suspended solids and that an additional slow mix flocculation improves it even more. The shorter the settling time, the more pronounced is the flocculation effect. The other graphs show that the more extensive use of coagulants, the less important is the role of orthokinetic flocculation. This means that the higher the hydraulic load (the lower the "foot-print") and the smaller the dose, the more important is optimisation of the orthokinetic flocculation.

## COARSE MEDIA FILTRATION FOR PRIMARY TREATMENT.

Direct filtration of wastewater in the primary treatment step has not been considered feasible because of the rapid build up of headloss and the large amount of washing water that this would require. In our experimentation with a suspended biofilm carrier (Ødegaard et al, 1994), we have realised, however, that a filter bed with these floating carriers as filter material, has the potential of removing particles at a low head-loss. The removal mechanisms are considered to be flocculation/sedimentation as well as biofilm adsorption. It was decided, therefore, to carry out an experiment of floating media filtration directly on raw sewage in order to evaluate the potential for such a process. After getting this interest, we came to realise that the idea had been investigated already, especially in Japan, where several filtration experiments with coarse filter-media have been carried out (Ishibashi et al, 1993, Mouri and Niwa, 1993 and Tanaka et al, 1995).

### Experimental set-up

Our experiments were tied up with a project carried out for the city of Trondheim in which the goal is to evaluate processes for the new treatment plant of the city. The primary goal is to remove suspended solids by 85 % at a very small "foot-print" of the plant. This will remove sufficient organic matter as well. The wastewater used had been passed through 1,5 mm screens at the existing treatment plant. This water was pumped to a constant head tank and then passed upflow through the 1,0 m filterbed (Figure 6) consisting of Kaldnes biofilm carriers (Ødegaard et al, 1994). This biofilm carrier is made of high density polyethylene with a density of  $0,95 \text{ g/cm}^3$ . It is shaped like a 8 mm high cylinder with a diameter of around 7 mm with a cross inside and fins on the outside of the cylinder. In a packed bed the specific surface area will be around  $700 \text{ m}^2/\text{m}^3_{\text{filtervolume}}$ . This filtermedium was used, not necessarily because it was considered to be the best one, but simply because this was the media we worked with in our suspended biofilm carrier research.

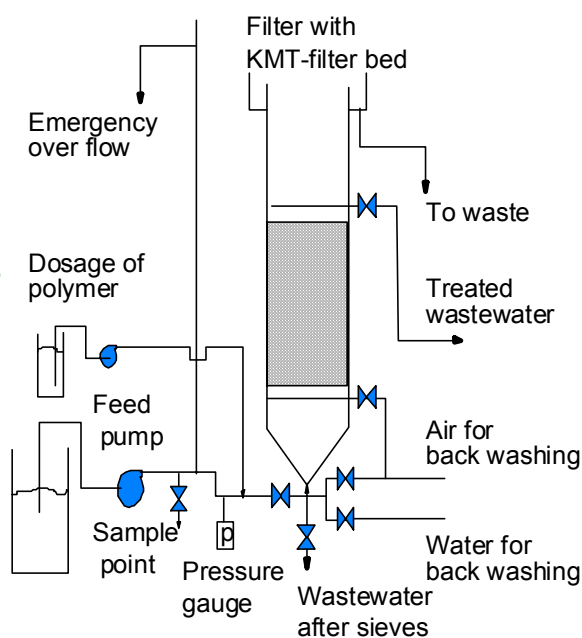




Fig. 6 The experimental set-up for the primary filter experiments

When the filter loss was exceeding 1,0 m, the filter was backwashed by firstly aerating the filter-column in order to suspend the filter-media and loosen captured particle and biofilm and secondly by supplying raw wastewater that subsequently was drained through the bottom of the filter to a sludge thickener tank. This resulted in a wash-water (in the form of raw-water) consumption of 4-4,5 m<sup>3</sup>/m<sup>3</sup><sub>filtervolume</sub> or 5-7 % of filtered water.

