Particle Separation from Municipal Wastewater by Coarse Media Filtration

A Part of NTNU/XUAT Postgraduate Course
Wastewater As a Resource
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Main topics

- Wastewater characterisation in municipal wastewater
- Wastewater treatment strategy
- Enhancement of particle separation and various processes
- Coarse media filtration of wastewater, tertiary, secondary, and primary
- Coarse media filtration for enhanced primary treatment
- High rate wastewater treatment schemes based on coarse media filtration
Wastewater characterisation—Fractionation procedure

Raw wastewater sample

63 µm sieve

7-8 µm filter

5 µm filter  1.2 µm filter  0.45 µm filter  0.1 µm filter

(Adapted from van Nieuwenhuijzen 2002)
Wastewater characterisation—Fractions, particle sizes and analyzed parameters

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Particle size range</th>
<th>Analyzed parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw wastewater</td>
<td>Whole range</td>
<td>COD, BOD, N, P, TSS, Turbidity, T, pH, conductivity</td>
</tr>
<tr>
<td>Settlesable</td>
<td>&gt;63 µm</td>
<td></td>
</tr>
<tr>
<td>Suspended</td>
<td>5-63 µm</td>
<td></td>
</tr>
<tr>
<td>Supra colloidal</td>
<td>1.2-5 µm</td>
<td></td>
</tr>
<tr>
<td>Colloidal</td>
<td>0.45-1.2 µm</td>
<td></td>
</tr>
<tr>
<td>Semi-dissolved</td>
<td>&lt;0.45 µm</td>
<td></td>
</tr>
<tr>
<td>Dissolved</td>
<td>&lt;0.1 µm</td>
<td></td>
</tr>
</tbody>
</table>

(Adapted from van Nieuwenhuijzen 2002)
Average fractionated wastewater composition (from van Nieuwenhuijzen 2002 (The Netherlands))

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Parameter</th>
<th>Dissolved 0.1-0.45 µm</th>
<th>Colloidal 0.45-1.2 µm</th>
<th>Supra Colloidal 1.2-5 µm</th>
<th>Suspended 5-63 µm</th>
<th>Settleable &gt;63 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>52±18%</td>
<td>48±18%</td>
</tr>
<tr>
<td>Turbidity</td>
<td>-</td>
<td>-</td>
<td>7±4%</td>
<td>10±7%</td>
<td>62±17%</td>
<td>21±12%</td>
</tr>
<tr>
<td>BOD5</td>
<td>48±12%</td>
<td>-</td>
<td>-</td>
<td>14±6%</td>
<td>30±8%</td>
<td>8±4%</td>
</tr>
<tr>
<td>COD</td>
<td>36±10%</td>
<td>3±4%</td>
<td>2±2%</td>
<td>11±6%</td>
<td>27±11%</td>
<td>21±9%</td>
</tr>
<tr>
<td>Ntotal</td>
<td>83±25%</td>
<td>1±1%</td>
<td>3±3%</td>
<td>4±2%</td>
<td>5±3%</td>
<td>4±4%</td>
</tr>
<tr>
<td>Ptotal</td>
<td>53±18%</td>
<td>3±3%</td>
<td>3±1%</td>
<td>5±2%</td>
<td>30±12%</td>
<td>6±3%</td>
</tr>
</tbody>
</table>
## Average BOD/N ratios per fraction (after van Nieuhuijzen 2002)

<table>
<thead>
<tr>
<th>Fraction Parameter</th>
<th>Dissolved &lt;0.1 μm</th>
<th>Colloidal material removed &lt;0.45 μm</th>
<th>Settleable material removed &lt;63 μm</th>
<th>Raw wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD/N-average</td>
<td>2.4±1.34</td>
<td>2.3±1.49</td>
<td>3.6±1.91</td>
<td>4.1±1.80</td>
</tr>
<tr>
<td>BOD/N-dry weather flow</td>
<td>2.9±0.95</td>
<td>2.9±0.91</td>
<td>4.2±1.09</td>
<td>4.7±1.20</td>
</tr>
<tr>
<td>BOD/N-storm weather flow</td>
<td>0.9±0.58</td>
<td>0.8±0.59</td>
<td>2.0±0.61</td>
<td>2.4±0.44</td>
</tr>
</tbody>
</table>
Particulate COD and particulate N—A comparison

