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The invention relates to a process for dewatering aqueous sludge comprising the steps of (a) adding to the aqueous sludge (i) a Fe(II)salt; and (ii) a cationic polymer; (b) allowing floe formation; and (c) filtrating the composition obtained in step (b).
Dewatering of Sludge

The invention relates to a process for dewatering aqueous sludge comprising the steps of (a) adding to the aqueous sludge (i) a Fe(III)salt; and (ii) a cationic polymer; (b) allowing floe formation; and (c) filtrating the composition obtained in step (b).

In conventional processes for dewatering aqueous sludge, cationic polymers are added as polymeric flocculants in order to induce floe formation (flocculation). The known processes for dewatering aqueous sludge are not satisfactory in every respect and there is a demand for improved processes. In particular, it is desirable to increase the residual dry matter (DS) in the filter cake and to decrease the moisture in the filter cake, respectively.

In China, for regulatory reasons, most sludge cake from chamber filter press is going to landfill. For filling land, the cake must be drier than 40% and also the sludge amount to fill land must not be greater than 8% (mixture ratio). Other 92% to fill the land is waste solid other than sewage plant sludge. Therefore, it is desirable (i) to increase the content of separated dry matter, if possible above about 40 wt.-%, i.e. to keep the sludge cake moisture below about 60 wt.-%; (ii) to adjust the pH of the sludge cake to a value within the range of from about 5 to about 8; and (iii) to keep the mixture ratio at about 8% or below.

In conventional processes, quick lime (CaO) has been added to the sludge in order to increase dry matter contents. As the addition of quick lime is expensive and laborious, there is a demand for simple processes for dewatering sludge which achieve high solids contents without the need of adding quick lime.

It is an object of the invention to provide a process for dewatering aqueous sludge having advantages compared to the processes of the prior art.

This object has been achieved by the subject-matter of the patent claims.

The invention relates to a process for dewatering aqueous sludge comprising the steps of (a) adding to the aqueous sludge (i) a Fe(III)salt; and (ii) a cationic polymer; (b) allowing floe formation; and (c) filtrating the composition obtained in step (b). It has been surprisingly found that by the process according to the invention the residual dry matter (DS) in the filter cake can be improved. In particular, it has been unexpectedly found that the content of
separated dry matter can be increased to about 40 wt.-% without the need of adding quick lime.

Figure 1 shows experimental results of example 1 concerning residual cake moisture after treating sludge with cationic polymer at a dose of 11 kg/t DS and FeCl₃ at a dose of 97 kg/t DS at a pressing time of 30 minutes.

Figure 2 shows experimental results of example 1 concerning residual cake moisture after treating sludge with cationic polymer at a dose of 11 kg/t DS and FeCl₃ at a dose of 97 kg/t DS at a pressing time of 10 minutes.

Figure 3 shows a selection of the experimental results of example 1 concerning residual cake moisture after treating sludge with cationic polymer at a dose of 11 kg/t DS and FeCl₃ at a dose of 97 kg/t DS at a pressing time of 10 minutes (selected data from Figure 2).

Figure 4 shows experimental results of example 2 concerning residual cake moisture after treating sludge with cationic polymer at a dose of 7.5 kg/t DS and FeCl₃ at a dose of 140 kg/t DS.

Figure 5 shows experimental results of example 2 concerning residual cake moisture after treating sludge with cationic polymer at a dose of 9 kg/t DS and FeCl₃ at a dose of 140 kg/t DS.

Figure 6 shows experimental results of example 2 concerning residual cake solids after treating sludge with cationic polymer at a dose of 7.5 kg/t DS and FeCl₃ at a dose of 140 kg/t DS.

Figure 7 shows experimental results of example 2 concerning residual cake solids after treating sludge with cationic polymer at a dose of 9 kg/t DS and FeCl₃ at a dose of 140 kg/t DS.