The filter was tested under various hydraulic loadings and with and without pre-treatment by addition of a low dose (normally 1 mg/l) of a low molecular weight, strongly cationic polymer (Sepco DC 242 or Sepco DC 244). It was tested in long terms experiments as well as short term experiments where head-loss development as well as sludge accumulation was monitored. Table 3 is summing up some average values of SS-removal efficiencies as well as filter run times and sludge accumulation during the filter run. Since the pilot plant was ran on the screened water of the full-scale plant, the water characteristics varied considerably over the time of the experiments.

As demonstrated in Table 2, removal efficiencies in the range of 80 to 90 % with respect to suspended solids were obtained. The wastewater was less concentrated in the period when polymer was applied, resulting in slightly lower removal efficiencies in this period. At corresponding filter velocities, however, the average effluent suspended solids concentration was somewhat lower when a cation polymer was applied.

Table 2 Average treatment results in experiments with floating filter based on Kaldnes biofilm carriers

Parameter	No coagulant used				1 mg/l cationic polymer added <sup>1)</sup>					
	2,5	5,0	7,5	10,0	242 <sup>2)</sup>	242 <sup>2)</sup>	242 <sup>2)</sup>	244 <sup>3)</sup>	244 <sup>3)</sup>	244 <sup>3)</sup>
Filter velocity (m/h)	2,5	5,0	7,5	10,0	5,0	7,5	10,0	5,0	7,5	10,0
Average SS <sub>in</sub> (mg/l)	207	239	208	187	200	170	161	154	128	144
(Long term experiments)		163			349	218	128	204	187	-
Average SS <sub>out</sub> (mg/l)	20,8	31,6	32,6	37,0	27,0	33,2	30,1	25,1	19,4	31,5
(Long term experiments)		23,6			26,6	37,6	19,4	30,4	36,4	-
Average removal (%)	90,0	86,8	84,3	80,0	86,5	80,5	81,3	83,7	84,8	78,1
(Long term experiments)		85,5			92,6	82,7	84,8	85,1	80,5	-
Filter run time before 1 m headloss (hrs)	32,0	12,0	6,0	3,0	14,0	10,0	6,0	15,0	12,0	5,0
Sludge accumulation (kg SS/m <sup>3</sup> <sub>filtervolume</sub> )	17,0	12,8	8,8	5,5	13,3	11,1	8,6	10,6	10,5	10,0
Sludge accumulation rate (kg SS/m <sup>3</sup> <sub>filtervolume</sub> *h)	-	1,24	1,51	1,84	0,97	1,19	1,49	0,73	0,92	1,17

1) 2 mg/l cationic coagulant at 5 m/h    2) Sepco DC 242    3) Sepco DC 244

A very moderate influence of filter velocity on treatment efficiency/effluent SS-concentration was experienced while the filter run time before 1 m head-loss (termination of filter run) was strongly dependent upon the filter velocity. The amount of sludge accumulated through the filter run, seemed to be less influenced by filter velocity when polymer was applied, indicating that the polymer increased the attachment forces between particles and filtermedium within the filter.

Sludge accumulation was close to linear with run time and the sludge accumulation rate is determined as the best fit of the slope of the recorded sludge accumulation versus filter run time. It is demonstrated that this sludge accumulation rate increases with filter velocity. It is a bit surprising that the rate of sludge accumulation is lower when a polymer was used.

A clear relation could be documented between effluent concentration and influent concentration as demonstrated in Figure 7 where all the data are plotted regardless of filter velocity for the situation of no polymer addition and polymer addition respectively. There is very little difference in treatment efficiency in the two situations (around 85 % in both cases). Better removal efficiencies with polymer are expected at higher dosages (around 4 mg/l). Generally the results must be said to be promising. Higher filtration rates will be tested and easy-to-operate filter backwash systems should be developed.