- Ødegaard (1999) and (2000): Averaged particulate COD is 69% of total COD in wastewater (Scandinavia). Particulate N is 32% of total N.
- Van Nieuwenhuijzen (2002): Average particulate COD is 64% of total COD in wastewater (Netherlands). Particulate N is 19% of total N.
- STOWA (1999): Particulate COD is 65-84% of total COD (also Netherlands).
- In France, 59-69% of total COD is particulate.
- Liao (2002): Domestic sewage 75-90% particulate COD; half industrial 50-88% particulate COD (Norway).
SS and COD in three wastewaters – Høvringen Wastewater Treatment Plant (HØRA)

HØRA: Mountainous area, no industry, after 1.5 mm rotary sieving, 1998

Particulate COD = 1,448 * SS
SS and COD in three wastewaters – Ladehameren Wastewater Treatment Plant (LARA)

LARA: Mountainous area, half industrial, after grit chamber 1999-2000, much higher SS and COD, different particulate COD/SS ratio.
SS and COD in three wastewaters – The Ødegaarden Wastewater Treatment Experimental Hall

Ødegaarden: Domestic sewage, after primary settling, 2000-2001, similar to HØRA
Fractal settling properties of particles

- Particles in wastewater are fractal, the big particles are formed by principal clusters by Cluster-cluster model. The mass and the density of particles are power functions with non-integer powers. So does the settling velocity.
- Settling velocity is related by Andresen column settling method.
- Corresponding particle size distribution is measured by Coulter Particle Size Analyser LS230.
- Comparisons between two raw wastewaters and between two dosing conditions are made.
Fractal properties of particles—expressions

<table>
<thead>
<tr>
<th>Property</th>
<th>Scaling relationship*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid volume--$v$</td>
<td>$v = \psi^{(D_3/3)} \xi_0 l_0^{(3-D_3)} l^{D_3}$</td>
</tr>
<tr>
<td>Encased volume--$v_e$</td>
<td>$v_e = \xi l^3$</td>
</tr>
<tr>
<td>Mass--$m$</td>
<td>$m = \rho_0 \psi^{(D_3/3)} \xi_0 l_0^{(3-D_3)} l^{D_3}$</td>
</tr>
<tr>
<td>Density--$\rho$</td>
<td>$\rho = \rho_0 \psi^{(D_3/3)} (\xi_0 / \xi)(l / l_0)^{(D_3-3)}$</td>
</tr>
<tr>
<td>Porosity--$\varepsilon$</td>
<td>$\varepsilon = 1 - \psi^{(D_3/3)} (\xi_0 / \xi)(l / l_0)^{(D_3-3)}$</td>
</tr>
<tr>
<td>Settling velocity--$U$</td>
<td>$U = \left[ \frac{2g \xi_0}{a \rho w \xi_2} \cdot (\rho_0 - \rho_w) \cdot \psi^{(D_3/3)} \cdot l_0^{(1+D_2-D_3)} \cdot v^{-b} \cdot l^{(D_3+b-D_2)} \right]^{1/(2-b)}$</td>
</tr>
</tbody>
</table>
Fractal particles—Logan’s results

Bacteria flocs stained by acridine Orange and blue (left).