In particular, the invention relates to a process for dewatering aqueous sludge comprising the steps of

(a) adding to the aqueous sludge
   (i) a Fe(III)salt; and
(ii) a cationic polymer which comprises cationic monomer units derived from monomers according to general formula (I)

\[
\begin{align*}
  &R_4 &A & (CH_2)_n &N &R_2 \\
  & & & & &X \nn
\end{align*}
\]

wherein

R₁, R₂ and R₃ are independently -C₄₋₄-alkyl;
R₄ is -H or -d-₄-alkyl;
A is -O- or -NR₅-, wherein R₅ is -H or -C₄₋₄-alkyl;
n is 2, 3 or 4; and
X⁻ is a counter ion;

wherein the content of cationic monomer units derived from monomers according to general formula (I) is at least about 90 wt.-%, relative to the total content of monomer units of the cationic polymer; and

wherein the cationic polymer has an intrinsic viscosity within the range of from about 50 cm³/g to about 2,000 cm³/g;

(b) allowing floe formation; and

(c) filtrating the composition obtained in step (b).

The cationic polymer may be employed in step (a) in solid form, as an aqueous solution, as a water-in-oil emulsion, or as dispersion in water. In a preferred embodiment, the cationic polymer is added to the aqueous sludge in step (a) in form of an emulsion.

The cationic polymer comprises cationic monomer units derived from monomers according to general formula (I). The cationic polymer may be a homopolymer, a copolymer, a terpolymer, and the like. Preferably, the cationic polymer is a homopolymer.

When the cationic polymer is a copolymer, it may comprise one or more monomer units derived from monomers according to general formula (I) optionally in combination with one or more non-ionic monomer units derived from non-ionic monomers.

The cationic polymer is typically prepared by vinyl addition polymerization of one or more cationic monomers, by copolymerization of one or more cationic monomers with one or more
nonionic monomers, or by copolymerization of one or more cationic monomers with one or more anionic monomers and optionally one or more nonionic monomers to produce an amphoteric polymer. Preferably, the cationic polymer is an acrylic polymer derived from radically polymerizable cationic monomer units and optionally, radically polymerizable nonionic monomers.

In general formula (I) the counter ion $X^-$ is not particularly limited. Preferably, the counter ion $X^- = \text{Cl}^-$. 

In a preferred embodiment, the monomer according to general formula (I) is an ester, i.e. $A = -0-$. Preferably, in general formula (I) $A$ is $-0-$, $R_1 = R_2 = R_3 = -\text{CH}_3$; $R_4 = -\text{H}$; and $n = 2$. When $X^- = \text{Cl}^-$, this monomer is also referred to as AETAC = Acryloyloxyethyl trimethylammonium chloride.

In another preferred embodiment, the monomer according to general formula (I) is an amide, i.e. $A = -\text{NR}_5^-$. Preferably, in general formula (I) $A$ is $-\text{NR}_5-$, $R_1 = R_2 = R_3 = -\text{CH}_3$; $R_4 = R_5 = -\text{H}$; and $n = 3$. When $X^- = \text{Cl}^-$, this monomer is also referred to as APTAC = acrylicamidopropyltrimethylammonium chloride.

In a preferred embodiment, the ionic polymer is a homopolymer or a copolymer comprising cationic repetition units derived from monomers selected from the group consisting of cationized dialkylaminoalkyl (meth)acrylates, and/or cationized dialkylaminoalkyl(meth)acryl amides. The cationic repetition units are preferably derived from monomers selected from the group consisting of cationized dialkylaminoalkyl (meth)acrylates, and cationized dialkylaminoalkyl(meth)acrylamides; especially trimethylammoniummethyl(meth) acrylate halide, trimethylammoniumpropyl(meth)acryl amide halide are particularly preferred.