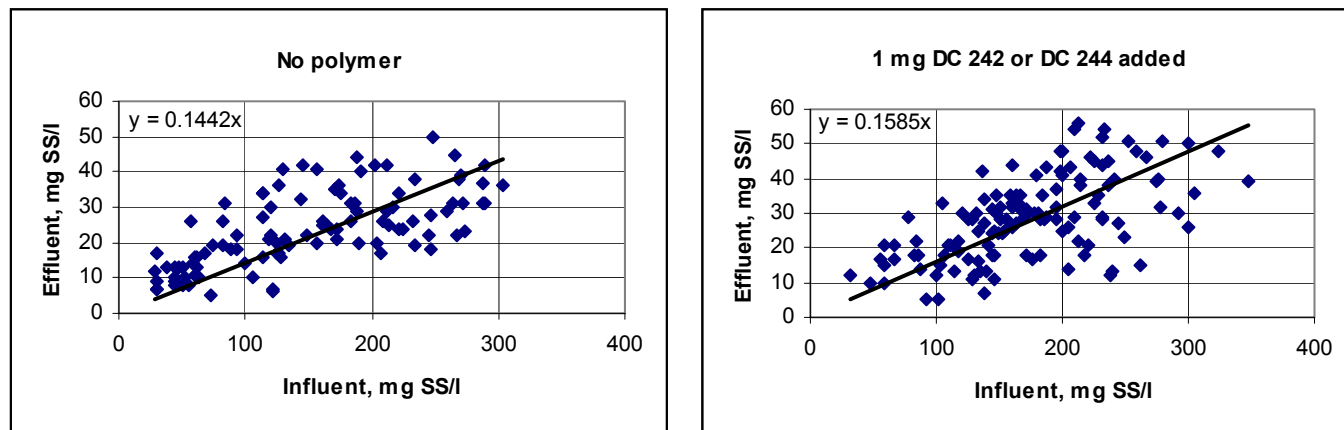


Fig. 7 Effluent SS-concentration versus influent concentration in the primary filters.

Biofilms will obviously establish themselves on the media and it is not probable that they are completely removed during backwashing. The wastewater entering the treatment plant is aerobic, typically containing 6-8 mg O<sub>2</sub>/l. This was reduced to 2-4 mg O<sub>2</sub>/l through the filter at a filter velocity of 5 m/h giving a corresponding reduction in soluble COD. Generally the total COD-reduction was in the range of 55-80 % (average 70 %) with effluent COD-concentrations in the range of 50 – 130 mg/l (average 85 mg/l).

## CONCLUSIONS

Since such a considerable fraction of the contaminants in wastewater is associated with particles, much may be gained from enhancing particle removal in the first step of wastewater treatment. In this paper the following three alternative routes to enhanced primary treatment are discussed and exemplified by experimental results:

1. Pretreatment of the wastewater by chemical coagulation
2. Improvement of flocculation- and sedimentation conditions as well as settling tank design
3. Use of an alternative particle separation method; high rate coarse media filtration

It has been demonstrated that coagulation with metal salts results in excellent particle- and consequently also organic matter removal, as well as phosphate removal, but the sludge production is high. Experimental results are presented, however, that demonstrate that almost equally good particle removal may also be obtained by the use of a cationic, polymeric coagulant at a much lower sludge production. Results from the use of both synthetic polymers and biopolymers are included. Better SS-removal results were obtained at a small iron-dosage (5,5 mg Fe/l) combined with a quite low dosage (2-3 mg/l) of a low molecular weight, strongly cationic polymer.

It has been demonstrated that optimal use of an anionic, polymeric flocculant may increase settling velocity of chemical flocs considerably and also that improved design of the settling tank in order to promote orthokinetic flocculation within the tank may enhance primary particle removal considerably. New designs of primary settling tanks, where these factors are taken into consideration, should be developed.

Results from the experimentation with a coarse-media upflow filter with plastic biofilm carriers as filter medium, treating raw wastewater with and without the addition of a cationic, polymeric coagulant, show that SS-removals in the order of 80-90 % may be obtained at plants with very small "foot-print". Filtration rates in the range of 5-10 m/h were tested. It was found that the treatment efficiency was little influenced by the filtration rate in this range, but that the filter run time before 1 m headloss was strongly influenced by the filtration rate. A low dose of cationic polymer (1 mg/l) did not improve treatment efficiency significantly but lead to longer filter runs, that was around 15 hrs at 5 m/h and 6 hrs at 10 m/h.

## ACKNOWLEDGEMENTS

Many of my students have contributed to this paper by letting me use data from their diploma thesis's, all of them written in Norwegian. I would therefore like to thank Njål Erland, Monica Fredvik, Svein Grutle, Kristin Skagestad, Dag Brevik and Zoltan Melics for their contributions.

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