Read bead flocs coagulated with small Yellow bead (right).
Andreasen’s fixed apparatus and the modified settling column
Comparison of three sizes of settling column

Small (SS 260 mg/l)
\[ y = 12,326 \ln(x) + 84,826 \]
\[ R^2 = 0.9708 \]

Medium (SS 396 mg/l)
\[ y = 11,011 \ln(x) + 80,842 \]
\[ R^2 = 0.9786 \]

Big (SS 168 mg/l)
\[ y = 8,9397 \ln(x) + 85,963 \]
\[ R^2 = 0.9766 \]
SS and particulate COD removal vs indicated settling velocity

$$SS\% = -8.9397 \ln(x) + 25.489$$
$$\text{Part.COD}\% = -9.1284 \ln(x) + 17.83$$

Particles are difficult to settle down because of low temperature and density
Particle size distribution of raw wastewater—A comparison
Settling velocity vs particle size—Effect of chemical addition

\[ V (\text{m/h}) = 0.001d_{99}^{1.2723} \]

\[ R^2 = 0.9807 \]

\[ V (\text{m/h}) = 0.0056d_{99}^{0.878} \]

\[ R^2 = 0.9826 \]

- 2 mg FO4440SH/l + 7 mg Fe/l
- No dose
- Addition of chemicals From 0.878 to 1.2723
SS removal of various particles in settling column

![Graph showing the removal ratio in percentage for different particle sizes and flow rates.](image)
Fractal settling velocity—comparison of two wastewaters

V\textsubscript{LARA} = 9.0938(d\textsubscript{99})\textsuperscript{1.2579} \\
R\textsuperscript{2} = 0.9272

V\textsubscript{Ødeg.} = 0.2868(d\textsubscript{99})\textsuperscript{0.878} \\
R\textsuperscript{2} = 0.9826

Calculated (primary particle 5 \textmu m, 1250 kg/m\textsuperscript{3}, 20 degree in water)

Experimented (raw wastewater from Ødeg. SS168 mg/l, 15March2001)

Experimented (raw wastewater from LARA SS 234 mg/l 05Dec2001)
Wastewater characterisation—Main conclusions

• Contaminants in wastewater are largely related to particles (SS, COD, BOD, N and P, bacteria, virus, parasites, heavy metals, micropollutants, etc).
• Particles may be difficult to settle down (low temperature and density), therefore conventional sedimentation may not be effective.
• Particles are fractal in properties, indicating the complication of the issue of concern.
• Wastewater characterisation should be considered in determination of treatment technologies.
Wastewater treatment strategy

- Wastewater as resources: water, bio-energy, heat energy, biosolids, nutrients recovery.
- Particle separation as one of priorities.

*Take out the particles first*  *Then deal with the solubles*

- **Enhanced primary**
- **Removal of solubles**
- **Organic concentrate**
  - Carbon source
  - Biogas
  - Nutrients

Make use of the concentrates

Utilize the resources from the concentrate

Ødegaard (2000)

Basic wastewater Treatment philosophy
Approaches to enhance particle separation

- Changes in particle size and density: coagulation/flocculation, pelletisation, biosorption and bioflocculation (by sludge recycling), additions of heavy particles (magnetite or microsand or the like), addition of air-bubbles (dissolved air flotation).
- Application external attracting forces: Direct current electrical field, high-grade magnetic field, multiple gravitational field.
- Decreases in particle separation distances: Inclined plate/tube settling, deep bed filtration, membrane filtration.
- Combinations: contact (coagulating) filtration, ActiFloc process, SirlFloc process, coagulating dissolved air filtration, hydrodynamic separators, coagulation membrane filtration.
Comparison of several particle separation processes

• Pre-precipitation: (Ødegaard and co-workers) metal salts plus polymers, removal efficiencies: SS 92.9%, COD 77.5%, BOD7 83.7%, total P 95%; overflow rate: 1-1.5 m/h (lab 7.5 m/h).

• ActiFloc process: (Guibelin et al 1994) Microsand 135 microns plus coagulant and flocculent, lammella settler up to 135 m/h, SS 80%, BOD 60%, P 80%.

• Hydrodynamic separator: (Andoh et al 1996) SS 60-90%, BOD 40-85%, P 40-95%, oil and grease 80-95%, total coliform 80-99%. Becker et al (2000) effluent 5 NTU and 20 mg TSS/l at 57 m/h.