Representative cationic polymers include copolymers and terpolymers of (meth)acrylamide with dimethylaminoethyl methacrylate, dimethylaminopropyl methacrylamide, dimethylaminoethyl acrylate, dimethylaminopropyl acrylamide, diethylaminoethyl methacrylate, diethylaminopropyl methacrylamide, diethylaminoethyl acrylate, diethylaminopropyl acrylamide, or their quaternary ammonium forms made with dimethyl sulfate, methyl chloride or benzyl chloride. A preferred cationic polymer comprises dimethylaminoethylacrylate methyl chloride quaternary salt/acrylamide copolymer. Another preferred cationic polymer comprises dimethylaminopropylacrylamid methyl chloride quaternary salt/acrylamide copolymer.
The cationic polymer has a high content of cationic monomer units, i.e. a high cationicity. The content of cationic monomer units derived from monomers according to general formula (I) is at least about 90 wt.-%, preferably at least about 92 wt.-%, more preferably at least about 94 wt.-%, still more preferably at least about 96 wt.-%, even more preferably at least about 98 wt.-%, most preferably at least about 99 wt.-% and in particular about 100 wt.-%, relative to the total content of monomer units of the cationic polymer. Thus, in a preferred embodiment of the cationic polymer according to the invention, the cationic polymer is essentially a homopolymer of cationic monomer units derived from monomers according to general formula (I) (cationicity = about 100%).

The cationic polymer according to the invention has an intrinsic viscosity within the range of from about 50 cm$^3$/g to about 2,000 cm$^3$/g, preferably from about 100 cm$^3$/g to about 1,500 cm$^3$/g. In a preferred embodiment, the cationic polymer has an intrinsic viscosity (in water) within the range of about 400±350 cm$^3$/g, more preferably about 400±300 cm$^3$/g, still more preferably about 400±200 cm$^3$/g, and most preferably about 400±100 cm$^3$/g. In another preferred embodiment, the cationic polymer has an intrinsic viscosity (in water) within the range of about 550±400 cm$^3$/g, more preferably about 550±300 cm$^3$/g, still more preferably about 550±200 cm$^3$/g, and most preferably about 550±100 cm$^3$/g. In yet another preferred embodiment, the cationic polymer has an intrinsic viscosity (in water) within the range of about 700±400 cm$^3$/g, more preferably about 700±300 cm$^3$/g, still more preferably about 700±200 cm$^3$/g, and most preferably about 700±100 cm$^3$/g.

The average molecular weight of the cationic polymer is limited in terms of its intrinsic viscosity (see above). Furthermore, typically, the cationic polymer has a weight average molecular weight within the range of from about 1.0×10$^6$ to about 1.0×10$^7$ g/mol, preferably from about 2.5×10$^6$ to about 7.5×10$^6$ g/mol. In a preferred embodiment, the cationic polymer has weight average molecular weight within the range of about 2.5×10$^6$±2.0×10$^6$ g/mol, more preferably about 2.5×10$^6$±1.5×10$^6$ g/mol, still more preferably about 2.5×10$^6$±1.0×10$^6$ g/mol, and most preferably about 2.5×10$^6$±5.0×10$^5$ g/mol. In another preferred embodiment, the cationic polymer has weight average molecular weight within the range of about 3.5×10$^6$±2.0×10$^6$ g/mol, more preferably about 3.5×10$^6$±1.5×10$^6$ g/mol, still more preferably about 3.5×10$^6$±1.0×10$^6$ g/mol, and most preferably about 3.5×10$^6$±5.0×10$^5$ g/mol. In yet another preferred embodiment, the cationic polymer has weight average molecular weight within the range of about 4.5×10$^6$±2.0×10$^6$ g/mol, more preferably about 4.5×10$^6$±1.5×10$^6$ g/mol, still more preferably about 4.5×10$^6$±1.0×10$^6$ g/mol, and most preferably about 4.5×10$^6$±5.0×10$^5$ g/mol. In another preferred embodiment, the cationic polymer has weight average molecular weight within the range of about 6.0×10$^6$±2.5×10$^6$ g/mol, more preferably about 6.0×10$^6$±2.0×10$^6$ g/mol,
still more preferably about $6.0 \times 10^6 \pm 1.5 \times 10^6$ g/mol, and most preferably about $6.0 \times 10^6 \pm 1.0 \times 10^6$ g/mol. In still another preferred embodiment, the cationic polymer has weight average molecular weight within the range of about $7.5 \times 10^6 \pm 2.5 \times 10^6$ g/mol, more preferably about $7.5 \times 10^6 \pm 1.0 \times 10^6$ g/mol, and most preferably about $7.5 \times 10^6 \pm 1.5 \times 10^6$ g/mol.