• Dissolved air flotation: (Pinto Filho et al 2001) SS 74-95%, COD 70-89%, Turbidity 77-90%, P >90%, overflow rates: conventional DAF 5-7 m/h, DAF-filter 10-15 m/h, turbulent DAF 25-40 m/h.

Common: well controlled coagulation flocculation+high dosages
Coarse media filtration—Tertiary filtration

- Granular deep bed filters for tertiary filtration: (Task Committee on Design of Wastewater Filtration Facilities 1986) a well established process—
  
  Media/size (mm)/depth(m): Sand/0.4-0.6/0.25-0.3, Sand/1.0-1.2/0.6-0.9, Anthracite/0.8-1.0/0.5-0.6, S or A/1.4-1.6/0.75-0.9, S or A/1.6-1.8/0.9-1.1, S or A/2.0-2.4/1.25-1.5. Total head loss 2-4 m, water production per cycle 200-400 m3/m2, SS-in 30-70 mg/l, filtration rate 0.08-0.4 m3/m2/min (4.8-24 m/h), SS removal 70%.

- Variation of operation: HydroClear filter—shallow depth pulsed-bed sand filter; DynaSand filter—deep bed continuous backwash filter.
Coarse media filtration-Secondary and primary effluent filtration

- Secondary filtration: (Sjøvold 1999, Von Vogt 2000, Ødegaard et al 2000) Media expanded clay aggregate (Filtralite) crushed in desired sizes, HC 1.5-4 mm/HC 1.5-6 mm, depth 1.2 m, filtration rate 5-12.5 m/h, MBBR effluent, SS 76-88%, COD 34-60%. (Ødegaard, Liao, and Hansen 2002) Kaldnes-Filtralite-Sand filter, Kaldnes media 11-24 mm/1 m, Filtralite 2.5-5 mm/0.5 m, Sand 1.2-2 mm/0.3 m, at 10 m/h and 2 mg/l polymer (high MW cationic), SS 90% effluent SS <15 mg/l, 20 m/h and 2 mg/l SS 85% effluent 25 mg/l, Sludge accumulation to 2-m head loss is 15-20 kg/m2-filterbed.

- Primary effluent filtration: (Jimenez et al 1999) Mexico City, compressive Fuzzy synthetic media filter, effluent SS less than 30 mg/l, 1.02-1.3 Hleminth egg/l, SS 45%, filtration rate 21-87 m/h at head loss 10 m.
Coarse media filtration—primary treatment

- Primary filtration:
  - Tanaka et al (1995)—ring shaped polypropylene net, porosity 90%, filtration rate 41.7 m/h, 2-3 mg/l cationic polymer, SS 80-90%, BOD5 44%, 2-m bed depth, head loss 0.2 m.
  - Wessman (1997)—Kaldnes media K1, 1-m depth, filtration rate 25 m/h, SS 73% at no dose.
  - Lerch (1998)—Kaldnes media, Star media, PS balls, PE discs in two stage filter, 30 m/h, SS 80-85% (no dose) or 90% (1.5 mg/l polymer).
  - Ødegaard et al (1998)—Kaldnes K1 media, 1 m depth, SS 75-85% at filtration rate 5-15 m/h and no dose condition.
Coarse media filtration (CMF) for enhanced primary treatment (EPT)

- Rationales of enhanced primary treatment by coarse media filtration.
- Kaldnes media: media characterisation and bed configurations.
- Comparison of single media floating filters.
- Comparison of dual media filters and optimisation.
- Mutlimedia filters.
- Discussions
- Conclusions
Rationales of EPT by CMF

- Contaminants in wastewater are largely related to particles.
- Particles may be difficult to settle down (low temperature and density) in conventional sedimentation.
- Particles interfere biodegradation.

- Enhancement of particle removal is very beneficial to downstream biological treatment.
- Coarse media filtration is very effective and efficient for particle separation if proper media bed.
- Synthetic plastic media can be manipulated in many ways.
Kaldnes media: characterisation

Two sizes K1 and K2 modified and two densities (950 and 1450 kg/m3) form four media K1L, K2L, K1H, and K2H.