The dosage of the cationic polymer that is added to the aqueous sludge in step (a) of the process according to the invention is not particularly limited. Suitable dosages may be easily determined by routine experimentation. In general, the cationic polymer dose is from about 50 ppm to about 5000 ppm, preferably from about 100 to about 1000 ppm, based on polymer solids, per dry ton solids.

Typical dosages range from about 1 kg (active)/t DS to about 40 kg (active)/t DS, preferably from about 5 kg/t DS to about 15 kg/t DS, or from about 5 kg (active)/t DS to about 25 kg (active)/t DS, wherein "active" refers to the weight of cationic polymer contained in the composition of the cationic polymer and "DS" refers to the dry matter contained in the aqueous sludge originally employed as starting material. In a preferred embodiment, the dosage of the cationic polymer that is added to the aqueous sludge in step (a) of the process according to the invention is within the range of about 5.0±4.0 kg (active)/t DS, more preferably 5.0±3.0 kg (active)/t DS, still more preferably 5.0±2.5 kg (active)/t DS, and most preferably 5.0±2.0 kg (active)/t DS. In another preferred embodiment, the dosage of the cationic polymer that is added to the aqueous sludge in step (a) of the process according to the invention is within the range of about 10±7 kg (active)/t DS, more preferably 10±6 kg (active)/t DS, still more preferably 10±5 kg (active)/t DS, and most preferably 10±4 kg (active)/t DS. In still another preferred embodiment, the dosage of the cationic polymer that is added to the aqueous sludge in step (a) of the process according to the invention is within the range of about 15±7 kg (active)/t DS, more preferably 15±6 kg (active)/t DS, still more preferably 15±5 kg (active)/t DS, and most preferably 15±4 kg (active)/t DS. In yet another preferred embodiment, the dosage of the cationic polymer that is added to the aqueous sludge in step (a) of the process according to the invention is within the range of about 20±7 kg (active)/t DS, more preferably 20±6 kg (active)/t DS, still more preferably 20±5 kg (active)/t DS, and most preferably 20±4 kg (active)/t DS.

Suitable products containing cationic polymers are commercially available (e.g. PRAESTOL® K 166 L and the like).
In step (a) of the process according to the invention, a Fe(III)salt is added to the aqueous sludge.

In step (a) the Fe(III)salt may be added to the composition in any form. Preferably, the Fe(III)salt is added in form of an aqueous solution or dispersion. Preferably, the content of the Fe(III)salt within the aqueous solution or dispersion is adjusted to a value within the range of from about 0.1 wt.-% to about 20 wt.-%, preferably from about 1 wt.-% to about 10 wt.-%, relative to the total weight of the aqueous suspension.

Suitable Fe(III)salts are commercially available. Suitable Fe(III)salts include but are not limited to organic Fe(III) salts such as Fe(III)citrate, Fe(III)oxalate, Fe(III)tartrate, and any solvates, particularly hydrates, and any combination thereof; and inorganic Fe(III)salts such as Fe(III)chloride, Fe(III)bromide, Fe(III)fluoride, Fe(III)phosphate, Fe(III)sulfate, Fe(III)nitrate, and any solvates, particularly hydrates, and any combination thereof.

Inorganic Fe(III)salts are particularly preferred, especially Fe(III)chloride (FeCl$_3$) and the hydrates thereof.

The dosage of the Fe(III)salt that is added in step (a) of the process according to the invention is not particularly limited. Suitable dosages may be easily determined by routine experimentation. Typical dosages range from about 40 kg/t DS to about 200 kg/t DS, preferably from about 80 kg/t DS to about 160 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a).

For the purpose of the specification, "t DS" and "TDS" both refer to "tons of dry substance".

In a preferred embodiment, the dosage of the Fe(III)salt that is added in step (a) of the process according to the invention is within the range of about 80±60 kg/t DS, more preferably 80±50 kg/t DS, still more preferably 80±40 kg/t DS, and most preferably 80±30 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a). In another preferred embodiment, the dosage of the Fe(III)salt that is added in step (a) of the process according to the invention is within the range of about 120±60 kg/t DS, more preferably 120±50 kg/t DS, still more preferably 120±40 kg/t DS, and most preferably 120±30 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a). In still another preferred embodiment, the dosage of the Fe(III)salt that is added in step (a) of the process according to the invention is within the range of about 160±60 kg/t DS, more preferably 160±50 kg/t DS, still more preferably 160±40...
kg/t DS, and most preferably 160±30 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a).

In a preferred embodiment of the process according to the invention, the Fe(III)salt and the cationic polymer are provided in form of a mixture that is added to the aqueous sludge in step (a). Preferably, said mixture contains water.

In step (b) of the process according to the invention, the cationic polymer is allowed to induce floe formation (floculation).

Typically, step (b) does not require any particular measure except that a certain period of time is needed for floculation. Typical floculation times range from seconds to a few minutes. The floculation times are a function of the sludge properties and the properties of the cationic polymer. Floculation times can be easily determined by routine experimentation. Floe formation may be monitored by conventional means, e.g. by means of a light microscope.

Floculation is step (b) of the process according to the invention is preferably achieved by means of a device that is particularly designed to facilitate floculation (floculation apparatus), also called "floe formers". Suitable devices are commercially available. A particularly preferred floe former is described in US 2004/0262230, which is incorporated by reference.

In a preferred embodiment, floe formation in step (b) is achieved by means of a floculation apparatus comprising a suspension inlet, suspension outlet and an inner cone mounted centrally in a conical outer housing, at least one of the inner cone and the outer housing being rotatable relative to one another, and a gap for through-flow of suspensions being present between the inner cone and the outer housing, wherein at least one of the inner cone and the outer housing is mounted so as to be axially displaceable and an actuator cooperates with the at least one of the inner cone and outer housing for controlled axial displacement of at least one of the inner cone and outer housing.

Preferably, the floculation apparatus further comprises a mixer for generating a highly turbulent suspension flow arranged directly upstream of the suspension inlet.

Further preferred embodiments of the floculation apparatus are disclosed in US 2004/0262230 and are not repeated herein.
In step (c) of the process according to the invention, the composition obtained in step (b) is filtrated. Preferably, filtration in step (c) is achieved by means of a filter press. Preferably, the filter press is selected from the group consisting of chamber filter press, plate filter press, frame filter press, membrane filter press and belt filter press.

Typically, in the course of filtration step (c) the treated sludge is pressed for a certain period of time by means of the filter press. Suitable pressing times can be determined by routine experimentation and are typically within the range of several minutes, e.g. within the range of from about 5 minutes to about 45 minutes. In a preferred embodiment, pressing time is about 10±5 min, more preferably about 10±5 min. In another preferred embodiment, pressing time is about 30±5 min, more preferably about 30±5 min.

The aqueous sludge to be dewatered by the process according to the invention is not particularly limited. Preferably, the aqueous sludge that employed as starting material in step (a) is selected from municipal sludge and industrial sludge. It may be digested sludge, activated sludge, coarse sludge, raw sludge, and the like, and mixtures thereof.

If appropriate, the aqueous sludge may be pretreated by conventional measures prior to performing the process according to the invention. Such conventional measures include but are not limited to slurrying, diluting, adjusting pH and the like.

The pH value of the sludge that is employed as starting material in step (a) is not particularly limited.

Typically, the pH value is within the range of from about 5 to about 11, preferably about 6 to about 10.5, more preferably about 7 to about 10.

The content of dry matter (DS) in the sludge that is employed as starting material in step (a) is not particularly limited.

Typically, the content of dry matter is within the range of from about 0.1 wt.-% to about 20 wt.-%, preferably from about 1 wt.-% to about 10 wt.-%.