- K1: diam. 11*8 mm.
  A cylinder with a cross inside and 18 short (1mm) outer fins

- K2 modified: diam.24*15mm.
  Two concentric cylinders with partitioning and 12 long (5mm) outer fins.
Media bed configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Media Combinations</th>
<th>Bed Heights</th>
<th>Porosities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single media</td>
<td>K1L or K2L</td>
<td>1 m bed</td>
<td>0.8</td>
</tr>
<tr>
<td>Dual media</td>
<td>K1L+K2H</td>
<td>0.5 m each</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual media</td>
<td>K1L/K2L</td>
<td>0.5 m each</td>
<td></td>
</tr>
<tr>
<td>Dual media</td>
<td>K1H/K2H</td>
<td>0.5 m each</td>
<td></td>
</tr>
</tbody>
</table>

Porosity 0.8 in K1 bed and 0.86-0.9 in K2 bed
Comparison of single K1L and K2L media filters—Set-up

• **Set-up**—
  Ladehameren Wastewater Treatment Plant (LARA).

• **Raw wastewater**—
  SS: $414 \pm 261$ mg/l  
  COD: $713 \pm 294$ mg/l  
  SCOD: $202 \pm 122$ mg/l.

• **Floerger FO4440SH**: High MW medium charge cationic polymer.
Comparison of K1L and K2L filters: SS removal (1)

A critical dosage ratio of 5 mg FO4440SH/g SS equals to 1-2 mg FO4440SH/l at SS-in 200-400 mg/l, little influence of filtration rate. No dose: K1L—65-70% up to 20 m/h, K2L—55% up to 20 m/h.
Comparison of K1L and K2L filters: SS removal (2)

K1L filter

- 0mg/l
- 1mg/l
- 3mg/l

Filtration rate (m/h)

SS removal (%)

K2L filter

- 0mg/l
- 1mg/l
- 3mg/l

Filtration rate (m/h)

SS removal (%)

Addition of polymer compensates decreases in SS removal at high filtration. 20 m/h is a turning filtration rate, below this small influence on SS removal.
Comparison of K1L and K2L filters:
Specific head loss

Specific head loss in K2L filter is only 1/10 of that in K1L filter.
Specific head loss strongly depends on dosage ratio.
Dosage ratio larger than 5 mg polymer/g SS has no benefit.
Comparison of K1L and K2L filters:

Length of filter cycle vs SS acc. rate in K1L filter (left) and K2L filter (right).
Comparison of K1L and K2L filters:

- K1L bed—small pores and quick clogging because of short outer fins.
- K2L bed—little clogging but breakthrough.
- Media—coarse enough to prevent clogging and fine enough for good
- Polymer and dosage—flocs just strong enough to withstand hydrodynamic
- A critical dosage ratio of 5 mg pol/g SS or 1-2 mg/l for SS in influent 200-
- Optimisation in media structure or in bed configuration is required for
Dual media filters and optimisation: Set-

- SS: 246 ± 73 mg/l
- COD: 458 ±135 mg/l
Dual media filters: The K1L/K2L filter

A critical dosage ratio of 5 mg pol/g SS is still there with SS removal of 70-90%. While no dose, around SS removal 70% is obtained up to 20 m/h. Specific head loss is 1/3 lower than in K1L filter.
Dual media filters: The K1L+K2H filter

A critical dosage ratio of 5 mg pol/g SS is still there with SS removal of 70-90%. While no dose, around SS removal 65% is obtained up to 20 m/h. Specific head loss is 1/3 lower than in K1L filter with more variation. The K2H layer moves up.
Dual media filters: The K1H/K2H filter

Similar SS removal compared with others, but much lower head loss. !! Specific head loss is lower at higher filtration rate.
While no dose, SS removal of 70-85% is obtained up to 20 m/h.
A natural grading effect of media bed occurs, more K1H on bottom.
**Dual media filters: A comparison of**

Different behaviours in specific head loss in three dual media filters reveal the influence of media bed configurations.
PSD changes in the K1H/K2H filter—10