In a preferred embodiment of the process according to the invention, no CaO is added to the aqueous sludge.
The following examples further illustrate the invention but are not to be construed as limiting its scope:

Intrinsic viscosities of tested highly cationic polymers:

<table>
<thead>
<tr>
<th>Praestol® Product</th>
<th>Chemical nature</th>
<th>Specific properties</th>
<th>Intrinsic viscosity [cm²/g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC 66 L</td>
<td>polyAPTAC</td>
<td>emulsion</td>
<td>580.0</td>
</tr>
<tr>
<td>BC 55 L</td>
<td>polyAPTAC-co-AM</td>
<td>90wt%+</td>
<td>709.3</td>
</tr>
<tr>
<td>BC 270 L</td>
<td>polyAPTAC-co-AM</td>
<td>70wt%+, slightly cross-linked</td>
<td>638.7</td>
</tr>
<tr>
<td>BC 470 L</td>
<td>polyAPTAC-co-AM</td>
<td>70wt%+</td>
<td>623.7</td>
</tr>
<tr>
<td>K 166 L</td>
<td>polyAETAC</td>
<td>Low Mw</td>
<td>439.3</td>
</tr>
<tr>
<td>K 166 L Stabilized</td>
<td>polyAETAC</td>
<td>polymerized isothermally</td>
<td>612.9</td>
</tr>
<tr>
<td>K 166 LX</td>
<td>polyAETAC</td>
<td>Stabilized with organic acid</td>
<td>612.9</td>
</tr>
<tr>
<td>DF 2680</td>
<td>polyAETAC-co-AM flocculant, polyAETAC dispersant</td>
<td>70wt%+, WW dispersion</td>
<td>749.7</td>
</tr>
<tr>
<td>A 3850</td>
<td>polyAETAC-co-AM flocculant, polyAETAC dispersant</td>
<td>50wt%+, high Mw, WW dispersion</td>
<td>1551.4</td>
</tr>
<tr>
<td>Titan 100 M</td>
<td>polyDIMAPA hydrosulfate</td>
<td>Emulsion, homopolymer</td>
<td>533.0</td>
</tr>
<tr>
<td>655 BC-K</td>
<td>polyAPTAC-co-AM</td>
<td>70wt%+, powder</td>
<td>732.3</td>
</tr>
</tbody>
</table>

APTAC = Acrylamidopropyltrimethylammonium chloride (= DIMAPA quat.)
AETAC = Acryloyloxyethyl trimethylammonium chloride (= ADAME quat.)
DADMAC = diallyldimethylammonium chloride
DIMAPA = dimethylaminopropylacrylamide
AM = acrylamide
WW = water-in-water

Example 1:

Raw Sludge: Shanghai Longhua Municipal Waste Water Treatment Plant
Sludge TDS: 3.6%
Sludge volume for each test: 200 ml
Praestol® concentration: 0.4%
FeCl₃ concentration (TDS): 3.8%
FeCl₃ cone. (product): 10%
Pressure: 5 bar

<table>
<thead>
<tr>
<th>Ex.</th>
<th>Praestol®</th>
<th>FeCl₃, [(product)kg/TDS]</th>
<th>EPAM, [kg/TDS]</th>
<th>Pressing Time [min]</th>
<th>Cake Thickness [mm]</th>
<th>Cake Moisture [%]</th>
<th>Filtrate [ml]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>K 166 L</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>5.90</td>
<td>73.85</td>
<td>194</td>
</tr>
<tr>
<td>1-2</td>
<td>K 166 L</td>
<td>125</td>
<td>11</td>
<td>10</td>
<td>5.90</td>
<td>75.35</td>
<td>192</td>
</tr>
<tr>
<td>1-3</td>
<td>DF 2680</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>5.90</td>
<td>74.53</td>
<td>200</td>
</tr>
<tr>
<td>1-4</td>
<td>BC 470 L</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>5.80</td>
<td>75.19</td>
<td>199</td>
</tr>
<tr>
<td>1-5</td>
<td>BC 270 L</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>6.20</td>
<td>75.61</td>
<td>200</td>
</tr>
<tr>
<td>1-6</td>
<td>BC 55 L</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>6.30</td>
<td>76.37</td>
<td>200</td>
</tr>
<tr>
<td>1-7</td>
<td>A 3850</td>
<td>97</td>
<td>11</td>
<td>10</td>
<td>6.40</td>
<td>77.68</td>
<td>200</td>
</tr>
<tr>
<td>1-8</td>
<td>BC 470 L</td>
<td>97</td>
<td>11</td>
<td>30</td>
<td>3.20</td>
<td>60.23</td>
<td>210</td>
</tr>
</tbody>
</table>
The experimental results are also displayed in Figure 1 to 3.