- Peak shifts to small sizes
- Ripening effect
PSD changes in the K1H/K2H filter—10

Peak shifts to small sizes
Ripening effect
Coag.-flocc.
Dual media filters: A summary

- There are lower head loss in dual media filters, especially in the
- Although SS removal and head loss in the K1L/K2L and the
- The K1H/K2H filter is the best for the reasons of lower head loss,
- The K1L/K2L filter is also a good choice for its low head loss and high
- The K1L+K2H filter should be ruled out for its unstable performance.
Backwashing: Single media filters

- Three backwash modes are compared: Batch mode Water supply from
Comparison of two backwash modes at air and water flow rates of 90 and 31.5 m/h
• The optimal backwash parameters: air flow rate 60 m/h, water flow
• The SS reduction versus water consumption follows exponential law.

\[ C = C_0 e^{-kt} \]

• Water consumption for SS reduction by 99% is 8.3 m3/m2.
• Optimal procedure: two-step procedure—A batch step of air-loosing
Backwashing: Dual media filters

- Backwashing of the K1L/K2L and the K1L+K2H filters follow the
- Backwashing of the K1H/K2H filter uses continuous mode with water
- Optimal backwash parameters for the K1L/K2L filter is air and water
Kaldnes-Filtralite-Sand (KFS) filter

- Combination of the K1H/K2H
- Candidate granular media:
- Compatibility of media
KFS filter: Set-up

Filter bed configuration:
- Top: K1H/K2H layer Ø12-24 mm L1000 mm
- Middle: Filtralite layer Ø2,5-5 mm L 500 mm
- Bottom: Sand layer Ø1-2,5 mm L 300 mm
- Support layer gravel Ø3-10 mm L 200 mm
KFS filter: 20 m/h

SS% and effluent SS vs time
Effluent SS 20-40 mg/l, SS% 80-90% (1-2 mg/l) or 70-80% (no dose)
SS accumulation up to 15-20 kg/m² bed.

SS% and head loss vs SS acc.
KFS filter: 10 m/h

SS% and effluent SS vs time
Effluent 20-30 mg/l, SS% 70-90%, SS accumulation 20-25 kg/m2 (0-2 mg/l high MW polymer) but 5 kg/m2 while 4 mg/l low MW polymer.
KFS filter: A comparison of head loss

Addition of polymer has less influence on head loss at higher filtration rate.
KFS filter: Further researches

- Optimisation of media structure and bed configuration.
- Backwashing procedures.
- Possible application to secondary filtration and tertiary filtration.
Comparison of the K1L, the K1L/K2L, and the K1H/K2H filters

- The K1L, the K1L/K2L and K1H/K2H filters are feasible for enhanced primary treatment under different filtration rates and polymer dosages.
- According to previous results on SS removal and specific head loss in three filters under no dose condition and optimal dosage ratio, the backwashing properties, and the assumed influent SS concentration 200 mg/l, a prediction to filtration performances is made for a) length of filter cycle, water consumption for backwash, water production.
A prediction: Filter length to 1-m headloss

- Filter length (hours) to 1 m headloss under no dose

- Filter length (hours) to 1 m headloss under 1 mg pol/l

- 6 hour line
A prediction: water consumption for backwashing

Water consumption as % of water prod. under no dose

Water consumption as % of water prod. under 1 mg pol/l

Filtration rate (m/h)

Filtration rate (m/h)
A prediction: Effective water production

Effective water production (m$^3$/m$^2$/d) under no dose

Filtration rate (m/h)