It becomes clear from the above data that at a pressing time of 10 min the Praestol® product of the K 166 L series provides the best results, i.e. the lowest cake moistures, and that an increase of the dose of FeCl₃ from 97 to 125 kg/TDS deteriorates the result.

**Example 2:**

Sludge from: Shanghai Haibing
Dry substance content: 5.0%
Volume/batch: 200 ml
DS/batch: 10 g
Pressing time: 30 min
Pressure: 6.5 (or 13) bar

<table>
<thead>
<tr>
<th>Ex.</th>
<th>EPAM, Praestol®</th>
<th>FeCl₃ [kg/TDS]</th>
<th>EPAM [kg/TDS]</th>
<th>Filtrate in 1 min [ml]</th>
<th>Cake Thickness [mm]</th>
<th>Filtrate in 30 min [ml]</th>
<th>Cake [Wt/g]</th>
<th>Cake Moisture [%]</th>
<th>Cake Solid [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>K 166 L Stabilized</td>
<td>140</td>
<td>9</td>
<td>70</td>
<td>18.1</td>
<td>198</td>
<td>35.45</td>
<td>73.3</td>
<td>26.7</td>
</tr>
<tr>
<td>2-2</td>
<td>K 166 L</td>
<td>140</td>
<td>9</td>
<td>90</td>
<td>18.6</td>
<td>196</td>
<td>37.29</td>
<td>73.7</td>
<td>26.3</td>
</tr>
<tr>
<td>2-3</td>
<td>K 166 L Low Mw</td>
<td>140</td>
<td>9</td>
<td>51</td>
<td>18.9</td>
<td>192</td>
<td>39.59</td>
<td>74.5</td>
<td>25.5</td>
</tr>
<tr>
<td>2-4</td>
<td>K 166 LX</td>
<td>140</td>
<td>9</td>
<td>65</td>
<td>18.8</td>
<td>192</td>
<td>40.1</td>
<td>74.8</td>
<td>25.2</td>
</tr>
<tr>
<td>2-5</td>
<td>BC 470 L</td>
<td>140</td>
<td>9</td>
<td>46</td>
<td>19.6</td>
<td>190</td>
<td>41.38</td>
<td>76.2</td>
<td>23.8</td>
</tr>
<tr>
<td>2-6</td>
<td>Titan 100 M</td>
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The experimental results are also displayed in Figure 4 to 7.

It becomes clear from the above data that at both dosages of cationic polymer (9 kg/TDS and 7.5 kg/TDS) the Praestol® products of the K 166 L series provide the best results, i.e. the lowest cake moistures.
Patent claims:

1. A process for dewatering aqueous sludge comprising the steps of
   (a) adding to the aqueous sludge
      (i) a Fe(II)salt; and
      (ii) a cationic polymer which comprises cationic monomer units derived from
           monomers according to general formula (I)

   \[
   \text{(I)} \quad R_4 \quad \text{A} \quad \text{(CH}_2)_n \quad \text{N} \quad \text{R}_2 \quad \text{R}_3 \quad \text{X}^{-}
   \]

   wherein
   - \( R_1, R_2 \), and \( R_3 \) are independently -\( C_{1-4}-\)alkyl;
   - \( R_4 \) is -H or -d-4-alkyl;
   - \( A \) is -O- or -NR_5-, wherein \( R_5 \) is -H or -\( C_{1-4}-\)alkyl;
   - \( n \) is 2, 3 or 4; and
   - \( X \) is a counter ion;

   wherein the content of cationic monomer units derived from monomers
   according to general formula (I) is at least about 90 wt.-%, relative to the
   total content of monomer units of the cationic polymer; and

   wherein the cationic polymer has an intrinsic viscosity within the range of
   from about 50 cm\(^3\)/g to about 2,000 cm\(^3\)/g;

   (b) allowing floe formation; and

   (c) filtrating the composition obtained in step (b).

2. The process according to claim 1, wherein the cationic polymer is essentially a
   homopolymer of cationic monomer units derived from monomers according to general
   formula (I).

3. The process according to claim 1 or 2, wherein the cationic polymer has an intrinsic
   viscosity within the range of about 550±200 cm\(^3\)/g.
4. The process according to any of the preceding claims, wherein in general formula (I) A is -0-, \( R_1 = R_2 = R_3 = -CH_3 \); \( R_4 = -H \); and \( n = 2 \).

5. The process according to any of the preceding claims, wherein in general formula (I) the counter ion \( X^- = C\Gamma \).

6. The process according to any of the preceding claims, wherein the dose of the cationic polymer that is added to the aqueous sludge in step (a) is within the range of from about 5 kg/t DS to about 15 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a).

7. The process according to any of the preceding claims, wherein the cationic polymer is added to the aqueous sludge in step (a) in form of an emulsion.

8. The process according to the preceding claims, wherein the Fe(III)salt is FeCl₃.

9. The process according to any of the preceding claims, wherein the dose of the Fe(III) salt that is added to the aqueous sludge in step (a) is within the range of from about 80 kg/t DS to about 160 kg/t DS, wherein DS refers to the content of dry substance within the aqueous sludge employed in step (a).

10. The process according to any of the preceding claims, wherein the Fe(III)salt and the cationic polymer are provided in form of a mixture that is added to the aqueous sludge in step (a).

11. The process according to claim 10, wherein the mixture contains water.

12. The process according to any of the preceding claims, wherein filtration in step (c) is achieved by means of a filter press.

13. The process according to claim 12, wherein the filter press is selected from the group consisting of chamber filter press, plate filter press, frame filter press, membrane filter press and belt filter press.

14. The process according to any of the preceding claims, wherein the aqueous sludge employed in step (a) is selected from municipal sludge and industrial sludge.
15. The process according to any of the preceding claims, wherein no CaO is added to the aqueous sludge.
Figure 1

Cake Moisture, %
Sludge: Longhua plant, 3.6%
Sludge volume: 200 ml/batch
FeCl₃: 97 kg/TDS
PraestoⓇ: 11 kg/TDS EPAM
Pressure: 5 Bar
Pressing Time: 30 min

Figure 2

Cake Moisture, %
Sludge: Longhua plant, 3.6%
Sludge volume: 200 ml/batch
FeCl₃: 97 kg/TDS
PraestoⓇ: 11 kg/TDS EPAM
Pressure: 5 Bar
Pressing Time: 10 min
**Figure 3**

Cake Moisture, %
- Sludge: Longhua plant, 3.6%
- Sludge volume: 200 ml/batch
- FeCl₃: 97 kg/TDS
- Praesto®: 11 kg/TDS EPAM
- Pressure: 5 Bar
- Pressing Time: 10 min

**Figure 4**

Cake Moisture %
- FeCl₃/EPAM kg/TDS: 140/7.5
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. C02F1/52 C02F1/56 C02F11/14 C08F220/34 C08F220/60
D21H17/37 D21H17/41 D21H21/10
ADD. C02F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C02F C08F D21H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published o n o r after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search: 30 June 2015

Date of mailing of the international search report: 10/07/2015

Name and mailing address of the ISA/ Receiving office
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016

Authorized officer
Zsigmond, Zol tan

Form PCT/ISA/210 (second sheet) (April 2005)
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