Effective water production (m$^3$/m$^2$/d) under 1 mg pol/l

Filtration rate (m/h)
## Design suggestion for three filters—No dose condition

<table>
<thead>
<tr>
<th>Parameters</th>
<th>K1L filter</th>
<th>K1L/K2L filter</th>
<th>K1H/K2H filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtration rate</td>
<td>10-20 m/h</td>
<td>10-20 m/h</td>
<td>10-30 m/h</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>30-60 m/h</td>
<td>30-60 m/h</td>
<td>60-90 m/h</td>
</tr>
<tr>
<td>Water flow rate</td>
<td>30-40 m/h</td>
<td>30-40 m/h</td>
<td>30-40 m/h</td>
</tr>
<tr>
<td>Expected SS removal efficiency</td>
<td>60-70%</td>
<td>60-70%</td>
<td>60-75%</td>
</tr>
<tr>
<td>Expected filter length to 1 m head loss</td>
<td>6-30 h</td>
<td>6-50 h</td>
<td>12-30 h</td>
</tr>
<tr>
<td>Expected water consumption for backwash</td>
<td>2.5-5%</td>
<td>2-5%</td>
<td>4-5.5%</td>
</tr>
</tbody>
</table>
Design suggestion for three filters—Optimal dosage ratio

<table>
<thead>
<tr>
<th>Parameters</th>
<th>K1L filter</th>
<th>K1L/K2L filter</th>
<th>K1H/K2H filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtration rate</td>
<td>10-12 m/h</td>
<td>10-15 m/h</td>
<td>10-25 m/h</td>
</tr>
<tr>
<td>Air flow rate and water flow rate</td>
<td>30-60 m/h</td>
<td>30-60 m/h</td>
<td>60-90 m/h</td>
</tr>
<tr>
<td></td>
<td>30-40 m/h</td>
<td>30-40 m/h</td>
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</tr>
<tr>
<td>Expected SS removal efficiency</td>
<td>80-85%</td>
<td>70-80%</td>
<td>70-80%</td>
</tr>
<tr>
<td>Expected filter length to 1 m head loss</td>
<td>6-7 h</td>
<td>6-10 h</td>
<td>6-12 h</td>
</tr>
<tr>
<td>Expected water consumption for backwash</td>
<td>10%</td>
<td>7-10%</td>
<td>6-9%</td>
</tr>
</tbody>
</table>
Upgrading of existing primary tank (1)

Floating filter is applied.

Part of primary tank as sludge thickener and the supernatant for backwash.

Water consumption is reduced significantly.

Similar way to upgrade circular tank.
Upgrading of existing primary tank (2)

Downflow filter is applied.

Part of primary tank as sludge thickener and the supernatant for backwash.

Water consumption is reduced significantly.

Similar way to upgrade circular tank.
A conception of bed configuration optimisation for primary filters

Pore size  Specific head loss  Additional head loss  SS accumulation

L=0  L=L0
Filtration mechanisms in primary filters

- The dominating mechanisms are 1) sedimentation, 2) interception, 3) straining (sieving), 4) in-filter flocculation. The last three mechanisms become more significant with filtration time in a filter cycle.
- Detachment of previously deposited particles (clusters) occurs largely depending on addition of chemicals. Floc strength plays a great role in the extent of detachment.
- Detachment may occur as a spell of particles moving away from media surface like “avalanche”.
- Wormholes develop very well in the first layers.
- Deposits are very permeable, implying the fractal properties need to be incorporated into interpretation and modeling of filtration process.
Conclusions of CMF for EPT

• Kaldnes based coarse media filtration was investigated and optimised.
• The K1L filter, the K1L/K2L filter, and the K1H/K2H filter were found to be feasible for primary filtration under different conditions.
• Media dimensions and structures had profound influences on filtration performances especially on head loss development.
• Combination of coarser and finer media into dual or multimedia filters was a direction for optimisation.
• High filtration performance at high filtration rate could be obtained under optimal filter bed configuration and dosage.
• Enhanced primary treatment by coarse media filtration makes the footprint of primary step very small with considerably lower organic and particle loadings to downstream steps.
High rate secondary treatment based on coarse media filtration

- Influent
  - Screen
  - K1H/K2H filter 10-20 m/h
  - High-rate MBBR HRT 0.5-1 hour
  - Removal of COD
  - Chemicals
  - Removal of SS and P

- Effluent
  - KFS filter 5-10 m/h
  - Removal of SS and P
High rate tertiary treatment based on coarse media filtration